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Analyzing scale independence in jobs-housing and commute efficiency metrics

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ABSTRACT

Understanding journey to work travel patterns remains an important concern for planners and policy-makers from the viewpoint of economic, environmental, and social sustainability. Researchers, keen to inform metropolitan scale planning efforts, have devised ways of benchmarking regional commuting and land use phenomena. The foundation for these benchmarks rests on metrics that quantify the home-job *proximity* in terms of the aggregate arrangement of workers relative to jobs. Emanating from the literature on 'excess commuting' and 'jobs housing balance', these metrics are increasingly moving towards policy applications. Despite major methodological developments over the last decade, a key methodological issue remains unresolved. Recently developed metrics under this regional macro-scale framework use zonal-based spatial data (e.g. census tracts or traffic analysis zones (TAZs)) and consequently the values of the metrics may be influenced by the scale (e.g. zone size varies between census blocks versus tracts) and zonal partitioning scheme. Moreover it is not known if values of these metrics vary across scale, and exhibit self-similarity, meaning whether it is possible to infer values from one scale to another. This study examines the relationship between the commuting efficiency framework and spatial scale issues by implementing a suite of commuting metrics in the Boise, Idaho USA metropolitan area. Simulations using geographic information systems (GIS), optimization techniques and fractal analysis show that newer metrics developed post 2002 do not vary with scale, while those devised pre-2002 vary with scale but do so in a predictable way.

1. Introduction

Journey to work travel patterns are an important concern for planners and policy-makers from the viewpoint of economic (e.g. productivity, healthcare cost), environmental (e.g. emissions), and social (e.g. job access, health, social interaction) sustainability (Horner, 2004; Black, 2010). Arguably, shorter work trips provide for better sustainability outcomes along all three dimensions. Work trip lengths are the outcome of household location decisions that are made in relation to individual-level socio-economic contextual factors (e.g. multi-worker households, home and neighborhood amenities, job turnover) and aggregate spatial structural factors (e.g. micro-level characteristics such as street connectivity, design, and land use mix at the local level, and macro-level attributes such as imbalance between home and job locations at the regional level) (Ma and Banister, 2006a; Yang et al., 2012). These are complementary views on the transport-land use link in that both focus on

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home and job locations and activity patterns, but whereas the former focuses on individuals' decisions and travel outcomes (Boarnet and Crane, 2001; Rodriguez, 2002; Cao et al., 2008; Scott and Horner, 2008), the latter focuses on the aggregate and often metropolitan-scale outcomes of individuals' choices in the form of the distribution of homes and jobs, the resultant spatial interaction, and the supporting transport infrastructure (White, 1988; O'Kelly et al., 2012; Murphy, 2012).

Focusing on the aggregate metropolitan level view of urban structure's impacts on travel patterns, two broad policy prescriptions aimed at reducing journey-to-work lengths can be identified; travel demand management through price incentives and subsidies, and land use change (Banister, 1999; Weitz, 2003; Cervero and Duncan, 2006). The former involves ways of reducing commutes within a given *fixed* land use pattern, and the latter focuses on reducing the spatial separation between homes and jobs through *physical* changes in the urban landscape. Though the strength of the impact of both pricing and land use change continues to be debated in the literature (Hensher and Puckett, 2007; Mahendra et al., 2012; Welsh and Mishra, 2013), policy that combines both approaches may likely yield the best commute reduction outcomes (Rodier et al., 2002; Guo et al., 2011).

Researchers, keen to inform metropolitan/regional scale planning and policy efforts, have devised ways of benchmarking both of the aforementioned commute reduction strategies. The foundation for both benchmarks rests on metrics that quantify the home-job *proximity* in terms of the aggregate arrangement of these activities. Home-job proximity gauges the jobs-housing balance and thus it measures the efficiency of urban form; urban form is more 'efficient' when homes and jobs are closer together (a better balance) than when they are farther apart (a worse balance). A typical summary measure of home-job *proximity* is the theoretical minimum required commute (MIN hereafter) (White, 1988). Given a fixed metropolitan home-job distribution, MIN is the average commute based on the lowest possible cost (in miles, minutes, or dollars) work trip distribution from a system perspective that connects all homes and jobs. By capturing the spatial relationship between workplaces and residences, MIN is used as a jobs-housing balance metric (Giuliano and Small, 1993) because a lower MIN value indicates homes and jobs are more proximal to each other and a higher MIN value indicates they are farther apart. Thus, MIN itself can be used as a benchmark of commute reduction strategies based on *physical* changes in urban form. In a policy context, MIN values for two land use patterns, current and planned, can be compared to determine if the alternative reduces the spatial separation between workplaces and residences (Horner and Murray, 2003; Horner, 2008; Corcoran et al., 2011). Better home-job proximity provides the potential for shorter commutes (Cervero, 1989; Sultana, 2002) and a moderately strong link between land use and transport outcomes has been found at a local and regional level (Horner, 2002, 2007). As a type of jobs-housing planning technique, Weitz (2003) suggests MIN "can be applied in local land-use regulations and large-scale development reviews."

In the second commute reduction approach, if urban form is held constant and compared with observed travel, or perhaps simulated travel based on proposed transportation pricing policies, then the potential for work travel reduction can be measured using what is known as the commuting efficiency framework. 'Commuting efficiency' is expressed as the difference between the actual observed commute (OBS hereafter) and MIN where a smaller difference indicates lower commute reduction potential because work travel is already more efficient and hence sustainable, and where a larger difference indicates less efficient travel patterns and thus higher commute reduction potential. Planners can use this framework in the following ways: (a) to compare OBS and simulated OBS based on travel demand management strategies against a fixed MIN; (b) to compare original OBS and MIN with simulated OBS and MIN based on land use change; (c) to incorporate both travel reduction policies in OBS and MIN comparison. Another application of this framework has been the relative comparison of the land use-work travel relationship between cities (e.g. Horner, 2002; Niedzielski, 2006) and within cities using local versions of the metric (e.g. Niedzielski, 2006; Horner, 2007).

Considerable methodological and policy-relevant progress has been made in the use of jobs-housing balance and commuting efficiency metrics (Layman and Horner, 2010). The original framework established by Hamilton (1982, 1989), Small and Song (1992) and Giuliano and Small (1993) has been extended in a number of new directions and now offers ways of measuring several dimensions of urban form and commuting efficiency. In addition to MIN that captures local jobs-housing balance, a measure of the best possible proximity, the theoretical random commute (RAND hereafter) has been proposed to capture the regional jobs-housing balance by modeling random commuting behavior (Yang, 2005; Charron, 2007; Murphy and Killen, 2011), and the theoretical maximum commute (MAX hereafter) was designed to capture the regional jobs-housing imbalance by modeling the worst possible proximity (Horner, 2002). This framework also offers three ways of measuring commuting efficiency: excess commuting (EC hereafter) (White, 1988; Giuliano and Small, 1993), capacity used (CU hereafter) (Horner, 2002), and commuting economy (CE hereafter) (Murphy and Killen, 2011). The components of the framework are readily applied to inform public policy questions including

- the relationship between residential and employment density on work trip lengths (Boussauw et al., 2012)
- the impact of home-job proximity on emissions and congestion (Scott et al., 1997; Loo and Chow, 2011b; Welsh and Mishra, 2013)
- the difficulty of reducing observed trip lengths incrementally (O'Kelly and Niedzielski, 2008, 2009)
- minimum energy land-use patterns (Keirstead and Shah, 2011)
- and the impact of land use change on
  - work travel patterns (Horner, 2007; Yang and Ferreira, 2008; Loo and Chow, 2011b)
  - home-job proximity (Horner and Murray, 2003; Horner, 2008; Layman and Horner, 2010; Loo and Chow, 2011a, 2011b; Lee, 2012).