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A spatial microsimulation approach for the analysis of commuter patterns: from individual to regional levels ☆

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ABSTRACT

The daily trip to work is ubiquitous, yet its characteristics differ widely from person to person and place to place. This is manifested in statistics on mode and distance of travel, which vary depending on a range of factors that operate at different scales. This heterogeneity is problematic for decision makers tasked with encouraging more sustainable commuter patterns. Numerical models, based on real commuting data, have great potential to aid the decision making process. However, we contend that new approaches are needed to advance knowledge about the social and geographical factors that relate to the diversity of commuter patterns, if policies targeted to specific individuals or places are to be effective. To this end, the paper presents a spatial microsimulation approach, which combines individual-level survey data with geographically aggregated census results to tackle the problem. This method overcomes the limitations imposed by the lack of available geocoded micro-data. Further, it allows a range of scales of analysis to be pursued in parallel and provides insights into both the types of *area* and *individual* that would benefit most from specific interventions.

1. Introduction

Commuting is a major reason for personal travel,[1] and a broad research area within transport geography. In many cases zonally aggregated census statistics—often the most reliable source of information about spatial variation in commuter patterns—form the basis of geographical commuting research (Horner and Murray, 2002; Titheridge and Hall, 2006). Recent advances in data availability and computational methods have, however, facilitated the analysis (Helminen and Ristimäki, 2007) and modelling (Buliung and Kanaroglou, 2002; Buliung and Kanaroglou, 2006) of commuting at *individual* and *household* levels. This trend—towards micro-level social and spatial analysis—has several potential benefits for decision makers, including:

- The ability to target specific *types* of commuters.
- The potential to model the impacts of small-scale interventions (e.g. a new bicycle path) on individuals living in the local area.
- Higher spatial resolution, allowing for realistic insight into the impacts of change on network usage (e.g. identify likely points of congestion).
- The results provide a foundation for agent-based and dynamic microsimulation models.

The shift towards micro-level analysis also has some potential disadvantages. These include greatly increased computational requirements for analysis, lack of available software or expertise, and the pitfalls of overcomplexity. As recent literature shows, new techniques for spatial microsimulation, which model individual characteristics and behaviour, can overcome the majority of these problems (see Section 2.3). A more fundamental barrier preventing the use of micro-level methods in many contexts is that accurate, geocoded microdata are simply unavailable. In the UK, for example, census-derived microdata are made available only as a Sample of Anonymised Records (SARs) at coarse geographical levels (Dale and Teague, 2002).[2] More specific surveys (such as the UK's National Travel Survey) can provide further insight into travel patterns at the individual level but these also omit high resolution geographical information to protect participants' anonymity.

We believe spatial microsimulation techniques, of the type described in this paper, hold great potential benefits for transport

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[1] In the UK, for example, commuting accounts for 16% of trips and 20% of the total distance travelled by personal transport modes (DfT, 2011).

[2] The SARs are divided into two parts: the 2% SAR, which allocates each individual to a geographic region with a population size of at least 120,000 (narrowing-down the results to one or more Local Authorities), and the 1% sample, which allocates each individual to a country (Dale and Teague, 2002).

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planners and policy makers who lack access to official, geocoded microdata (individual-level data allocated to small areas). With such 'spatial microdata', new analysis options are created, including route choice between origin destination pairs, localised intervention evaluations and cross-tabulated contingency tables. These applications should also be of use in the rare (yet increasingly common) situations where official geolocated microdata are provided. In the UK, as in many other countries, spatial microdata must be simulated, as reliable secondary data sources are limited to (1) zonally aggregated census data, and (2) non-geographical, individual level microdata from national surveys. This paper builds on the pioneering theoretical work on spatial microsimulation and applies it to the issue of commuting.

The aim of the research presented in this paper is to bring micro-level analysis within reach for transport planners and researchers already acquainted with aggregated census data on commuting. Detailed non-geographical microdatasets on commuting already exist, but many analyses for evaluating the impact of commuting policies require *spatial* microdata. As indicated above, there are a number of reasons why such spatial microdata may be needed: planning for more sustainable commuting is a complex problem that operates on a range of scales, including that of individuals (Vega, 2012; Verhetsel and Vanelslander, 2010). In the words of Li et al. (2012, p. 313), "a more spatially disaggregated method is needed". To summarise the research problem, tools to aid the design and evaluation of policies affecting commuters are needed. These tools should be flexible, able to operate at a range of levels and shed light on various issues, from the potential of telecommuting (where internet access facilitates working from home, saving transport fuel) to levels of access to public transport, walkways and cycle paths.

The remainder of this paper is organised as follows: Section 2 reviews relevant literature on commuting, transport modelling and spatial microsimulation, highlighting the potential benefits of incorporating individual level socio-demographic data into transport studies. Section 3 outlines the data and methods required to fulfil this potential, and and shows how spatial microsimulation has been implemented in this paper. Section 4 presents some outputs from the spatial microsimulation model. The purpose is to illustrate the new types of analysis opened-up and policy relevance of distributional impacts. Finally, in Section 5, these results are discussed and placed in the context of current practise in transport planning and policy evaluation.

2. Literature review

2.1. Modelling commuter patterns

Commuting has been a topic of research for many decades, reflecting its role in relation to economy, to individual and household well-being and, increasingly, to environment. From this extensive literature, it is apparent that commuting should, in theory, be relatively easy to model. This is because journeys to work tend to be:

- Regular, occurring on a near-daily basis for most people and following predictable hourly, weekly and annual patterns (Akkerman, 2000).
- Non-discretionary—work trips, unlike trips made for socialising and holidays, are an essential part of daily working life. In other words, the demand for commuter travel is non-elastic, and responds slowly to changes in the cost of travel (DePalma and Arnott, 2012).
- Destination-constrained. It is often challenging to change one's work location (e.g. after moving house), as embodied in the common assumption of fixed workplaces (Vega and Reynolds-Feighan, 2009).

These characteristics mean that commuting flows should follow more regular patterns over space and time than travel for other purposes, such as holidays or shopping. In addition, commuting statistics are widely available from national censuses, which often contain a question on travel to work. This data availability and relative predictability has made commuting well-suited to academic research, and a number of methodological advances have been demonstrated using travel to work statistics.

This is well illustrated by comparing the methods of Ibeas et al. (2012) with those employed 16 years earlier by Forrest et al. (1996). In the former, four (increasingly complex) spatial econometric models were harnessed to investigate links between house prices and commuter accessibility. The latter used a single linear regression model to explore the house-price accessibility relationship with respect to a case study of Metrolink, a light rail scheme in Manchester. Increased range and complexity of methodologies can also be seen by comparing the descriptive methods used by Knowles (1996) with the statistical tests employed by Senior (2009) for exploring the transport impacts of the same scheme.[3]

The most recent major methodological advance to use commuting data is the radiation model (Simini et al., 2012). Based on census-derived inter-county commuter flow data across the USA, Simini et al. (2012) developed a probabilistic method of predicting the flows between any two zones, based only on knowledge of population and employment. If the claims stand up to further tests, this could represent a step forward in the modelling capabilities of transport geographers (Brockmann, 2012), for example by allowing individual trips to be predicted and by providing realistic estimates of commuter flows in areas where no flow data is available. In general, however, methods for investigating commuting have advanced gradually, in-line within the 'normal science' of transport geography. In addition, most modelling efforts have been constrained to the geographical scale at which data is made available.

2.2. Scales of analysis

Despite the advances outlined above many geographic approaches for analysing commuting patterns operate only at a single level of analysis. This is often the lowest geographical level for which the required data are available. Indeed, prior to the 21st century, personal transport models tended to be simplistic, assuming 'mono-centric' cities (see Fig. 3) and and taking little or no account of geographic factors beyond distance (Akkerman, 2000; Horner and Murray, 2002). This was problematic for practitioners aiming to evaluate interventions, the impacts of which may be geographically heterogeneous and highly localised (e.g. bicycle paths) or focused on specific socio-economic groups (e.g. telecommuting). Due to data, software and computing limitations, evaluations of the impacts of policies affecting personal transport have tended to be over-simplistic, considering only a single scale of analysis.[4] Ideally, however, macro (geographic) *and* micro (individual-level) factors would be included. The efforts towards such an approach "that integrates [spatial] demographic microsimulation with urban simulation and travel demand" are making progress and could signify a major step forward for personal transport models for policy evaluation (Ravulaparthy and Goulias, 2011, p. 4). Increasingly, newly available micro-level datasets are being incorporated into

[3] The former study harnessed descriptive statistics based on primary data and hand-crafted maps to investigate the transport impacts of Metrolink. The latter employed multiple regression and chi-squared tests of survey data to identify longer-term changes in behaviour attributed to the light rail system.

[4] See, for example, Lovelace et al. (2011) for a non-geograhical example of city-level aggregation, and Li et al. (2012) or Titheridge and Hall (2006) for analyses that use only a single geographical level of analysis.