Access Across America: 2022 Methodology

Prepared by the

Accessibility Observatory at the University of Minnesota

October 17, 2024

ACCESSIBILITY OBSERVATORY

UNIVERSITY OF MINNESOTA

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Authors

Andrew Owen
Lead Researcher

Shirley Shiqin Liu
Researcher

Saumya Jain
Researcher

Eric Lind
Director

Accessibility Observatory
Center for Transportation Studies
University of Minnesota

Acknowledgements

The development of this report was made possible by sponsorship from:

- California Department of Transportation
- Connecticut Department of Transportation
- District Department of Transportation
- Federal Highway Administration
- Florida Department of Transportation
- Illinois Department of Transportation
- Maryland Department of Transportation
- Massachusetts Department of Transportation
- Michigan Department of Transportation
- Minnesota Department of Transportation
- North Carolina Department of Transportation
- Texas Department of Transportation
- Virginia Department of Transportation

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 the *Access Across America* report series for 2022. An overview of the methodology for the Observatory's 2022 reports and calculations is provided below, and detailed descriptions can be found in the following sections.

- **Data Sources**
  1. U.S. Census TIGER/Line 2020 geography files
  2. U.S. Census Longitudinal Employer-Household Dynamics (LEHD) 2020 Origin-Destination Employment Statistics (LODES)
  3. TomTom North America, Inc. MultiNet and Speed Profile data products
  4. OpenStreetMap (OSM) North America extract, retrieved January 2022
  5. General Transit Feed Specification (GTFS) schedule data from transit operators, various dates
- **Data Preparation**
  1. Divide the geographical United States into analysis zones for efficient parallelization
  2. Construct automobile network with road segment speed data for each analysis zone
  3. Assign Level of Traffic Stress (LTS) scores to each street link and intersection across the United States
  4. Construct unified pedestrian/transit/bike network for each analysis zone
- **Accessibility Calculation**
  1. For each Census block in the United States, calculate travel time to all other blocks within 120km for each departure time at 1-hour intervals, over the 24-hour period
  2. Calculate cumulative opportunity accessibility to jobs for each block and departure time, using thresholds of 5, 10, 15, ..., 60 minutes
  3. Average accessibility for each included CBSA over all blocks, weighting by number of workers in each block
  4. Calculate weighted ranking for each included metropolitan area

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 on-network travel time calculation, and calculations are performed for every census block (excluding blocks that contain no land area) in the United States. Block-level accessibility results are then aggregated across core-based statistical areas (CBSAs) for metropolitan-level analysis. These geography definitions are provided by the U.S. Census Bureau's TIGER/Line files.[1] This project uses the geography definitions established for the 2020 decennial census.

2.2 Employment and Worker Population

Data describing the distribution of labor and employment in the region are drawn from the U.S. 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 2020, the most recent available as of the performance of the 2022 accessibility calculations.

Note: The LODES dataset used in this report does not include job location data from the states of Alaska, Arkansas, or Mississippi.[3] None of the top 50 metropolitan statistical areas reported in the *Access Across America* lie within those states; however, Memphis (49th by total employment) borders both Arkansas and Mississippi, and thus access to jobs from areas within Memphis is likely to be underreported given the absence of those nearby job locations in the dataset.

2.3 Auto Network

Data describing the auto travel network across the country were licensed from TomTom North America, Inc., and include the MultiNet and Speed Profile products. MultiNet provides auto network geometries for roadways of all functional classifications from local streets to major highways, and Speed Profile provides average roadway speed information, for each roadway segment, at a 5-minute resolution level throughout the day. The data products used in this project contain speed data collected by GPS devices during the June 2020–June 2022 period. For road segments where speed data are provided separately for different days of the week, data for Wednesday are used.

2.4 Bicycle and Pedestrian Network

Data describing the bicycle and pedestrian network across the country were obtained from OpenStreetMap[4]. The network data used in this report were retrieved from OpenStreetMap, as existed in

[1] https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html

[2] http://lehd.ces.census.gov/data/

[3] a detailed LODES data release notes is here: https://lehd.ces.census.gov/data/lodes/LODES8/LODESTechDoc8.1.pdf

[4] http://openstreetmap.org

January 2022. The bicycle network is composed of all roadway features that are not restricted-access (e.g. interstate highways) as well as all separated facilities and off-street paths on which bicycles are permitted. The bicycle network elements include OpenStreetMap tag data, which describe attributes such as the presence of bike lanes; these tag data are used in the Level of Traffic Stress (LTS) assignment procedure.

Level of Traffic Stress (LTS) is a score for how "stressful" a given street is to bike on, based on physical attributes of the roadway and bicycle facilities, if any. LTS evaluation is outlined in Mekuria et al. (2012). The LTS process ingests a variety of roadway characteristics, such as the presence or absence of bike facilities, numbers of lanes, and roadway speeds, and assigns a value of 1 (lowest stress) to 4 (highest stress) to street segments based on these characteristics. Hierarchical classification rules assign bicycle LTS ranks to street segments and intersections, based upon OSM tag data.

The pedestrian network is composed of features with the "footway," "pedestrian," and "residential" tags.

2.5 Transit Schedules

Detailed digital transit schedules in GTFS format[5] were obtained from Transitland,[6] a data platform that archives transit schedule data from transit providers worldwide. Travel time calculations for this year's project are based on schedules valid for January 19, 2022 (a Wednesday with normal, non-holiday service). When a schedule for that date is not available for a given transit operator, the schedule which comes closest to including it is used.

[5] https://developers.google.com/transit/gtfs/

[6] https://www.transit.land/

3 Accessibility Calculation

3.1 Overview

Accessibility evaluations rely on an underlying calculation of travel times. Travel times by driving, biking, transit, and walking are evaluated from each Census block centroid based on detailed networks. 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 5, 10, 15, …, 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 worker in the metropolitan area.

Finally, the worker-weighted average accessibility values across the 10 through 60 minute thresholds at 10-minute intervals 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 the *Access Across America* reports for 2022.

3.2 Travel Times: Auto

3.2.1 Software

Auto travel time calculations are performed using custom-built extensions to OpenTripPlanner (OTP), an open-source multimodal trip planning and analysis tool. OpenTripPlanner is a graph-based routing system that 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).

3.2.2 Auto Travel Time

The time cost of travel by auto is composed of one primary component — travel time by auto from the centroid of the origin census block to the centroid of the destination census block. In reality a vehicle must be accessed and egressed in parking facilities, though attached parking facilities and street parking are sufficiently ubiquitous in most North American cities to equate the end of an auto trip with the final opportunity destination. The time cost of auto travel is dependent on the time of day, and congestion levels can lessen or worsen within minutes. TomTom's Speed Profile dataset contains average roadway speed information, for each roadway segment, at a 5-minute resolution level. As OTP traverses the network on an auto trip, roadway speed information is updated at every 5 minute increment in travel time, to afford a much more accurate and realistic travel time informed by historical data on roadway speed variations. This also results in a congestion-aware routing framework; if a particular route segment exhibits sufficiently high levels of congestion and speed reduction, the OTP router may find a shortest path which avoids this segment on trips occurring at the time of day during which this congestion occurs.

3.3 Travel Times: Walk, Bike, and Transit

3.3.1 Software

Travel time calculations for walking, biking, and transit are performed using R5, an open-source multimodal routing engine targeting OpenStreetMap and GTFS transit data. R5 is available at https://github.com/conveyal/r5.

3.3.2 Walk Travel Time

Using the pedestrian network derived from OSM, this analysis makes the assumption that all walking or rolling travel takes place at a speed of 3.6 km/hour along designated pedestrian facilities such as sidewalks, trails, etc. The total travel time includes the time cost of traveling by walk or roll from the origin to the nearest part of the pedestrian network, if there is one.

3.3.3 Bike Travel Time

The time cost of travel by bike is composed of multiple components. *Initial access time* refers to the time cost of traveling by foot from the origin to a nearby piece of the transportation network, where the traveler may begin riding a bicycle. *On-bicycle time* refers to time spent riding the bicycle on the trip. *Barrier-crossing time* refers to time spent walking a bicycle across an intersection, or along the sidewalk of a street, of higher traffic stress than the trip's maximal LTS tolerance would allow. Finally, *destination access time* refers to time spent traveling from a nearby street link or intersection on the bicycle network to the destination. All of these components are included in the calculation of bike travel times.

This analysis makes the assumption that all walking portions of the trip—initial, any barrier crossings, and destination—take place by walking at a speed of 3.6 km/hour along designated pedestrian facilities such as sidewalks, trails, etc. On-bicycle travel time is calculated with an assumed bicycle speed of 12 km/hour.

3.3.4 Transit Travel Time

The time cost of travel by transit is composed of multiple components. *Initial access time* refers to the time cost of traveling by walk or roll from the origin to a transit stop or station. *Initial wait time* refers to the time spent after reaching the transit station but before the trip departs. *On-vehicle time* refers to time spent on-board a transit vehicle. When transfers are involved, *transfer access time* and *transfer wait time* refer to time spent accessing a secondary transit station and waiting there for the connecting trip. Finally, *destination access time* refers to time spent traveling from the final transit station to the destination. All of these components are included in the calculation of transit travel times.

This analysis makes the assumption that all access portions of the trip—initial, transfer(s), and destination—take place by walking or rolling at a speed of 3.6 km/hour along designated pedestrian facilities such as sidewalks, trails, etc. On-vehicle travel time is derived directly from published transit timetables, under an assumption of perfect schedule adherence. An unlimited number of transfers are allowed.

Just as there is no upper limit on the number of vehicle boardings, there is no lower limit either. Transit and walking are considered effectively a single mode. The practical implication of this is that the shortest path by "transit" is not required to include a transit vehicle. This allows the most consistent application and interpretation of the travel time calculation methodology. For example, the shortest walking path from an origin to a transit station in some cases passes through potential destinations where job opportunities exist. In other cases, the shortest walking path from an origin to a destination might pass through a transit access point which provides no trips which would reduce the origin–destination travel time. In these situations, enforcing a minimum number of transit boardings would artificially inflate the shortest-path travel times. To avoid this unrealistic requirement, the transit travel times used in this analysis are allowed to include times achieved only by walking or rolling.

3.4 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 3.2, cumulative opportunity accessibility values are calculated for each Census block in each CBSA using thresholds of 5, 10, 15, 20, …, 60 minutes.

3.5 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.

3.6 Weighted Accessibility Ranking

Metropolitan area rankings are based on an average of person-weighted job accessibility for each metropolitan area over the twelve travel time thresholds. In the weighted average of accessibility, destinations reachable in shorter travel times are given more weight, as they constitute more attractive destinations. 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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