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Gridlock in the Greater Toronto Area: Its geography and intensity during key periods

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ABSTRACT

For most urban road users, images of gridlock elicit thoughts of freeway travel or downtown commuting, creating a powerful collective conversation about trading off urban opportunity for traffic strife. But while congestion plays a powerful role in shaping mental images of cities and better policymaking, new sources of traffic data are only beginning to be used by geographers and planners to explore how congestion influences the experiences and opportunities of users. By employing spatial analytical methods to assess social implications of congestion and estimating spatial variations in user experiences, geographers can leverage new data sources to enrich the congestion research still dominated by engineering approaches. This study contributes to the existing literature on measuring traffic congestion by proposing novel means of assessing time-varying, space-varying, and scale-varying congestion performance indicators and scaling these up to generalize about user experiences in a region. In this study, a transportation network is designed using geographic information systems (GIS) which incorporates time-varying elements of transportation system performance. Performance indicators are then estimated using origin-destination matrices calculated from time-varying road networks using census tracts as units of observation in the Greater Toronto Area (and secondarily in the Hamilton region) within the Greater Golden Horseshoe region of southern Ontario. These metrics illustrate how new data can be deployed to monitor traffic congestion at different times and in different locations in even more detail for large urban areas.

Introduction

Many think of congestion as most endemic around major downtowns and near major freeway facilities, but do we know as much about the geography of congestion as we think? Traffic congestion, an inconvenience of urban living, features almost daily in the public discourse about travel. The construct of sustainability has brought a system of thinking about broader social implications and consequences of mobility and transportation policy. But while congestion's implications for commuting and social outcomes is well-documented, the spatial nuances of understanding such social experiences at the level of system users has rarely been applied in the study of traffic congestion (Horner, 2004). Instead, engineering approaches dominate congestion research (Mondschein, Brumbaugh, & Taylor, 2009). Conventional discourse of congestion as a downtown or even as a freeway phenomenon remains strong based on admittedly incomplete performance metrics of traffic congestion, but employing spatial analytical tools using new sources of transportation performance data can provide new insight into spatial and temporal variations in traffic congestion and how these shape user experience.

This study contributes to the existing literature on measuring traffic congestion by proposing novel means of assessing time-varying, space-varying, and scale-varying congestion performance indicators and scaling these up to generalize about the experiences of a region. In this study, a transportation network is designed using a geographic information system (GIS) which incorporates time-varying elements of transportation system performance. Performance indicators are then estimated using origin-destination matrices calculated from time-varying road networks using census tracts as units of observation in the Toronto Census Metropolitan Area (CMA) – henceforth referred to as the Greater Toronto Area (GTA). The GTA, the focus of this study, and Hamilton

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CMA, of secondary interest in this study, represent the primary components of the Greater Golden Horseshoe, the vast majority of population and economic mass in southern Ontario, Canada. While previous measures of road system performance are based on facilities, the ones employed in this study are spatially explicit and based on the potential origins and destinations of trips using a network in a geographic information system – providing additional insight into potential user experience.

Literature review

Congestion has been measured using a variety of means (Bertini, 2005) over many years dating back before the early road building programs (U.S. Bureau of Public Roads 1939). Missing from most of these studies is a portrait of congestion which employs a network approach to reflect spatial and temporal variations in user experiences. The focus of geographers and planners on linking public policy with social and environmental spatial processes holds much promise in strengthen how congestion might be measured and managed to support sustainability. Travel costs feature prominently in research on transportation geography (Boscoe, Henry & Zdeb 2013; Horner, 2004; Scott, Kanaroglou & Anderson 1997). But the lack of network-specific data which captures variations in how the transportation system functions at different times has historically provided a hurdle in better integrating metrics of travel costs into geographic research on accessibility and the potential to engage in opportunities (Yiannakoulias, Bland, & Svenson, 2013).

In fact, better understanding the complex nature of congestion-related travel costs is critical to forming better transportation planning policy. Congestion alleviation and travel time savings serve for many as the central justifications for transportation policy intervention (Metz, 2008; Taylor, 2004). Insofar that congestion influences travel times (Levinson & Wu, 2005) and travel times, in turn, reflect broader attributes of transportation service quality, understanding congestion's multiple dimensions has broader implications than just congestion management. Nevertheless, to more effectively understand, monitor, and manage congestion, better tools are needed – particularly to reflect its spatial and temporal complexities.

The proliferation of new types of data have changed how transportation services can be studied. Performance evaluation has had a resurgence in light of new data, the need to justify policy investment and ensure accountability (Klase, 2014; Yusuf & Leavitt, 2014), and the need to monitor transportation performance for new project delivery methods (Lawther & Martin, 2014). But conventional methods of studying congestion are not best suited for leveraging new data to better understand congestion. Traditional engineering approaches have estimated congestion using deterministic volume-capacity functions which produce estimates of travel delay and level of service at the level of pieces of infrastructure (Transportation Research Board, 2010). Inferred travel conditions are then scaled up to the levels of regions or facilities to illustrate average congestion levels based on traffic volume and performance estimates, but these metrics do not reflect the potential experiences of system users (Gordon, Kumar, & Richardson 1989; Gordon, Kumar, & Richardson 1991). More recently, observed speed data has been employed into conventional congestion measures to estimate aggregate performance at the region-level (Schrank, Eisele, & Lomax 2012) and in some cases, global positioning system data has enabled local performance metrics, including in Chicago (Sweet & Chen, 2011) and Accra (Moller-Jensen, Kofie, & Allotey 2012). Instead, employing geographic information systems (GIS) with disaggregate road performance data using network analysis methods has tremendous potential to augment engineering studies with better spatial and temporal understandings of users' congestion experiences.

Congestion study approaches

Congestion is most fundamentally a cultural construct which should be framed relative to broader social values (Weinstein, 2006). So while most definitions of congestion center on volume-induced slowing of transportation services documented by engineers, measuring congestion depends on culture-specific assessments of how transportation services should function. Researchers have striven to design congestion measures which reflect the broad range of performance conditions (Boarnet, Kim, & Parkany 1998, Schrank et al., 2012). But as congestion has many different dimensions, different metrics can lead to confusion in interpreting the meaning, social consequences, and policy implications of traffic congestion (Boarnet et al., 1998).

The research challenge of better measuring congestion is embedded in the question of when it matters more, or when it is more "costly" – a question of enormous policy relevance. Congestion's costs can be distilled to first-order travel delay, second-order economic and social costs, and public policy costs of managing congestion (Sweet, 2011). Thus, measuring congestion and identifying how roads should function inherently entails a preconceived notion of which of congestion's implications are most problematic. Although some empirical measures of congestion appear to be objective, all metrics inherently are normative because they establish a scale by which how things should function is invariably assessed. Conventional engineering approaches to congestion research have dominated, but new geographic and economic research has provided a more complex portrait of congestion's extent, implications, and meaning for economic and social outcomes (Mondschein et al., 2009) – a research gap upon which this research focuses.

Some empirical congestion metrics seemingly require no judgment on the part of the researcher on how transportation services should function, while other metrics are inherently normative and more meaningful. Common measures include travel times, speeds, level of service, volume-to-capacity ratios, delay, queue length, and traffic density (Bertini, 2005). Among these, empirical estimates include road speeds, travel times, queue lengths, and traffic density and each captures elements of congestion but inherently provide little information on "better" or "worse" function. For example, road speeds are conventionally estimated using simplified speed-flow-density functions which obscure variations in infrastructure performance and user experiences. Instead, nascent geographic research on congestion using observed (and not inferred) road performance data has explored spatial variations in road speeds which underscore variations in user experiences. For example, Moller-Jensen et al. (2012), use global positioning system (GPS) – based road speed data to highlight spatial variation sin congestion in Accra. Likewise, Sweet and Chen (2011) employ GPS-based road performance data to explore variations in speed and reliability in the Chicago region.

Normative measures of traffic congestion rely on assessing empirical measures relative to benchmarks of what acceptable, desirable, or uncongested system performance should be (Weinstein, 2006). Among normative benchmarks, engineering benchmarks are most common while economic benchmarks and social benchmarks have increasingly become objects of inquiry. Normative engineering congestion metrics include volume-to-capacity ratios, level of service, and delay and these approach congestion as a problem with the transportation system (Bertini, 2005). Most engineering studies focus on free-flow speeds as a benchmark for estimating congestion, but others focus on the optimal speed (usually between 70% and 90% of free-flow speeds) which accommodates the maximum vehicle flow (Hall, 1987; Navin & Hall, 1989).