The impact of local work and residential balance on vehicle miles traveled: A new direct approach

Allister Loder[a,*], Reto Tanner[a,b], Kay W. Axhausen[a]

[a] Institute for Transport Planning and System (IVT), ETH Zürich, Stefano-Franscini-Platz 5, Zürich CH-8093, Switzerland
[b] Division of Systems Analysis and Econometrics (SEC), Department of Transport Science, KTH Royal Institute of Technology, Teknikringen 72, SE-100 44, Sweden

ARTICLE INFO

ABSTRACT

This paper introduces a new approach for explaining the effects of spatial competition for opportunities based on a cumulative opportunities measure of accessibility. We focus on the case of the labor market where some municipalities offer too few workplaces for their local population, forcing some of their residents to long drives. We apply this new accessibility measure to explain households' annual mileage in Switzerland using a Heckman model to account for carless households.

We find that car travel demand is much greater in municipalities with a relative undersupply in the local labor market compared to a balanced or oversupplied local labor market. The results show that driving increases with greater distance to the labor market center. The model estimates allow policy makers and planners to quantify as a first assessment the expected average mileage in each municipality for new settlements and to identify municipalities with low expected annual mileage.

1. Introduction

The relationship between travel and the built environment has been one of the most studied in urban planning. Neighborhoods with large development density, land use diversity, street connectivity, destination accessibility and lower distance to public transport are generally found to reduce driving (Ewing and Cervero, 2017). Typically, the motivation for driving is to reach destinations for activities such as work or leisure. Destination accessibility is a measure to quantify for a location the generalized costs to reach potential destinations, because it provides a measure of the spatial interaction of land-use and transportation systems (Hansen, 1959; Weis and Axhausen, 2009). While there is no one best measure of accessibility (Handy and Niemeier, 1997), Geurs and van Wee (2004) emphasized the need for accessibility measures that are relatively easy to interpret for researchers and policy makers in evaluating land-use and transportation changes. They concluded that these relatively easy to interpret measures typically lack many details, but complexity and difficulty of interpretation increases with higher levels of detail.

With an expected population growth in Switzerland at a rate of 0.7% from 8.4 million in 2015 to over 10 million in 2045[1], additional drivers will increase the negative externalities of traffic related to ecological impact, time losses and infrastructure. For an optimal land-use strategy that minimizes these negative impacts, urban and transport planners need to understand how the built environment itself affects driving. There is general consensus on how measures of accessibility are related to driving: areas with greater levels of accessibility exhibit less driving (Ewing and Cervero, 2010, 2017). However, "*perhaps the simplest approach*" (Owen and Levinson, 2015) of defining accessibility, the cumulative opportunities measure, fails to take spatial competition effects for opportunities into account (Geurs and van Wee, 2004). This is particularly important for the labor market; too few available workplaces may force workers to drive longer distances, even though their place of residence provides generally high levels of job accessibility. Thus, to derive optimal land-use strategies, it is important to understand the effect of competition for workplaces while maintaining the readability of results. In terms of accessibility, so far, this remains an open task. In this paper, we address this gap. We propose a new measure of accessibility that builds upon the cumulative opportunities measure, but accounts for local job competition.

We generate the new accessibility measure with car travel times from the macroscopic Swiss national transport model. Travel times are available at traffic analysis zones (TAZ) level. This zones follow in most instances the municipal borders, but are further subdivided in areas with high population density, i.e. in cities. With population and employment data available at TAZ level, we compute for each TAZ the

---

cumulative opportunities measure of accessibility to population and to workplaces up to certain travel time threshold. We also control for accessible workplaces beyond this threshold up to a second, more distant, threshold. We then transform the three accessibility measures into ordinal variables and obtain the new accessibility measure by interacting the three ordinal accessibility measures. We use the new accessibility measure to analyze the effects of the population and workplace distribution on driving, measured by the annual mileage of a household. We account for carless households using Heckman's (1976) selection model. We not only find that compact developments exhibit less driving, but also that less competition for workplaces or less need to drive longer to workplaces reduces driving. To the best of our knowledge, this is the first analysis that combines the cumulative opportunities measure of accessibility with competition for opportunities, which has been addressed, so far, only in more complex accessibility measures (Geurs and van Wee, 2004) and the literature on excess commuting (Hamilton and Röell, 1982), which does not include an accessibility perspective.

The remainder of this paper is organized as follows. The next section provides a brief literature overview on measuring and analyzing the spatial distribution of population and workplaces relevant to travel behavior. Thereafter, we explain how we obtained the new accessibility measure and how we prepared the socio-demographic data for the analysis of households' driving behavior, which is followed by a discussion on methodological approaches for modeling car use. Then we present the results and subsequently discuss the new accessibility measure and our results.

2. Background

Accessibility is not only a transport, but also a social and economic indicator. Geurs and van Wee (2004) defined accessibility as "*the extent to which land-use and transport systems enable (groups of) individuals to reach activities or destinations*". An important distinction is between *individual* and *locational* accessibility. The first type of accessibility measures describe the ease of a traveler to reach destinations given individual constraints. The letter types of accessibility measure the costs of reaching potential destinations within a transportation system (Owen and Levinson, 2015).

Geurs and van Wee (2004) discussed perspectives on accessibility and identified four relevant components. First, a transportation component describing travel time, costs or speeds between origin and destination. Second, a land-use component describing amount, quality and spatial distribution of opportunities that are supplied at each destination, e.g. number of employed (Hansen, 1959), population (Killer et al., 2013) and or retail (Crozet et al., 2012). Third, a temporal component introducing temporal constraints for the availability of opportunities and individuals. Fourth, an individual component describing personal needs and constraints. Geurs and van Wee (2004) concluded that an accessibility measure should be sensitive to changes in all four components, however, "*applying the full set of criteria would imply a level of complexity and detail that can probably never be achieved in practice*". Also, Horner (2004) noted as a limitation of individual accessibility measures that they are incapable of producing generalized assessments of intra-urban structure because they focus on personal geographies. Handy and Niemeier (1997) concluded that no best approach to measure accessibility exists, while Owen and Levinson (2015) called the location based measure of cumulative opportunities the "*perhaps the simplest approach*". In this approach, accessibility is the count of all opportunities at destination that are reachable within a specific time threshold (Morris et al., 1979). Another popular location-based accessibility measure was introduced by Hansen (1959). In his approach, opportunities at reachable destinations are weighted by a gravity-based function of, e.g. travel time, distance or costs, before summing up all reachable opportunities. In this gravity-based approach, opportunities at destinations farther away are less desirable, similar to

decreasing gravitational force between more distant planets. However, both approaches face implementation limitations. While for cumulative opportunity measures one has to decide on the threshold values (Morris et al., 1979), for gravity-based approaches an appropriate weighting function has to be chosen and parametrized (Geurs and van Wee, 2004).

The interactions between the land-use and transportation system are approached as an optimization problem in the literature on excess or wasteful commuting (Ma and Banister, 2006a; Barr et al., 2010); observed commuting patterns are compared to the average minimum commute, which is the solution of the optimization where, for a given distribution of residential and work locations, commuting trips are reallocated to minimize average travel costs. Figuratively speaking, workers are assigned to the closest working places in terms of travel time or distance, ignoring job qualifications (Hamilton and Röell, 1982; Hamilton, 1989). The measure of an average minimum commute is also considered to be a measure of the jobs-housing balance (Ma and Banister, 2006b). Recently, Kanaroglou et al. (2015) summarized the literature on excess commuting and provided a review and evaluation of metrics used for assessing excess commute. We refer the interested reader to the detailed discussion of indicators and metrics in that paper. This approach covers the effect of competition for jobs and the requirement to drive longer if too few jobs are available, but it lacks the spatial aspects of accessibility and land-use measures.

In summary, the literature shows a variety of accessibility measures and different approaches such as excess commuting, to address the interaction between land-use, transportation systems and the competition for opportunities. However, depending on scope and objective of analysis, a distinct metric has to be chosen, while the researcher bears in mind the implications of the chosen metric. We choose - to illustrate our new approach - the relatively easy to interpret measure of cumulative opportunities measure of accessibility.

3. Data

In this section, we first describe the procedure of obtaining the new accessibility measure and, second, the preparation of the socio-demographic data for explaining households' driving behavior by the new accessibility measure.

3.1. Accessibility data

Following the accessibility perspectives by Geurs and van Wee (2004), the proposed new accessibility measure is a location-based accessibility measures, precisely speaking a contour measures or cumulative opportunity measure. Despite limitations, this kind of measure has proven its applicability in many studies. Owen and Levinson (2015) called this approach "*perhaps the simplest approach*", because it simply counts of opportunities at destination that are reachable within time thresholds. In this analysis, we measure the competition of a local population for local workplaces in two regions. The first region, $R1$, is limited by travel time threshold cut_1 around a location. The second region, $R2$, is defined between the travel time thresholds cut_1 and cut_2, assuming $cut_2 > cut_1$.

In our model, the population in $R1$ is competing for available jobs in $R1$, but we also control for the level of available jobs in $R2$ to reduce the bias introduced by arbitrary choosing the travel time thresholds (Morris et al., 1979). Thus, for each TAZ, we compute the accessibility to workplaces $Work_{R1}$ and the amount of population Pop_{R1} for region $R1$ with Eqs. (1) and (2), respectively. $I(x)$ is an indicator function and equals to one if its argument is positive, including zero, and equals zero otherwise.

$$Work_{R1} = \log\left(\sum_{i=1}^{N} Work_i \cdot I\left(cut_1 - tt_{ij} \geq 0\right)\right)$$

(1)