Access Across America: Walking 2014 Methodology

Final Report

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16. Abstract (Limit: 250 words)

Accessibility is the ease of reaching valued destinations. It can be measured for various transportation modes, to different types of destinations, and at different times of day. There are a variety of ways to define accessibility, but the number of destinations reachable within a given travel time is the most comprehensible and transparent, as well as the most directly comparable across cities.

This report describes the data and methodology used in the separate publication, *Access Across America: Walking 2014*. That report estimates the accessibility to jobs by walking in the 50 largest (by population) metropolitan areas in the United States. Walking mode-share for commute trips nationally is around 2.8%, and 5.0% within large cities in the United States. Rankings are determined by a weighted average of accessibility, giving a higher weight to closer jobs. Jobs reachable within ten minutes are weighted most heavily, and jobs are given decreasing weight as travel time increases up to 60 minutes.

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Contents

1 Summary

This document describes the methodology used by the Accessibility Observatory at the University of Minnesota to produce the accessibility metrics and related data that are presented in *Access Across America: Walking 2014*. An overview of the methodology is provided below, and detailed descriptions can be found in the following sections.

- **Data Sources**
  1. U.S. Census TIGER 2010 datasets: blocks, core-based statistical areas (CBSAs)
  2. U.S. Census Longitudinal Employer-Household Dynamics (LEHD) 2011 Origin-Destination Employment Statistics (LODES)
  3. OpenStreetMap (OSM) North America extract, retrieved April 2014
  4. American Community Survey Reports: walking mode share, 2008-2012
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- **Data Preparation**
  1. Construct pedestrian travel network graph for each CBSA
- **Accessibility Calculation**
  1. For each Census block, calculate travel time to all other blocks within a 5km radius for a single departure time
  2. Calculate cumulative opportunity accessibility to jobs for each block, using thresholds of 10, 20, …, 60 minutes
  3. Average accessibility for each CBSA over all blocks, weighting by number of workers in each block
  4. Calculate weighted ranking for each metropolitan area
  5. Calculate correlations between person-weighted accessibility, walk mode share, and walk score.

2 Data Sources

2.1 Geography

All calculations and results in this project are based on geographies defined by the U.S. Census Bureau. Census blocks are the fundamental unit for travel time calculation, and block-level accessibility results are aggregated across core-based statistical areas (CBSAs) for metropolitan-level analysis. These geography definitions are provided by the U.S. Census Bureau's Topologically Integrated Geographic Encoding and Referencing (TIGER) program.[1] This project uses the geography definitions established for the 2010 decennial census.

Accessibility calculations are performed for every block in a given CBSA, excluding blocks which contain no land. Blocks outside of the CBSA are included as potential destinations as described in Section 4.2.

2.2 Employment and Worker Population

Data describing the distribution of labor and employment in the region are drawn from the US Census Bureau's Longitudinal Employer-Household Dynamics program (LEHD)[2]. The LEHD Origin-Destination Employment Statistics (LODES) dataset, which is updated annually, provides Census block-level estimates of employee home and work locations. This project uses LODES data from 2011, the most recent available as of this writing.

2.3 Pedestrian Network

Data describing the pedestrian network in each metropolitan area were obtained from OpenStreetMap[3], an open-access online database of transportation network structures and other spatial information. OpenStreetMap, like Wikipedia, is comprised of contributions from many individuals. In urban areas, it typically provides a much more detailed and up-to-date representation of pedestrian networks than datasets available from federal, state, regional, or local sources. The data used in this project were retrieved from OpenStreetMap on April 16, 2014. Specifically, the pedestrian network is comprised of features with the "footway," "pedestrian," and "residential" tags.

2.4 Walk Mode Share & Walk Score

Walk mode share describes the percentage of network users in a given metropolitan area that use the walking mode, and is often used to rank metropolitan areas in hierarchy of walkability. Walking mode share data is taken from the American Community Survey Reports for 2008-2012[4] Walk Score is a walkability ranking service and data platform managed by Redfin, a realtor aggregating service. Walk scores for a given origin point are calculated based on proximity to services in various categories, with

[1] `https://www.census.gov/geo/maps-data/data/tiger.html`
[2] `http://lehd.ces.census.gov/data/`
[3] `http://openstreetmap.org`
[4] McKenzie (2014)

a distance-decay weighting function, and on pedestrian friendliness factors such as population density and built environment (road) metrics[5]. Scores are aggregated and averaged across metropolitan areas, to allow reporting of metro-wide scores and rankings. To test if the singular measure of job-opportunity accessibility for walking is a reasonable ranking measure, correlations between both 30-minute worker-weighted average accessibility and distance-weighted worker-weighted average accessibility, and walk score, were performed.

Certain cities were excluded from the correlations due to incomplete data; cities without a walk score value available were Providence, Tucson, and Salt Lake City; cities without a walk mode share value available from McKenzie (2014) were Buffalo, St. Louis, New Orleans, Cincinnati, Richmond, Tampa, Orlando, Riverside, Birmingham, and Salt Lake City.

[5] http://www.walkscore.com/cities-and-neighborhoods/

3 Data Preparation

3.1 Analysis Area Definition

This project relies on the efficient calculation of shortest paths between a large number of origin–destination pairs - between every possible pair of origins and destinations. If there are N origins, and $M > N$ destinations including the buffer, the number of computations is $O(M * N)$ (more precisely, $C = M * N - 1/2 * (M + N)$). However, as walking times do not vary throughout the day as transit schedules do, and thus walking accessibility is independent of departure time, only one set of accessibility calculations for multiple thresholds must be performed for each metropolitan area. The computations were performed for all CBSAs on a single workstation in a reasonable amount of time.

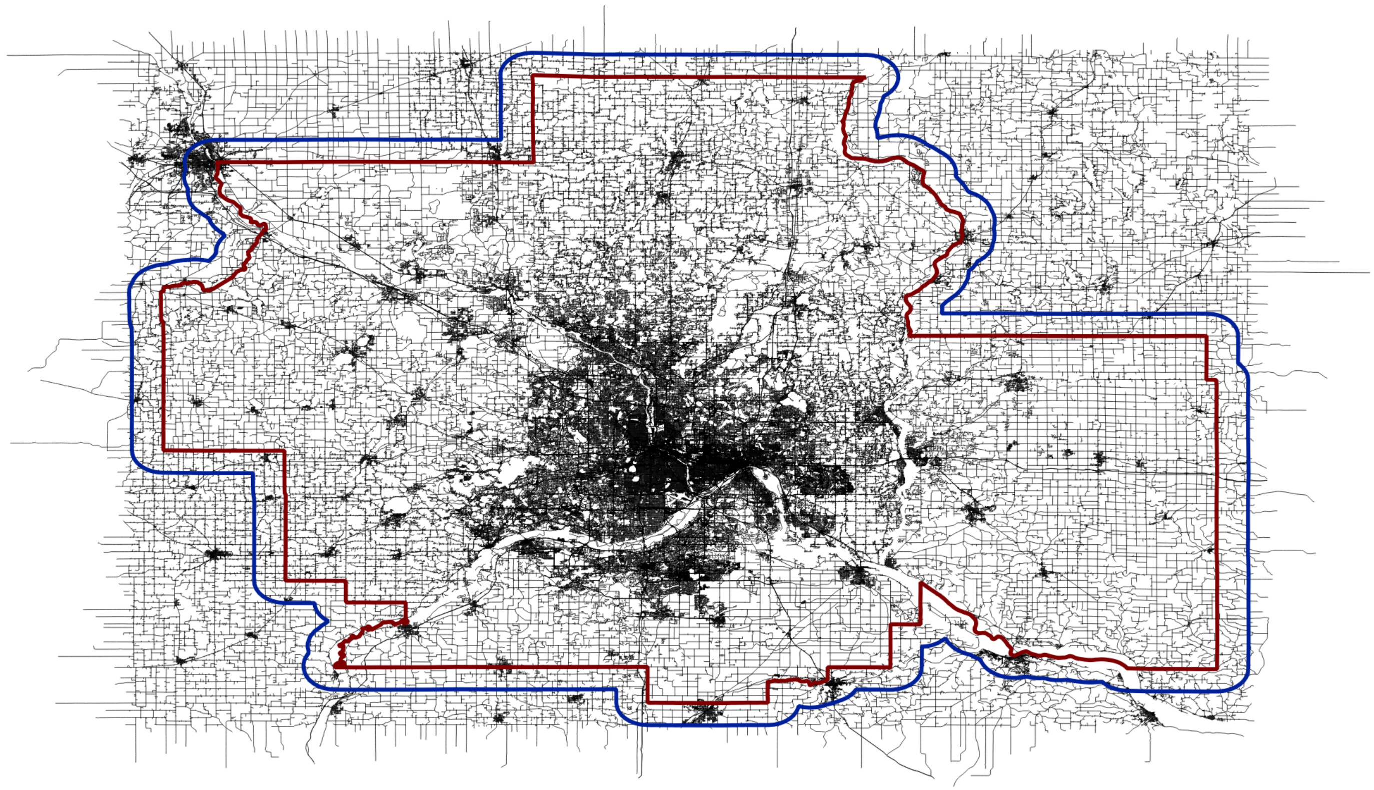

Figure 1: Boundaries and OpenStreetMap extract for the Minneapolis–Saint Paul, MN CBSA. The red boundary is the exact outline of the CBSA region, and the blue outline represents a 5-kilometer buffer region, to include destinations outside of the CBSA region when calculating accessibility.

The set of all centroids of census blocks within the CBSA region constitute the origin points from which accessibility is calculated. Assuming a walking speed of 5km per hour, all census blocks whose centroids lie within the CBSA region itself, plus a 5km buffer of the boundary of the CBSA, are included as destinations.

3.2 Graph Building

Travel time calculations in this project are performed using the OpenTripPlanner (OTP) software, described in more detail in Section 4.2. OTP includes a graph building function that compiles pedestrian network data from OpenStreetMap. A graph is built for each CBSA area, using a rectangular bounding box as depicted above, based on a 5km buffer from the widest and tallest points of the CBSA shape. This is combined with origin and destination locations to create a single analysis bundle that contains all data necessary to calculation accessibility values for the blocks in a single CBSA at once.

4 Accessibility Calculation

4.1 Overview

Accessibility evaluations rely on an underlying calculation of travel times. Here, walking travel times are evaluated from each Census block centroid based on a detailed pedestrian network. Travel time calculations are performed for a single departure time, as the characteristics of the pedestrian travel network are modeled here as time-independent. These travel times are the basis of a cumulative opportunities accessibility measure which counts the number of opportunities (in this case, jobs) reachable from each origin within 10, 20, 30, 40, 50, and 60 minutes.

This block-level dataset provides a *locational* measure of accessibility — it indicates how many jobs can be reached from different points in space. This location measure is then weighted by the number of workers residing in each Census block and averaged across the entire metro area to produce *worker-weighted* accessibility. This metric indicates the accessibility that is experienced by the average typical worker in the metropolitan area.

Finally, the worker-weighted average accessibility values across the 10 through 60 minute thresholds are averaged for each metropolitan area to produce a weighted accessibility ranking.

The following sections describe the specific tools, algorithms, and parameters that were used to produce the data presented in *Access Across America: Walking 2014*.

4.2 Travel Times

4.2.1 Software

Walking travel time calculations are performed using OpenTripPlanner (OTP), an open-source multi-modal trip planning and analysis tool. OpenTripPlanner is a graph-based transit routing system which operates on a unified graph including links representing road, pedestrian, and transit facilities and services. OTP is available at `http://opentripplanner.org` and is described and evaluated in Hillsman and Barbeau (2011).OTP's Analyst extension provides efficient and parallelized processing of many paths from a single origin based on the construction of shortest path trees. Locally-developed Python libraries and scripts were used to automate the graph creation, OTP processes, and data post-processing and imaging.

4.2.2 Walking Trip Parameters

The time cost of travel by walking is comprised of a single component. *Total travel time* refers to the time cost of walking from origin to destination, including egress and ingress at the origins and destinations. A walking trip is much simpler than a transit trip, which involves pre-boarding waiting time, on-vehicle time, any transfer waiting times, and finally the time required to access the destination from the transit station. This reduces the complexity of the accessibility calculations.

This analysis makes the assumption that walking speed is uniform at 5 km/hour along designated pedestrian facilities such as sidewalks, trails, etc.

4.3 Cumulative Opportunities

Many different implementations of accessibility measurement are possible. El-Geneidy and Levinson (2006) provide a practical overview of historical and contemporary approaches. Most contemporary implementations can be traced at least back to Hansen (1959), who proposes a measure where potential destinations are weighted by a gravity-based function of their access cost and then summed:

$$A_i = \sum_j O_j f\left(C_{ij}\right) \tag{1}$$

$$\begin{aligned} A_i &= \text{accessibility for location } i \\ O_j &= \text{number of opportunities at location } j \\ C_{ij} &= \text{time cost of travel from } i \text{ to } j \\ f\left(C_{ij}\right) &= \text{weighting function} \end{aligned}$$

The specific weighting function $f\left(C_{ij}\right)$ used has a tremendous impact on the resulting accessibility measurements, and the best-performing functions and parameters are generally estimated independently in each study or study area Ingram (1971). This makes comparisons between modes, times, and study areas challenging. Levine et al. (2012) discuss these challenges in depth during an inter-metropolitan comparison of accessibility; they find it necessary to estimate weighting parameters separately for each metropolitan area and then implement a second model to estimate a single shared parameter from the populations of each. Geurs and Van Wee (2004) also note the increased complexity introduced by the cost weighting parameter.

Perhaps the simplest approach to evaluating locational accessibility is discussed by Ingram (1971) as well as Morris et al. (1979). *Cumulative opportunity* measures of accessibility employ a binary weighting function:

$$f\left(C_{ij}\right) = \begin{cases} 1 & \text{if } C_{ij} \leq t \\ 0 & \text{if } C_{ij} > t \end{cases} \tag{2}$$

$$t = \text{travel time threshold}$$

Accessibility is calculated for specific time thresholds and the result is a simple count of destinations that are reachable within each threshold. Owen and Levinson (2012) demonstrate this approach in an accessibility evaluation process developed for the Minnesota Department of Transportation. Using the results of the travel time calculations described in Section 4.2, cumulative opportunity accessibility values are calculated for each Census block in each CBSA using thresholds of 10, 20, 30, 40, 50 and 60 minutes.

4.4 Person-Weighted Accessibility

The accessibility calculation methods described in the sections above provide a *locational* accessibility metric — one that describes accessibility as a property of locations. The value of accessibility, however, is only realized when it is experienced by people. To reflect this fact, accessibility is averaged across all blocks in a CBSA, with each block's contribution weighted by the number of workers in that block. The result is a single metric (for each travel time threshold) that represents the accessibility value experienced by an average worker in that CBSA.

4.5 Weighted Accessibility Ranking

Metropolitan area rankings are based on an average of person-weighted job accessibility for each metropolitan area over the six travel time thresholds. In the weighted average of accessibility, destinations reachable in shorter travel times are given more weight. A negative exponential weighting factor is used, following Levinson and Kumar (1994). Here time is differenced by thresholds to get a series of "donuts" (e.g., jobs reachable from 0 to 10 minutes, from 10 to 20 minutes, etc.).

$$a_w = \sum_t (a_t - a_{t-10}) \times e^{\beta t}$$

$a_w =$ Weighted accessibility ranking metric for a single metropolitan area

$a_t =$ Worker-weighted accessibility for threshold t

$\beta = -0.08$

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