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Research Article

# Time dependent accessibility

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**Abstract**

Many place based accessibility studies ignore the time component. Relying on theoretical frameworks that treat distance between two fixed points as constant, these methods ignore the diurnal and seasonal changes in accessibility. Network distances between two nodes are dependent on the network structure and weight distribution on the edges. These weights can change quite frequently and the network structure itself is subject to modification because of availability and unavailability of links and nodes. All these reasons point to considering the implications of volatility of accessibility of a place. Furthermore, opportunities have their own diurnal rhythms that may or may not coincide with the rhythms of the transportation networks, impacting accessibility. Using the case of transit, where all these features are readily apparent simultaneously, I demonstrate the volatility in accessibility for two counties in North Carolina. Significant diurnal changes are observed in quarter of the locations and in the rest the changes are minimal mostly because of low levels of transit accessibility. I argue not for minimizing the volatility, but for acknowledging its impacts on mode choices, location choices and therefore on spatial structure of cities.


*Keywords:* Accessibility; Public transportation; Social justice

## 1. Introduction

Many studies on transportation accessibility assume that the underlying spatial topology is invariant. Borne out of a Newtonian conceptualization of space, accessibility is measured as either as a cumulative measure of opportunities that are available from a location at a certain distance (or other appropriate metric such as travel time) or weighted measure usually based on gravity or a random utility (for discussion see El-Geneidy & Levinson, 2006; Handy & Niemeier, 1997). In each of these approaches, there are no diurnal or seasonal changes in the distance metric between any two given points in space. The underlying assumption is that distance metric ( e.g. Euclidean/Manhattan) in a Cartesian plane is time invariant. The differences in the accessibility of a location then usually stems from the changes of the attributes of the locations and attractors (e.g. employment, destination types, types of households etc.) and the interest is usually on relative accessibility of one location with respect to another (Dalvi & Martin, 1976). In this paper, I want to argue that accessibility also depends upon the variable distance metric and should be given adequate attention.

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A Leibnitzian conception of space, by contrast, is a conceptualization of space that dependent on locations of objects relative to one another (Galton, 2001). Despite this abstractness, I argue that such mode of thinking allows us to rethink the distance metric as a variable and lends itself particularly well to a imagining a topological structure that changes over time. However, the network distance between two nodes is invariant, only if the underlying network structure is invariant. Many accessibility analyses not only focus on relative accessibility of locations, but also on relative changes in accessibility once a set of infrastructure investments (changes to network structure) are made (e.g. Golub, Robinson, & Nee, 2013). Furthermore, when travel times are used as measure of impedance, the distance metric during peak and off-peak hours between any two given points are different even without any physical changes to the network; the edges shorten and lengthen depending on the time of the day. In other words, the weighted network changes with time (though the weights remain finite).

Consider the scenario where particular nodes or edges are no longer available. This situation is quite common during hazardous events (Litman, 2006) when some links and nodes disappear from the networks (or the weights become infinite) and therefore depending on their centrality can dramatically change the network distances between any two given nodes. This is another case of variant topological network. Thus, space with variable topological structure is not uncommon. All the above examples presented make a compelling case for considering the variable distance metric. There is perhaps a no better use case than transit that encompasses all the above situations. Even within an hour, the impedance between any two nodes (stops) is varying because of intermittent schedules and wait times.

However, until recently even transit accessibility is still measured using invariant topological networks (Mavoa, Witten, & McCreanor, 2012; Tomer, Kneebone, & Puentes, 2011). These invariant networks usually assume a transit network during the peak morning commute. Automobile remains a dominant mode compared to transit, because it not only widens the spatial aspects of accessibility but the temporal aspects as well (Clifton, 2004). This is particularly true for non-work activities that fall outside the traditional work day schedule. Infrastructure support for bread-winning is the norm because of gendered assumptions that undergird planning analyses (Clifton, 2004; Law, 1999), and the transit provision is biased towards peak hours and work days.

Unlike automobiles because the underlying network structure is dependent on un/harmonized schedules between different lines in the transit system that facilitate transfers, changes in these levels of service on a single line has ripple effects through the entire system. Depending on the time of the day, a line in the transit system may not be running and thus removing a set of links and nodes from the network. Thus, the impedance metric is very elastic within a single day and between weekdays and weekends. All these features make the case for using understanding the temporal patterns of transit accessibility, as there are analogues in other situations described earlier.

It is, therefore, useful to study how the periodicity and breaks in the patterns of transit accessibility. It provides a starting point for understanding changes in other accessibility metric (such as automobile) instead of relying on the maxmin approach that underlies the consideration of peak travel times, or worse using max approach that ignores congestion all together.

Furthermore, accessibility that only accounts for invariant impedance is usually based upon the assumptions that travel to work, and more insidiously, travel to particular kind of work (regular shift) is singularly important. Using Current Population Survey data from 2004, McMenamin (2007) claims that almost 30% of the US workers are able or constrained to work in shifts other than regular shifts. Furthermore, accessibility to amenities other than work is also important (Handy & Clifton, 2001) and because these amenities such as restaurants, retail establishments, hospitals have different rhythms than a traditional 9-5 job, changes in accessibility during the day and by seasons have implications both for users of as well as those employed at these amenities (Weber & Kwan, 2002).

In their wide ranging review, Geurs and van Wee (2004) suggests that accessibility should account for land-use component, transportation component, temporal component and personal component. They suggest that each of these components is indirectly related to one another. Mamun et al. (2013) use a different approach to account for temporal coverage by accounting for per capita service frequency and distance decay factor. In this paper, I want to argue that there are more direct relationships and should be accounted for our in our measures of accessibility. While the spatial distribution of opportunities is important, it is also related to the temporal dimensions of these distributed opportunities (activity hours, duration etc.) (Crang, 2004). The temporal component not only affects the time available for opportunities by a person, but also whether or not such opportunities can be accessed by a person by a particular mode and with a reasonable cost.