



## A spatio-temporal accessibility measure for modelling activity participation in discretionary activities

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### ABSTRACT

Accessibility is a key indicator for the number of opportunities experienced by an individual, and it is generally assumed that higher levels of accessibility lead to higher levels of activity participation and satisfaction. Despite the fact that this relationship has been tested in preceding studies, no clear pattern of correlation has been found between an individual's accessibility and his/her participation in out-of-home discretionary activities. Previous studies mostly applied aggregate, spatial accessibility measures that do not account for the heterogeneity related to an individual's spatio-temporal constraints. However, in addition to locations' spatial distribution, personal constraints related to the mandatory activities a person undertakes – and therefore, his/her available time budget throughout the day – impact activity choices and scheduling. This paper proposes a disaggregate, person-based accessibility measure that takes spatial and temporal constraints into consideration for the travel behavior of 11,599 individuals in the Wasatch Front region, Utah. This method is compared to an aggregate, home-based accessibility measure to assess both methods' ability to predict activity participation. The results show a highly significant, moderate correlation between the proposed person-based accessibility measure and participants' surveyed partaking in discretionary activities. Both the model prediction and the locally weighted regression smoother indicate that the greatest change in participation occurs within the mid-range of accessibility levels, and not in the low end of the accessibility range as was expected. In addition, the home-based method shows a negative and highly significant relationship to activity participation, which indicates that aggregate accessibility measures may provide counterintuitive findings.

### 1. Introduction

From the second half of the 20th century, investments in automobile-oriented transportation infrastructure have dramatically increased mobility levels (Miller, 2007). When considering the theory of constant travel time budgets, this higher mobility has likely led to increased trip generations, and more trips being made to destinations at greater distances (Zahavi, 1978). The literature lends support to the view that the rate at which trips are generated in a population is linked to the ease of making trips to potential destinations. This assumption coincides with some of the well-known definitions of accessibility, such as 'the potential of opportunities for interaction' by Hansen (1959) or 'the freedom of individuals to decide whether or not to participate in different activities' by Burns (1979). Moreover, since the introduction of the concept of accessibility, transport policy has established this concept to be founded on the basic economic principle of supply and

demand. The provision of accessibility is deemed to lead to an increased trip generation and, therefore, a higher participation in out-of-house activities for which the general demand is high (Thill and Kim, 2005). So, there are good reasons to believe that higher levels of mobility, but really its ensuing accessibility benefits, lead to increased participation in discretionary activities and, therefore, more social inclusion for various segments of the population.

Various studies have aimed at addressing this interaction, in order to highlight the extent to which accessibility-enhancing policy decisions have the ability to generate an increase in activity participation. Until this moment, diverging correlations are found, and the empirical validation in the literature remains inconclusive on a uniform definition. In this retrospect, accessibility is often considered from a purely spatial point of view. Where the friction of travel cost is reduced, more trips to destinations at greater distances – and, potentially, more participation in activities – would be generated. However, this perspective does not

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take into account the inter- and intrapersonal heterogeneity related to an individual's personal constraints. From a time geographic perspective, individuals additionally have more time available to partake in certain activities at destinations at shorter distances, which could increase the utility gained from the activity or provide more flexibility in activity scheduling. Person-based accessibility metrics address a traveler's daily and long-term scheduling of their activity demands and enforced commitments by considering the location and duration of mandatory activities, the time budgets for discretionary activities, trip-chaining and travel cost (Geurs and van Wee, 2004). In the past decade, the literature on person-based or activity-based accessibility measures has burgeoned (Patterson and Farber, 2015). These metrics are founded on Hägerstrand's classical time geography and apply time-use concepts, based on the notion that time and space dimensions are interdependent and should both be incorporated in activity and travel demand models (Hägerstrand, 1970; Kwan, 1998; Lee et al., 2007). Accordingly, individuals are bound to particular locations at specific times of the day. Space-time concepts have been commonly applied to determine the opportunity to engage in activities given both spatial and temporal limitations due to land use and transportation and communication infrastructures (Fransen et al., 2015; Kwan, 1998; Neutens et al., 2012). To date, a large number of activity-based travel demand models exist that provide highly detailed space- and time-sensitive measures of person-level accessibility (Bhat et al., 2013; Davidson et al., 2007; Timmermans et al., 2002). Nonetheless, empirical research on the benefits of applying space-time measures of potential accessibility to predict realized activity participation remains scarce.

Validation of this conception is of crucial concern given the ongoing paradigm shift towards planning for increased accessibility, which is widely motivated by environmental as well as social justice considerations (Martens, 2016). Herein, zone-based measures fail to grasp all individuals' life experiences related to the full spectrum of aspects of social exclusion or transport poverty (Miller, 2006). In addition to aspects of time, various socio-demographics such as car ownership, age or disabilities influence the level of social exclusion risks a person is exposed to (Delbosc and Currie, 2011; Lucas, 2011; Preston and Rajé, 2007). A growing number of transport investments aim at increasing access to opportunities in areas with existing low levels of accessibility and neighborhoods with a low socio-economic status (SES). However, the extent to which this benefits the well-being of people living there has not been thoroughly examined. The vulnerable or impaired population, for example, has proven to be of little concern for targeted policies, despite their generally low levels of well-being in relation to transportation (Currie et al., 2010).

The motivation for this paper stems from the discussion above. A person-based travel demand analysis enables to incorporate complex travel patterns and trip-chaining behavior into the analysis. The accessibility is measured on an individual level and, as such, accounts for a person's spatial patterns as well as daily temporal constraints. The resulting disaggregate accessibility index better reflects the realized travel behavior and activity participation and, resultantly, contributes to the existing strand of literature. Introducing the socio-demographic characteristics on the individual or household level enables the identification of the various significant factors that simultaneously impact participation. In addition, it allows to highlight disparities between individuals with different socio-demographic characteristics.

The remainder of the paper is organized as follows. First, it continues with a brief background in Section 2, which highlights the inability of previous studies to determine a uniform and clear association between accessibility and activity participation, and investigates the possibilities of incorporating temporal constraints to better predict this relationship. Section 3 reports on the study area and data applied for the analysis. Subsequently, the methodology is explained in Section 4. The paper provides the major results in Section 5 and concludes with both limitations to and further research possibilities for the study in the discussion section.

## 2. Background

An extensive body of literature exists on the benefits of the provision of accessibility to generate more opportunities to reach certain destinations in a wide range of domains (e.g., health care (Dewulf et al., 2013; McGrail and Humphreys, 2009), shopping (Farber et al., 2011; Widener et al., 2015), employment (Albrechts, 2010; Owen and Levinson, 2015)). Herein, the availability of more opportunities – and therefore, an improved potential accessibility – is considered to generate more realized activity participation. However, to date, no unambiguous conclusion on this relationship can be made, as strongly diverging empirical evidence supporting as well as contradicting the significance of this relationship is available.

On the one hand, a group of studies support this claim. Koenig (1980), for example, examined the relations between a single gravity-based accessibility measure and observed trip rates for participants in different French cities, and highlighted accessibility as a powerful determinant of the trip frequency. Similarly, Purvis et al. (1996) applied a home-based model to study the impact of work accessibility on non-work trip frequency for the San Francisco Bay Area. The model showed an inverse relationship between work trip duration and home-based nonwork trip frequency. A more recent study by Thill and Kim (2005) estimated Poisson regression models of automobile trip generation by trip purpose using survey data for Minneapolis-St. Paul, Minnesota. They tested alternative measures of accessibility for statistical significance, and found confirmation to support the theoretical arguments and empirical evidence that trip generation is related to geographical accessibility. Additionally, the authors concluded that different accessibility measures capture different facets of how individuals interact with the spatial structure and distribution of opportunities. The socio-economic characteristics of the population such as income, car ownership, household size, age and driver's license information, and even lifestyle choices have been proved to have a strong impact on both trip generation and activity participation (Krizek and Waddell, 2002). Lu and Pas (1999) composed a structural equation model to examine the relationships between socio-demographics, activity participation and travel behavior. The results showed that travel behavior can be explained better by incorporating activity participation endogenously in the model, than through socio-demographics alone.

On the other hand, a strand of research has found contradicting conclusions. In a study for Uppsala (Sweden), Hanson and Schwab (1987) used passive home-based and work-based accessibility measures to study the relationship of an individual's travel behavior to his/her location, while controlling for several socio-economic (e.g., sex, automobile availability or employment status) as well as travel variables (e.g., mode use, trip frequency or trip complexity). Especially at the intraurban scale, they concluded that higher accessibility levels were only marginally significant for most groups and not significant for female participants. Contrary to the strong trip frequency-accessibility relationship posited frequently in the literature and deductive formulations, they found that accessibility has a greater impact on mode choice and travel distance than on discretionary trip frequency. A study for 300 households in the Reading area (UK) by Downes and Morrell (1981) showed no significant correlation between household location relative to the town center and household weekday travel time budgets or trip rates. Moreover, the study indicated a linear dependency of both dependent variables on household size and car ownership. Interestingly, Cordera et al. (2016) highlight the importance of discerning between trip generation to work-related, mandatory activities and discretionary, non-mandatory activities as well as between transport modes. In their study on the relevance of accessibility in trip generation for the urban area of Santander, they found that a higher accessibility was related to a decrease in trip generation by private vehicle for work purpose, whereas it increased the trip rate to discretionary activities by other transport modes. Additionally, they bring attention to the role spatial effects between observations play.

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