8/21/2013

TCI SCOPING PAPER SERIES

PROPORTION OF JOBS/HOUSING WITHIN X MILES OF TRANSIT & PROXIMITY TO AMENITIES

Prepared for the Georgetown Climate Center and the Transportation and Climate Initiative

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Introduction

Accessibility – which is at the heart of indicators focused on the proportion of jobs/housing within a certain distance of transit, as well as proximity to amenities – is a measure of the "ease with which people can reach their opportunities or services." This concept involves three factors, namely: people, activities, and linkages (Lei, et al, 2010). Measures of accessibility typically focus on determining the ease with which people can reach desired destinations using the linkages available to them.

> Accessibility is a measure of the "ease with which people can reach their opportunities or services.

Why is accessibility of interest in the context of the Transportation and Climate Initiative (TCI)? In addition to reducing the carbon content of fuel and improving vehicle efficiency, reductions in vehicle miles traveled (VMT) are critical to realizing necessary reductions in CO_2 emissions from the transportation sector. Cervero and Duncan (2006) concluded jobs-housing balance reduced travel more than housing-retail-service mixing based on data from the San Francisco Bay area. However, both strategies appeared to have beneficial effects on the reduction of VMT and Cervero and Duncan (2006) postulated that pursuing both strategies could yield combined benefits, such as inducement of trip chaining for more efficient travel. Close spatial proximity to a variety of amenities and transit accessibility (both important tenants of smart growth) are instrumental in forming this "third leg" of the emissions reductions "stool," as they serve to decrease the distances traveled in the course of everyday life, and offer a viable alternative to, or more efficient use of, the personal vehicle when travel is necessary (Ewing et al, 2007; Pearce et al, 2006).

There are also "social equity" considerations related to accessibility, in that lower income households are at a distinct disadvantage in sprawling suburban environments where personal vehicles are a must. Instead, areas in which amenities -such as jobs, healthcare, and groceries - are reachable on foot or by taking public transit, are better able to sustain the livelihood of these populations (Minocha, et al, 2008). However, Ross and Svajlenka (2011) found that in the Washington, DC region, housing costs are out of reach for low- and mid-skill workers in areas identified in this report as offering strong transit access to employment.

Analytical Approaches

There are a number of techniques that can be applied to gauge study area residents' access to transit and other amenities; and many of these are dependent on Geographic Information Systems (GIS) for their calculation.[1] Six categories of analytical approaches to measure proximity/access have been identified in the literature. Specifically, those focused on: system accessibility, integral accessibility, system facilitated accessibility, space-time geography, utility theory, and relative accessibility (Lei, et al, 2010).

> System accessibility is one of only two measures of proximity/accessibility that can be approximated without the aid of GIS.

Measures of "system accessibility" are the most straightforward to carry out, and focus on users' physical access to a system as a function of time, distance, or the effort needed to reach it. Appealing for the ease with which they can be calculated, and because they make no assumptions about mode selection and availability; these measures really speak to proximity, rather than accessibility. In fact, calculations of system accessibility may overestimate actual accessibility, as they fail to consider the ease with which the system allows travel to specific destinations.

[1] The scale of the study area at which proximity/accessibility of amenities can be gauged is quite malleable, and will likely be determined by the study's intent as well as the availability, and comparability of data.

System accessibility is one of only two measures of proximity/accessibility that can be approximated without the aid of GIS[2], and at its simplest is calculated using a straightforward set of analytical steps. First, the amenities of interest (be they transit stops, grocery stores, hospitals, or anything else), as well as the population whose ability to access those amenities is under study[3], must be identified. The boundaries within which a destination can be deemed "accessible" must then be determined. When using GIS, these boundaries are typically delineated using a buffering function, with a distance of between ¼ mile and ½ mile . If GIS is not available, Census-determined spatial extents, such as block groups or blocks, may be used. In GIS, the buffers are used like "cookie cutters" to slice through the other data layers, revealing the total study population(s) within the desired distance of the point of interest. In non-GIS assisted analyses, population counts for the areas of interest can be summed to determine the total population that enjoys easy access to the amenities under study.

Example Analyses

- Transit accessibility in Seattle's Queen Anne Community was measured by creating quarter mile buffers around transit stops. Any street that intersected the buffer was considered to have good transit access (Nyerges, 1995).
- A 1994 study found that employees living within a quarter mile buffer of Boston's transit stops had good access to the city's medical facilities (Azar et al, 1994).
- In an attempt to measure neighborhood accessibility, Aultman-Hall looked at the average and maximum distances between a collection of neighborhoods and destinations including schools and transit access points (Aultman-Hall et al, 1997).

[2] The other being integral accessibility, discussed below.
[3] The population of interest may be total population, daytime population, number of households, streets, or another, study-specific measure.

- Hillman and Pool (1997) created a software system for transit operators to measure the accessibility of transit stops in London.
- The Florida Transit Geographic Information System was designed by Gan et al. (2005) to identify transit accessible areas in the state, calculate the proportion of the service area actually served by transit, as well as to identify areas into which transit service could be expanded according to levels of housing density and employment.

Advantages	Disadvantages
Can be calculated with or without GIS	May overestimate accessibility by failing to account for costs associated with available travel modes
Data needs are limited	
Is not mode specific	

"<u>Integral accessibility</u>" seeks to quantify the total accessibility associated with a collection of destinations. In their most simplistic form, measures of this type count opportunities to engage in a particular activity within a predetermined distance or time of a given start point (Lei, et al, 2010).

They are quite similar to approaches focused on system accessibility, in that they rely on the drawing of buffers around points (in GIS), or the identification of spatial extents of interest (in non-GIS assisted approaches). The two are essentially mirror opposites, however, because where system accessibility focuses on destinations and seeks to identify the population to which they are accessible, integral accessibility works by focusing on origins, and identifying the number of amenities of a particular type (or types) that can be accessed from them.

Like the previous variety of metrics, integral accessibility fails to capture some determinants of actual accessibility, such as time and cost constraints.

Example Analyses

- Both Wachs and Kumagai (1973) and Talen and Anselin (1998) carried out simplistic analyses of integral accessibility, by simply counting the activities of a certain type that occurred within a predetermined "reasonable" travel distance from a particular starting location.
- A more complicated approach involves creating "location profiles," which represent aggregate accessibility for various activity types at certain cutoff distances from a starting point. Approaches of this kind were used by both German and Ritsema van Eck (1995) and de Jong and Ritsema van Eck (1996).

Advantages	Disadvantages
Can be calculated with or without GIS	May overestimate accessibility by failing to account for costs associated with available travel modes
Data needs are limited	
Is not mode specific	

"System facilitated accessibility" considers a user's ability to get to their desired destination, by taking into account the cost or travel time associated with doing so using a particular mode. Central to these efforts is the calculation of trips between specific origins and destinations using network analyses; hence, in addition to data on populations and destination locations, the analyst must have access to reliable network data, such as a layer depicting roadways within the study area.

What's more, with calculations of system facilitated accessibility (and all of the other GIS-based approaches discussed throughout the remainder of this paper), a point (or points) of origin from which accessibility is to be determined must be defined. In cases where address data for populations of interest are available, these can serve this purpose, otherwise, specific public locales, such as transit hubs, shopping or employment centers, or medical facilities, can be used.

Example Analyses

- A very simplistic approach to measuring system facilitated accessibility was carried out by Liu and Zhu (2004), when they determined transit time by dividing distances by average travel speeds.
- More complicated approaches take into consideration system characteristics such as transfer and wait times, as well as schedule information. Hillman and Pool (1997), for instance, determined travel times between origins and destinations by accounting for walk time to a transit stop from an origin point, time spent waiting for the chosen travel mode, any wait time at intermediate change points, and total time traveling aboard a transit vehicle.
- A shortest path model was developed by O'Sullivan et al. (2000) that analyzed a multimodal network of bus and rail, using published service schedules, to create a shortest path model to a central business district.

Advantages	Disadvantages
May render more accurate estimates of accessibility than measures of system accessibility and integral accessibility	Cannot be estimated without GIS
	Mode specific
	Data requirements and GIS expertise are more intensive than less sophisticated analytical techniques

The fourth category, "space-time geography," recognizes that movement is a function of mobility and a person's available time budget. Calculations of this sort often rely on GIS network data to derive space-time accessibility measures (Lei, et al, 2010).

Example Analyses

- Kim and Kwan (2003) created a model to account for facility operating schedules and transport network properties by calculating the sum of available opportunities, weighted by service time availability.

Advantages	Disadvantages
May render more accurate estimates of accessibility than measures of system accessibility and integral accessibility	Cannot be estimated without GIS
	Mode specific
	Data requirements and GIS expertise are more intensive than less sophisticated analytical techniques

"Utility theory" positions travelers as consumers, with various modes constituting their choice set. Users are assumed to be logical, in that they will select the mode of maximum utility; a determination made by taking into account user characteristics and destination, as well as attributes of the available travel options, such as time, cost, and comfort level (Lei, et al, 2010).

Example Analyses

- Rastogi and Rao (2002, 2003) created a utility theory model related to transit access in India, which incorporated socioeconomic variables, such as income, transit-specific factors, including distance to stations, modal split, and modal preference data, to estimate an accessibility index.

Advantages	Disadvantages
May render more accurate estimates of accessibility than measures of system accessibility and integral accessibility	Cannot be estimated without GIS

	Data requirements and GIS expertise are more intensive than less sophisticated analytical techniques
	Mode specific

Finally, comparisons of access between users and modes are at the heart of measures that focus on "relative accessibility." For example, the choice between taking transit or a personal vehicle (assuming one is available) depends on a variety of considerations, including cost, time, safety, and convenience. Transit's value, according to methods of this type, is determined relative to other available options; hence, its appeal can be impacted by parking costs, route locations and schedules, etc.

Because it involves building networks for each available mode, running scenarios, and determining which are the optimal travel scenarios, models of the utility theory type are unique from, and more complicated than, their system facilitated accessibility and space time geography counterparts.

Example Analyses

- Sheppard (1995) analyzed relative accessibility by constructing a travel time ratio to construct diversion curves for modal split.

Advantages	Disadvantages
May render more accurate estimates of accessibility than measures of system accessibility and integral accessibility	Cannot be estimated without GIS
Not mode specific	Data requirements and GIS expertise are the most sophisticated of the approaches discussed here

The techniques described above can be expanded and repeated according to the study needs. For example, a change index can be created by repeating the analysis for different time periods and comparing the results. A comparison can also be made between the study area and a control location (such as the surrounding region, a similar town in another state, or other place of interest) by computing output for both and examining the differences.

Data Sources

Population

Population data can be accessed from the US Census Bureau's American Community Survey (ACS) at a variety of scales.[4] Information about amenities, however, must be collected from disparate sources, each of which is discussed below.

Transit

The first step in gathering data on transit is to decide what types of services are of interest. Are only high flow stations worth considering, or do all stops merit inclusion? Is rail the primary target, or are other modes of equal or greater interest? The answers to these and related questions will help inform the data collection approach. As a general rule, the most reliable data can be obtained from local sources. In the case of transit, this would be from the agencies themselves, or from a state DOT.

If, for some reason, local data are not available, the Bureau of Transportation Statistic's (BTS) National Transportation Atlas Database (NTAD) is a good source of for information on bus rapid transit and rail (fixed guideway modes). The NTAD is a collection of GIS layers, and is updated annually and can be accessed for free in the form of downloadable zip files and DVDs.

The database is known to have some gaps, however. For example, data on New York City is incomplete. Before incorporating NTAD data into an analysis, it is important to verify that it provides an accurate representation of the location of interest.

[4] For an in-depth discussion of the ACS, its uses, and limitations, see the "Travel Mode Share" paper of this same series.

The database also fails to differentiate between stops based on use levels, representing those with limited service schedules in the same manner as even the busiest urban stations. If the desired analysis is intended to focus on "high flow" locations, a local or regional agency should be able to help in their identification.

Another, even more complete source of data on transit stops is the Center for Transit Oriented Development's (CTOD) National TOD Database (NTD). The NTD, which was created in 2009, contains information about all existing and proposed fixed guideway stations in the country, including ferry stops. Although not directly accessible through a web-based interface, since the data were gathered using federal funding, they must be made available to the public upon request. Bus route information may also be available from the Federal Transit Administration (FTA). These data were first collected by Bridgewater State College in 1995, and have been converted into GIS layers, easing their incorporation into an analysis of this kind.

Streets

Data layers representing local streets and roadways may be accessible from MPOs or local planning agencies, or they can be obtained from the US Census in a downloadable format from among their Topologically Integrated Geographical Encoding and Referencing (TIGER) products.[5]

Businesses and Healthcare Facilities

Accurate, free, downloadable data on the locations of business and healthcare facilities are not publically available for all areas; however, they can be purchased from a number of

[5] TIGER line and shapefiles are available at: http://www.census.gov/geo/maps-data/data/tiger.html

privately-maintained data sources. Among the best known of these are ReferenceUSA[6] and Dunn and Bradstreet[7], which have information about private and public businesses of all kinds (grocery stores, pharmacies, daycares, etc.) and healthcare facilities. Information on new home buyers and movers is also available, which could be useful in analyses to determine the impacts of new initiatives, policies, and investments. Data of this kind can also be obtained by purchasing the ESRI Business analyst and Community Analyst for ArcGIS or Placeways' CommunityViz.

Although not as comprehensive and reliable as purchased sources, some information may also be available for free download online. Websites of interest include ArcGIS.com, the GIS data depot[8] and geoonestop.org.[9]

Parks and Open Space

As with other data, local sources are best, meaning that if state-maintained land use/land cover information are available, they should be utilized. If, however, local data are not available, the National Land Cover Database (NLCD)[10] can provide information on open spaces and undeveloped lands for use in GIS analyses (Vogelmann et al, 1998).[11]

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[6] Available at: http://www.referenceusa.com/Home/Home
[7] Available at: http://www.dnb.com/
[8] Available at: http://data.geocomm.com/
[9] Available at: http://xps.geoonestop.org/
[10] The NLCD can be accessed at: http://www.mrlc.gov/nlcd2001.php
[11] For a comprehensive discussion of the National Land Cover Database (NLCD), see the paper on "Growth in Previously Developed/Designated Areas" paper of this series.

Conclusions and Recommendations

There are a number of analytical approaches to gauge the proximity and accessibility of transit and other amenities. Of these, the more simplistic offer the advantage of being readily computable, either using GIS or through simple mathematical manipulations, but may over estimate accessibility because they fail to account for real world travel costs, such as monetary and time constraints. More sophisticated approaches, in contrast, require the use of GIS by someone well-versed in its construction and operation, but the accuracy of the results can far surpass those of less complex methodologies.

Given this, the following recommendations have been formulated for TCI's use:

Recommendations

If in-house GIS resources are limited or non-existent and a "snapshot" of proximity/accessibility is desired:	Use a system accessibility or integral accessibility measure to determine proximity/accessibility for the study area using the most current data.
If in-house GIS resources are limited or non-existent and a temporal comparison of proximity/accessibility is desired (i.e. to gauge the effectiveness of an investment, policy, or other intervention):	Use a system accessibility or integral accessibility measure to determine proximity/accessibility for the study area using data from before and after the intervention; compare results.
If in-house GIS resources are limited or non-existent and a spatial comparison of proximity/accessibility is desired (i.e. to gauge these characteristics of the study area as opposed to the region or a control site);	Use a system accessibility or integral accessibility measure to determine proximity/accessibility for the study area and region/control site; compare results.
If in-house GIS resources are robust and a single mode of travel is of interest and a "snapshot" of proximity/accessibility is desired:	Use a system facilitated accessibility, space-time geography, or utility theory approach to determine proximity/accessibility using the most current data.
If in-house GIS resources are robust and a temporal	Use a system facilitated accessibility, space-time geography, or utility theory approach to determine

comparison of proximity/accessibility is desired (i.e. to gauge the effectiveness of an investment, policy, or other intervention):	proximity/accessibility for the study area using data from before and after the intervention; compare results.
If in-house GIS resources are robust and multiple modes of travel are of interest and a “snapshot” of proximity/accessibility is desired:	Use a relative accessibility approach to determine proximity/accessibility for the study area using the most current data.
If in-house GIS resources are robust and multiple modes of travel are of interest and a temporal comparison of proximity/accessibility is desired (i.e. to gauge the effectiveness of an investment, policy, or other intervention):	Use a relative accessibility approach to determine proximity/accessibility for the study area using data from before and after the intervention; compare results.
If in-house GIS resources are robust and multiple modes of travel are of interest and a spatial comparison of proximity/accessibility is desired (i.e. to gauge these characteristics of the study area as opposed to the region or a control site):	Use a relative accessibility approach to determine proximity/accessibility for the study area and region/control site; compare results.

References

1. AULTMAN-HALL, L., ROORDA, M. and BAETZ, B.W., 1997, Using GIS for evaluation of neighborhood pedestrian accessibility. Journal of Urban Planning and Development, 123(1), pp. 10–17.

2. AZAR, K.T., FERREIRA, J.J.R. and WIGGINS, L., 1994, Using GIS tools to improve transit ridership on routes serving large employment centers – the Boston south end medical area case-study. Computers Environment and Urban Systems, 18(3), pp. 205–231.

3. Cervero, Robert and Duncan, Michael. 2006. *Which Reduces Vehicle Travel More: Jobs-Housing Balance or Retail-Housing Mixing?* Journal of the American Planning Association, 72:4, 475-490.

4. DE JONG, T. and RITSEMA VAN ECK, J., 1996, Location profile-based measures as an improvement on accessibility modelling in GIS. Computers. Environment. and Urban Systems, 20, pp. 181–190.

5. Energy Information Administration (EIA). 2011. Methodologies for estimating fuel consumption using the 2009 national household travel survey.

6. Ewing, Reid, Keith Bartholomew, Steve Winkelman, Jerry Walters, and Don Chen. 2007. Growing cooler: The evidence on urban development and climate change. Chicago, IL: Urban Land Institute.

7. GAN, A., LIU, K. and UBAKA, I., 2005, Florida Transit Geographic Information System (FTGIS). GIS-in-Transit Conference, Centre for Urban Transportation Research. Tampa, FL.

8. HILLMAN, R. and POOL, G., 1997, GIS-based innovations for modeling public transport accessibility. Traffic Engineering and Control, 38(10), pp. 554–556.

9. ICF International. 2011. Evaluation and testing of sustainable community performance measures (draft).

10. KIM, H.M. and KWAN, M.P., 2003, Space-time accessibility measures: a geocomputational algorithm with a focus on the feasible opportunity set and possible activity duration. Journal of Geographical Systems, 5(1), pp. 71–91.

11. Lei, T. L., and R. L. Church. 2010. Mapping transit-based access: Integrating GIS, routes and schedules. *International Journal of Geographical Information Science* 24 (2): 283-304.

12. LIU, S. and ZHU, X., 2004, Accessibility analyst: an integrated GIS tool for accessibility analysis in urban transportation planning, Environment and Planning B: Planning and Design, 31, pp. 105–124.

13. Minocha, Inshu, P. S. Sriraj, Paul Metaxatos, and Piyushimita Thakuriah. 2008. Analysis of transit quality of service and employment accessibility for the greater chicago, illinois, region. *Journal of the Transportation Research Board* 2042 : 20-29.

14. NYERGES, T., 1995, Geographic information system support for urban/regional transportation analysis. In S. Hanson (Ed.), The geography of urban transportation (New York: The Guilford Press), pp. 240–265.

15. O'SULLIVAN, D., MORRISON, A. and SHEARER, J., 2000, Using desktop GIS for the investigation of accessibility by public transport: an isochrones approach. International Journal of Geographical Information Science, 14, pp. 85–104.

16. RASTOGI, R. and RAO, K., 2002, Survey Design for Studying Transit Access Behavior in Mumbai City, India. Journal of Transportation Engineering, 128(1), pp. 68–79.

17. RASTOGI, R. and RAO, K.V.K., 2003, Defining transit accessibility with environmental inputs. Transportation Research Part D: Transport and Environment, 8(5), pp. 383–396.

18. Ross, Martha and Prchal Svajlenka, Nicole. 2011. *Connecting to Opportunity: Access to Jobs via Transit in the Washington, D.C. Region.* Available at: http://www.brookings.edu/research/papers/2012/11/%7E/media/D3589634EEC94C09B895AB17D126DC1F.ashx

19. SHEPPARD, E., 1995, Modeling and predicting aggregate flows. In S. Hanson (Ed.), The geography of urban transportation (New York: The Guilford Press), pp. 100–128.

20. TALEN, E. and ANSELIN, L., 1998, Assessing spatial equity, an evaluation of measures of accessibility to public playgrounds. Environment and Planning A, 30, pp. 595–613.

21. VOGELMANN, J. E., T. L. SOHL, P. V. CAMPBELL, and D. M. SHAW. 1998. REGIONAL LAND COVER CHARACTERIZATION USING LANDSAT THEMATIC MAPPER DATA AND ANCILLARY DATA SOURCES. *Environmental Monitoring and Assessment* 51 : 415–428.

22. WACHS, M. and KUMAGAI, T.G., 1973, Physical accessibility as a social indicator, Socio- Economic Planning Sciences, 7, pp. 437–456.