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Daily fluctuations in transit and job availability: A comparative assessment of time-sensitive accessibility measures

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ABSTRACT

Accessibility to jobs by transit is increasingly incorporated into transportation and land-use planning objectives, as it is proven to be a relevant indicator for assessing land-use and transport performance. With a rise in time-sensitive accessibility measures, choosing the appropriate measure is increasingly challenging for engineers, planners and policy-makers. This research presents a comparative analysis of three accessibility measures, two of which are time-sensitive. Relative accessibility measures are generated for five time periods based on a) constant transit service and number of jobs (constant); b) variable transit service and constant number of jobs (static) and c) variable transit service and variable number of jobs available (dynamic). The measures are first assessed by incorporating them into a transit mode share model. Interestingly, findings show that all three measures behaved similarly in the three regression models. Furthermore, all accessibility measures are found to be highly correlated. The study suggests that the most commonly used accessibility measure (constant measure at 8 am) is representative of the relative accessibility (static or dynamic) over the course of the day and is thus appropriate and meaningful to be used by policy-makers, engineers and planners.

1. Introduction

Accessibility is increasingly incorporated into transportation and land-use planning objectives (Geurs et al., 2012; Handy, 2008; Lucas, 2012; Manaugh et al., 2015; Preston and Rajé, 2007), as it is proven to be a relevant indicator for promoting equitable transport systems (Martens et al., 2012), sustainable urban transportation (Banister, 2008; Boschmann and Kwan, 2008; Handy, 2008) and social inclusion among disadvantaged groups (Lucas, 2012; Preston and Rajé, 2007). Increasing accessibility by transit allows meeting the needs of individuals while reducing automobile dependence (Handy, 2002). For engineers and planners, choosing appropriate metrics is central in order to evaluate desired goals and develop effective policies (Geurs and van Wee, 2004; Handy and Niemeier, 1997). A plethora of accessibility measures have been developed (Geurs and van Wee, 2004; Handy and Niemeier, 1997; Páez et al., 2012), with a trend towards more detailed and complex approaches (Geurs et al., 2012). Namely, recent research seeks to address the fluctuation in accessibility by transit that may occur over the day due to variations in service (Anderson et al., 2012; El-Geneidy et al., 2016; Farber et al., 2014; Wangtu et al., 2015). Various approaches are put forward, based on different methodological and conceptual basis, and addressing different levels of complexity.

Given recent theoretical developments and a growing interest for applicable accessibility metrics, this methodological study explores whether time-sensitive measures of location-based accessibility to jobs by transit throughout the day provide a more appropriate measure of accessibility than the constant ones. By doing so, this research seeks to address the gap between accessibility research and its practical applications. The research setting is the Greater Toronto Hamilton Area (GTHA). Building on previous studies (El-Geneidy et al., 2016; Fan et al., 2012; Legrain et al., 2015), we generate three accessibility measures for five daily time periods. The first accessibility measure is constant over the day, while the two other measures take into account the fluctuations in transit and job availability during the day. Using one data set, this study compares the three different measures and is of relevance to engineers and planners who want to balance between the accuracy and the simplicity of a measure. This research, although based on one region, provides methodological insight that can be relevant to other regions.

2. Literature review

2.1. Accessibility

In transportation planning, accessibility is largely defined as the potential of an individual to reach opportunities (Preston and Rajé, 2007). While mobility studies are mainly interested in travel speed, accessibility includes a broader range of factors that affect the capacity or the ease of reaching a location. Based on an extensive literature review of

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accessibility definitions, Geurs and van Wee (2004) identify four components of accessibility: the transport component, the land-use component, the individual component and the temporal component. The transport component, widely studied in mobility and accessibility studies, is related to the transport infrastructure and is usually mode specific. The land-use component refers to the location and the characteristic of opportunities or the location of people. Most studies focus on opportunities such as jobs, health services and shops. The individual component reflects the personal characteristics that might affect one's travel needs or capacity, including factors such as age, gender, car ownership, education, household composition and income. The last dimension is the temporal component, including the availability of opportunities across the day (example, opening hours of shops), the individual's schedule, as well as the transit schedule.

2.2. Accessibility measures

Given the wide scope of factors affecting accessibility, measures of accessibility are also diverse. The measures of accessibility can be person-based, measuring the opportunities at the individual level, or location-based, measuring the number of opportunities accessible from one location (Geurs and van Wee, 2004; Miller, 2005; Owen and Levinson, 2015). Person-based accessibility accounts for individual factors affecting one's ease of reaching its desired destination, whereas location-based accessibility presents aggregated measures. While location-based measures do not capture the individual component of accessibility, they allow assessing it at the regional scale and are thus most commonly used by policy-makers (Dodson et al., 2007). Because of its planning relevance, location-based accessibility is the focus of our study. The most common measure of location-based accessibility is the cumulative-opportunity measure (Geurs and van Wee, 2004). This method counts the number of opportunities that can be accessed from one location within a given travel time. A second common method is the gravity-based method, first introduced by Hansen (1959), which takes into account all opportunities available in the region and then discounts them based on the travel time from the origin. While the cumulative-opportunity measure is simpler, the gravity-based measure provides an estimation that better reflects reality.

Accessibility measures can be translated into relative accessibility indicators to compare the levels of accessibility across groups or modes (Niedzielski and Boschmann, 2014; Páez et al., 2010) or across a region (Manaugh and El-Geneidy, 2012; Widener et al., 2015). Zonal relative accessibility allows policy-makers to assess the geographic distribution of opportunities and transportation services (Handy and Niemeier, 1997).

2.3. Accessibility by transit

As transit gained importance in accessibility research, numerous studies assessed accessibility to transit (Moniruzzaman and Páez, 2012; Olszewski and Wibowo, 2005; Zielstra and Hochmair, 2011), counting for example the number of transit stops within a specified walking distance. While these measures provide an indication of the presence of transit service in an area, they do not assess the quality of this service to reach desired destinations. Accessibility by transit to opportunities is hence increasingly researched as it provides a more comprehensive measure regarding the quality of transit service in a region.

Typical measures of accessibility by transit primarily focus on the transport component (transport infrastructure and transit service availability) and the land-use component (location of homes, workplaces, health services, shops, etc.). Accessibility by transit is based on travel time, calculated using the transport network characteristics, and on the location of opportunities and home locations. Measures are typically based on a single departure time, using a fixed number of opportunities, without considering opening hours of services, or, in the case of jobs, starting time (Owen and Levinson, 2015).

2.4. Time-sensitive measures

While temporal factors are predominant in studies of person-based accessibility (Miller, 2005), using for example the space–time prism, first developed by Hagerstrand (1970), they are marginal in location-based accessibility studies. Although technical progress has been made for calculating travel time by transit, namely with the use of the General Transit Feed Specification (GTFS) (Lei and Church, 2010; Owen and Levinson, 2015), daily fluctuations are seldom taken into account when measuring accessibility (Owen and Levinson, 2015). Furthermore, very few studies have included the combined influence of spatial and temporal factors in accessibility by transit (Dodson et al., 2007).

Nevertheless, growing research highlights the importance of developing measures that are sensitive to temporal constraints (Anderson et al., 2012; Dodson et al., 2007; El-Geneidy et al., 2016). In this regard, some studies have attempted to address accessibility daily fluctuations by taking into account variations in transit service. A first stream of research assesses variation of transit service based on fluctuation of the demand (Polzin et al., 2002; Wangtu et al., 2015). Most commonly, studies investigate transit service variation with regard to transit schedules. Mavoa et al. (2012) and Dill et al. (2013) address fluctuations in transit service by adding a transit frequency variable together with the accessibility measure while Dodson et al. (2007) measure transit frequency at different times of the day to assess transit service. Other studies take into account the daily fluctuations of transit service by basing the accessibility measures on various departure times. Fan et al. (2012) calculate travel time at every hour of the day and provide a daily accessibility based on average hourly travel times. Owen & Levinson (2012) and Lei and Church (2010) calculate the minimum travel time within a time window. On the other hand, Anderson et al. (2012) and Owen and Levinson (2015) generate a continuous accessibility measure, accessibility being calculated at every minute. Farber et al. (2014) adopt a similar approach, measuring accessibility by transit to supermarkets at every minute of the day. Minute-by-minute accessibility measurements provide a higher resolution than previous approaches based on hourly or single departure time, hence accounting for flexible departure times.

While variation in transit service is accounted for in these studies, it is assumed that the opportunities at destinations (jobs in most studies) are available throughout the day. It does not take into account starting and leaving time constraints that are imposed on workers. For example, nurses or construction workers are more likely to work during non-typical working hours. This is especially relevant when travelling by transit, since transit service is generally lower during non-typical working hours. Legrain et al. (2015) address this limitation by combining variation in both transit and job availability. They measure accessibility at five different time periods during the day, matching transit time and number of jobs starting within a given time period.

Given the recent rise in the development of time-sensitive accessibility measures, assessing the different approaches is essential to help engineers and planners choose the method that best suits their needs. The utility of a measure depends on multiple criteria that are often in conflict with each other. On the one hand, measures must be theoretically sound, sensitive to multiple accessibility components (Geurs and van Wee, 2004; Handy and Niemeier, 1997). On the other hand, measures should be easy to operationalize, and easily interpretable and communicable (Geurs and van Wee, 2004; Handy and Niemeier, 1997). The choice of measure also depends on the objectives pursued by the engineers and planners (Geurs and van Wee, 2004; Handy and Niemeier, 1997).

Despite the recent progress in addressing the temporal component of accessibility, to our knowledge no study has yet assessed time-sensitive measures utility on a comparative basis. This study thus questions whether using time-sensitive measures, accounting for fluctuations in job availability and/or transit service throughout the day, improves their utility relatively to traditional constant measures.