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Discrete choice in commuter space: Small area analysis of diurnal population change in the Tokyo Metropolitan Region

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ABSTRACT

Considerations of metropolitan commuting have often related to urban space as a continuum, and to commuting itself as a process. This approach has led to escalating complexity in the measurement, modeling and analysis of commuting, often with no commensurate results. The present study extends an alternative approach that considers commuter space of a metropolis as a discrete set of small areas. Each small area throughout the metropolis is a nighttime location of some households and, as a possible discrete destination choice of individuals within households, each subarea is also a daytime location of some persons. Each subarea, therefore, may be thought of as attaining two values, corresponding to its daytime (e.g., noontime) and nighttime (e.g., midnight) populations. The diurnal demographic shift of subareas, as a set of binary events, or toggles, between daytime and nighttime populations, is associated with commuter access throughout the metropolis. Diurnal shift offers structural simplicity aimed at estimating small-area daytime populations across a metropolitan region that might suitably precede and complement conventional continuum considerations of commuting. Using data for the Tokyo Metropolitan Region, we identify average household size as the nighttime indicator of small-areas, and daytime population density as their daytime indicator. The potential for the estimation of daytime populations across metropolitan regions where daytime population data are unavailable, is underscored by the clear tendency towards inverse relation of these two indicators of diurnal shift.

1. Introduction

It is a commonplace observation that housing and employment, as two primary urban ingredients, have been the historic force behind the emergence of urban transportation (Muller, 2004). Instructive in this regard has been also the view that facilitation of access between home and workplace has yielded urban traits which came to characterize the contemporary metropolis, if not its very essence (Burke, 1975). But transportation and access are, clearly, not the same, and within the contemporary metropolis the two notions attain differing, and even contradictory, meaning.

Advances in motorized and automated transportation, particularly in the first half of the 20th century, were thought to lead, along with robust infrastructure, to ever-increasing efficiency in urban access (Carver, 1948, pp. 39–42). The advent of the automobile held a promise to make this goal readily attainable, thus heavily contributing to the growth of suburbs and their populations. It was precisely the automobile that had nourished, over the last half-a-century, a spiraling escalation of motorized commuting and suburban sprawl, two urban trends feeding upon each other. The intensifying feedback between commuter transportation and suburban sprawl ultimately gave rise, in the second half of the twentieth century, to the notion of 'wasteful' commuting by Hamilton (1982).

Emerging from the predicament of commuting as leading to urban dysfunction has been the discernment of a paradox inherent in the concept of urban transportation itself (Hung, 2009). Metropolitan automobile commuter transportation, as a case in point, has come to be seen as an obstruction to traffic itself, in addition to being the main culprit of urban carbon dioxide emissions and safety liability, and thus also raising questions of urban sustainability (May & Nash, 1996). In a study of Boston and Atlanta Yang (2005) has shown how urban transportation has defeated its own purpose over the last several decades, during which overall efficiency in urban accessibility has declined. According to Yang, spatial decentralization, which has been mainly due to improved urban transportation, has eventually lead to longer commutes. Over the last three or four decades several other authors have, in fact, disproved the claim that increasing mechanization and automation of urban transportation has enhanced overall accessibility to urban dwellers (e.g., Horner, 2004; Sinha, 2003; Verbit, 1975). Arguably, much of present-day metropolitan transportation can be viewed as undermining the very concept of accessibility in the city.

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Yet it is precisely within the urban contradiction between transportation and access that a prime question regarding commuting emerges. The spatial perception of urban transportation is the fluid dynamics model (Bellomo, Delitala, & Coscia, 2002), whereby the medium in which transportation occurs is an urban continuum. Access, on the other hand, implies a discrete choice of presence at one place out of several others (e.g., Froehlich, 2008; Stern, 1993). In the foremost sense, therefore, within the contemporary city the two concepts, transportation and access, carry ambiguity regarding the nature of urban commuting as continuous or discontinuous notions. The two representations of commuting, the one as a continuum concept in urban transportation, and the other, as a choice in urban access to and from a finite and discrete range of subareas, imply two diverse frameworks of reference, both consistent with, and intelligible within the scope of their own differing assumptions.

Access as a non-continuous, discrete event vs. transportation as a continuous process, are two alternative aspects of the spatio-temporal relationship between places of residence and work in a metropolis. The ambiguity regarding discrete vs. continuous stance is projected, accordingly, upon the concepts of commuting and commuting space, as well. As a concept, thus, commuting carries an implicit quandary as to whether it is a notion of an urban continuum or, alternatively, a discrete expression of urban configuration by separate spatial categories and distinct temporal marks of day and night throughout the urban diurnal period.

The present study pursues a simplification ensuing from the consideration of access in discrete commuter space, utilizing the notions of daytime populations and diurnal population shift throughout small areas of a metropolis. By probing diurnal population shift as a juxtaposition of demographic measures of daytime and nighttime populations in small-areas throughout the metropolis, we suggest that urban commuter access can be best perceived as a binary event, thus yielding a straightforward and expedient approach to observation as well as analysis of urban commuter space. A binary expression of urban access is a toggle between values of daytime and nighttime populations throughout metropolitan subareas. In a case study of the Tokyo Metropolitan Region, presented here, a strong association emerges between average household size as a *nighttime* population parameter, and *daytime* population density, the two diurnal measures pointing to a high inverse correlation between them.

2. Urban transportation and urban commuter space

The vast majority of commuting studies have pursued the conventional supposition that urban commuting, much as transportation itself, is a process occurring in a continuum. As a description or explanation of a movement of people or vehicles across physical space and time in a city, such premise could hardly be questioned. But commuting notions based on the proposition of a continuous urban space and time also illustrate how, over the past several decades, continuum urban models have increasingly acquired complexity, yet not necessarily clarity (Batty, 2008).

Fluid dynamics notions of urban transportation (also Kachani & Perakis, 2006) are not the sole source of the continuum paradigm in commuting. Historically and methodically, the continuum approach to commuting can be seen associated also within past century's studies that often saw migration and commuting in a single context (Cameron & Muellbauer, 1998). Twentieth century quantitative research of migration, in turn, has progressed mainly along the lines of classical physics, dominated by gravity or distance decay models. This approach has been most vividly expressed in a statement by Robert Lucas: "Migration is comparable to a flow of water or electricity – an adjustment flow responding to pressure differentials at opposite ends of a pipeline" (Lucas, 1981, p. 85).

Over the last two decades an approach that parts with the continuum paradigm in urban concepts began to emerge. The alternative view, conceiving of commuting as a set of discrete events has been advanced not necessarily in rejection of the continuum approach, but as a different viewpoint on the same phenomenon of commuting (e.g., Brownstone & Golob, 1992). The discrete-event stance of commuting does not negate the continuum standpoint, much as the discrete notion of space and time in nuclear physics does not contradict its classical continuum concept. Rather than mutual contradictions, the discrete-vs.-continuum standpoints are simply alternative, and mutually exclusive, conventions (Lesne, 2007). The operational advantage of the discrete-event viewpoint on urban space and time, however, seems to provide a much needed simplification of urban concepts (Visser, van der Wees, & Hertzberger, 2000). The discrete space approach in commuting had focused on the choice of travel modes (Habib, Day, & Miller, 2009; Jou, Hensher, Liu, & Chiu, 2010; Lane, 2011; Ulfarsson & Shankar, 2008), but recent research has shifted also to discrete choice of daytime activity by commuters (Salon, 2009).

For all its relative novelty this latter approach too could be said to have its source in early empirical research on commuting. In his doctoral study of Lousville, Kentucky, Warren Thornthwaite introduced in 1929 the seminal distinction between daytime and nighttime populations throughout a metropolitan region, as a spatio-temporal toggle. Half a century later an empirical study by Janelle and Goodchild (1983) had led to the notion of access in the city as a discrete choice between places of primary nighttime location of people, and their daytime locations. The study by Janelle and Goodchild had centred on measures derived from movement diary data over urban space throughout the 24-h weekday. Out of necessity to meet sample-size constraints, the authors aggregated the data to represent demographic profiles for a limited set of subareas within an urban region at discrete intervals of the day. Even though no explicit attention was given to commuting, commuter access between places of daytime and nighttime location were seen as the prime source of diurnal demographic change in the metropolis.

Whereas population change in traditional demography has been measured in intervals of years and across large geographic regions, small-area and small-interval demography as a topic of inquiry, has emerged fairly recently, mainly in urban analysis. Demographic change in small areas through small intervals of time, such as noontime vs. midnight, is perceived here as a discrete shift between daytime (noontime) and nighttime (midnight) populations of each small-area, rather than as a gradual change in a continuum. Commuter access as a toggle between a nighttime location (place of residence) and a primary daytime location (place of work, study or other major daytime activity), will be here addressed comprehensively throughout subareas of a metropolis, as a reasoned extension of the discrete notions of commuter space and time instigated by Thornthwaite, and Janelle and Goodchild. The main advantage of the emerging approach is that it provides a simple methodological context to commuting which circumvents the incongruity between urban transportation and urban access.

3. Access in the Janelle–Goodchild commuter space

Commuting behavior has long been identified with economic reasoning emerging from the common attempt at minimizing costs (in time or money) related to metropolitan commutes between residence and work (e.g., Bhat, 2001). By and large as a result of this generally observed behavior, some recurring socio-spatial patterns common to metropolitan regions seem to have surfaced across the industrialized world. Universal features in demographic