Access Across America: Auto 2021 Methodology

Prepared by the

Accessibility Observatory at the University of Minnesota

July 18, 2023

ACCESSIBILITY OBSERVATORY

UNIVERSITY OF MINNESOTA

Driven to Discover[SM]

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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 *Access Across America: Auto 2021*. An overview of the methodology for the Observatory's 2021 auto reports and calculations 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) 2019 Origin-Destination Employment Statistics (LODES)
  3. TomTom North America, Inc. MultiNet and Speed Profile data products
- **Data Preparation**
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  2. Construct automobile network graph with road segment speed data 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 Topologically Integrated Geographic Encoding and Referencing (TIGER) program.[1] This project uses the geography definitions established for the 2010 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 2019, the most recent available as of the performance of the 2021 accessibility calculations.

Note: The LODES dataset used in this report does not include job location data from the states of Alaska, Arkansas, or Mississippi. These states did not report these employment statistics to the Census for the 2019 year.[3] None of the top 50 metropolitan statistical areas reported in the *Access Across America: Bike 2021* 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 2019–June 2021 period and averaged. For road segments where speed data are provided separately for different days of the week, data for Wednesday are used.

[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/LODESTechDoc8.0.pdf

3 Data Preparation

3.1 Analysis Zone Definition

This project relies on the efficient calculation of shortest paths between a very large number of origin–destination pairs given the national scope, repeated for many departure times. In order to efficiently parallelize these calculations across multiple computers, the geographical USA is divided into 4879 "analysis zones" each including no more than 5,000 Census blocks. Figure 1 shows the Census block and CBSA boundary structure for the Minneapolis–St. Paul region, and figs. 2 and 3 illustrate the process of constructing analysis zones on the national and local scales, respectively.

To simplify the calculation of local time, which is necessary to determine average roadway speeds on specific segments for a given minute of the day, time zone geometries based on U.S. Census data[4] were used as parent geometries of the analysis zone areas. This way, each analysis zone is guaranteed to have a single associated time zone, whereas the use of non-time zone parent geometries would complicate local time lookup when calculating roadway segment speeds and accessibility.

[4] http://efele.net/maps/tz/world/tz_world.zip

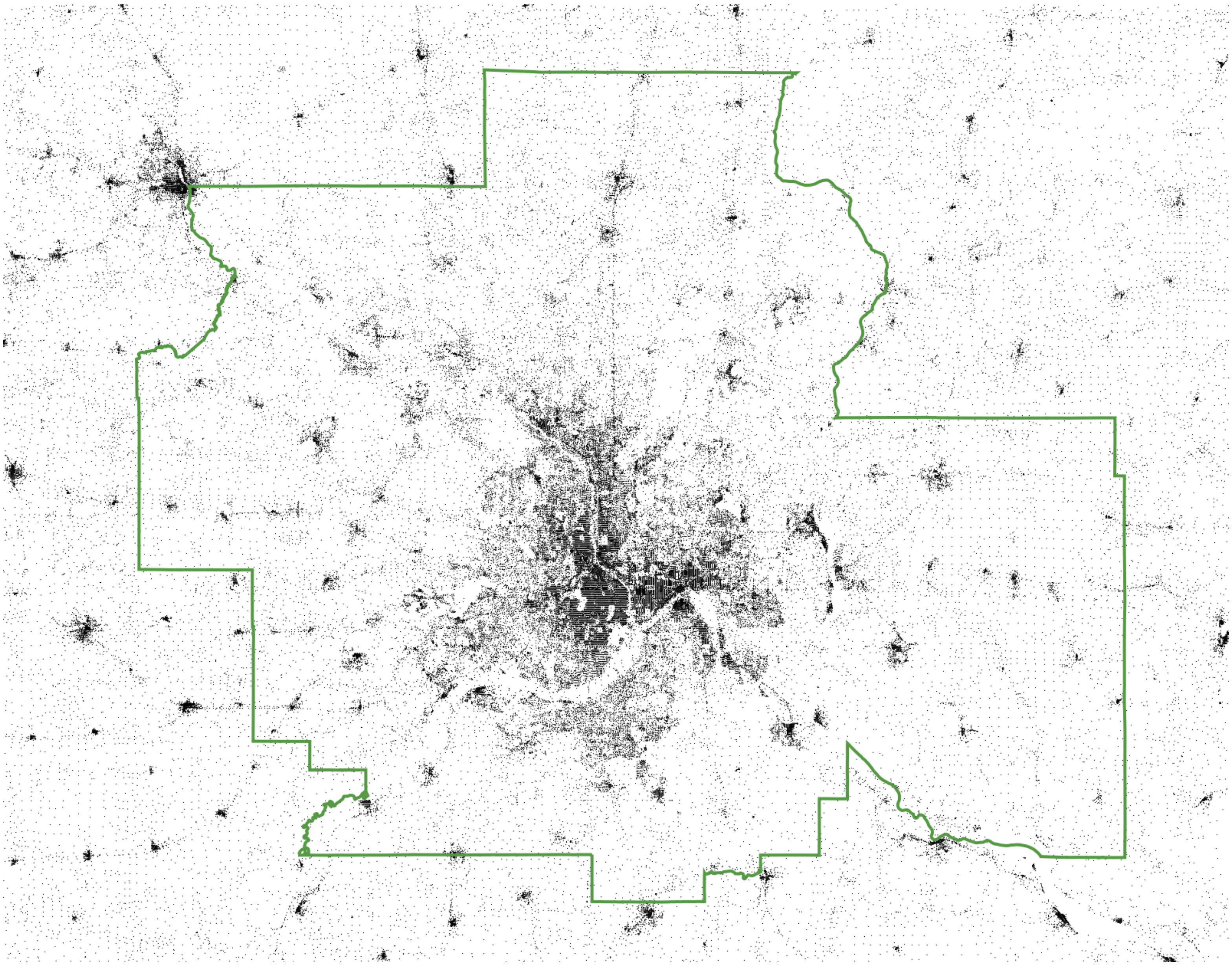

Figure 1: Boundary and Census blocks for the Minneapolis–Saint Paul, MN CBSA. Each dot represents the centroid of a single Census block.

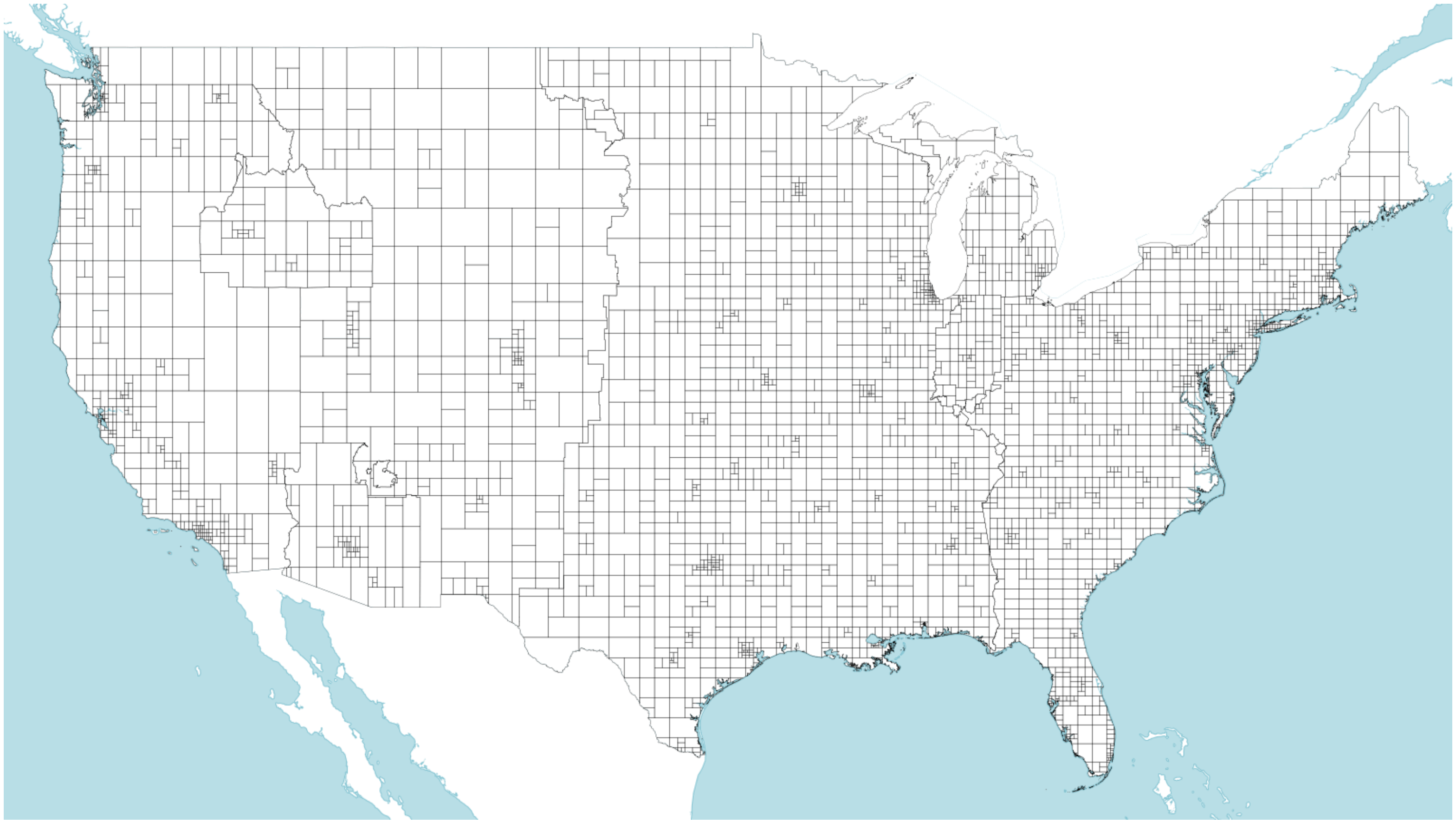

Figure 2: The United States divided into analysis zones. Each zone contains a maximum of 5,000 Census block centroids.

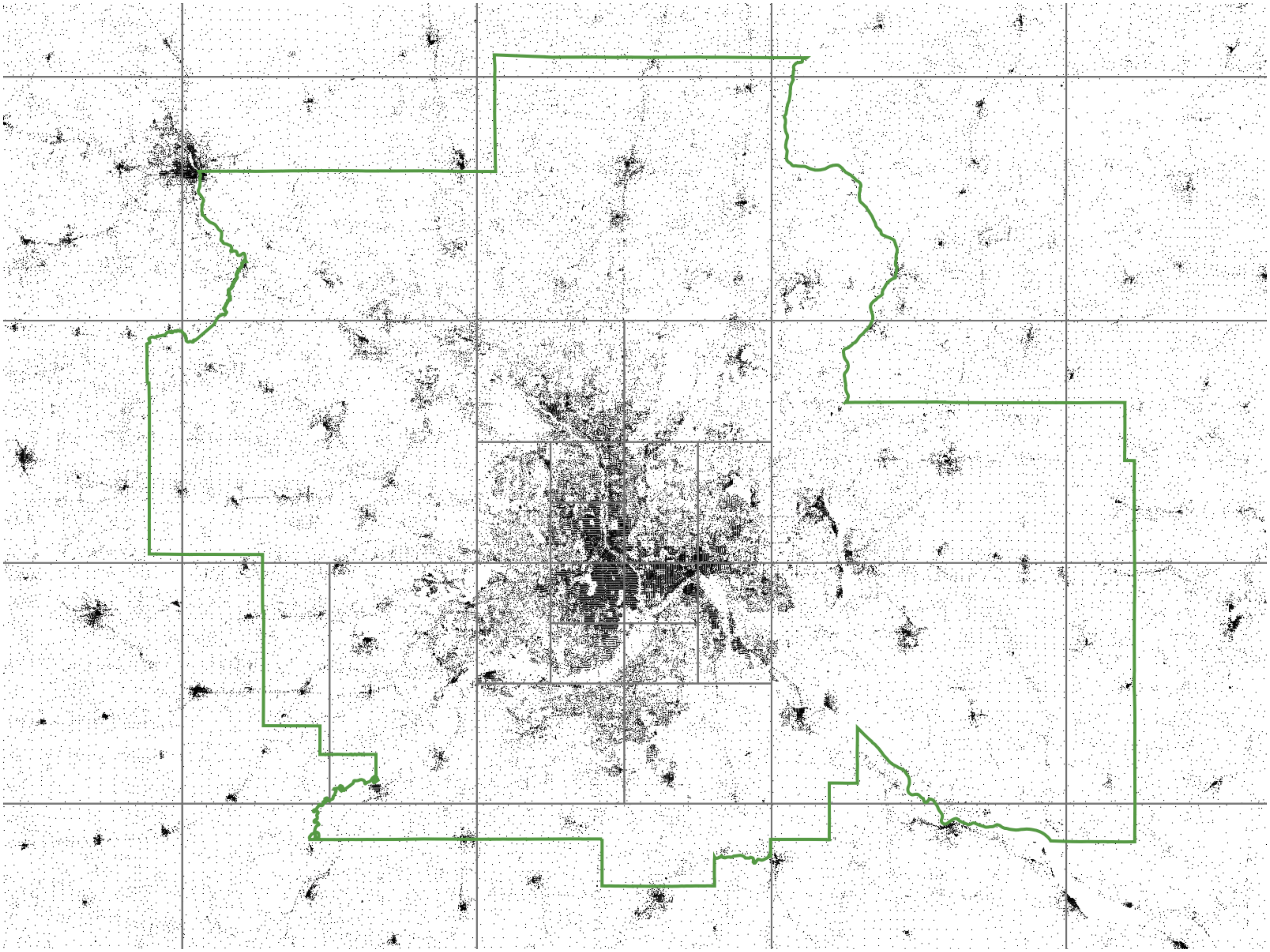

Figure 3: Example of the analysis zone structure within an urban area - Minneapolis & St. Paul, Minnesota

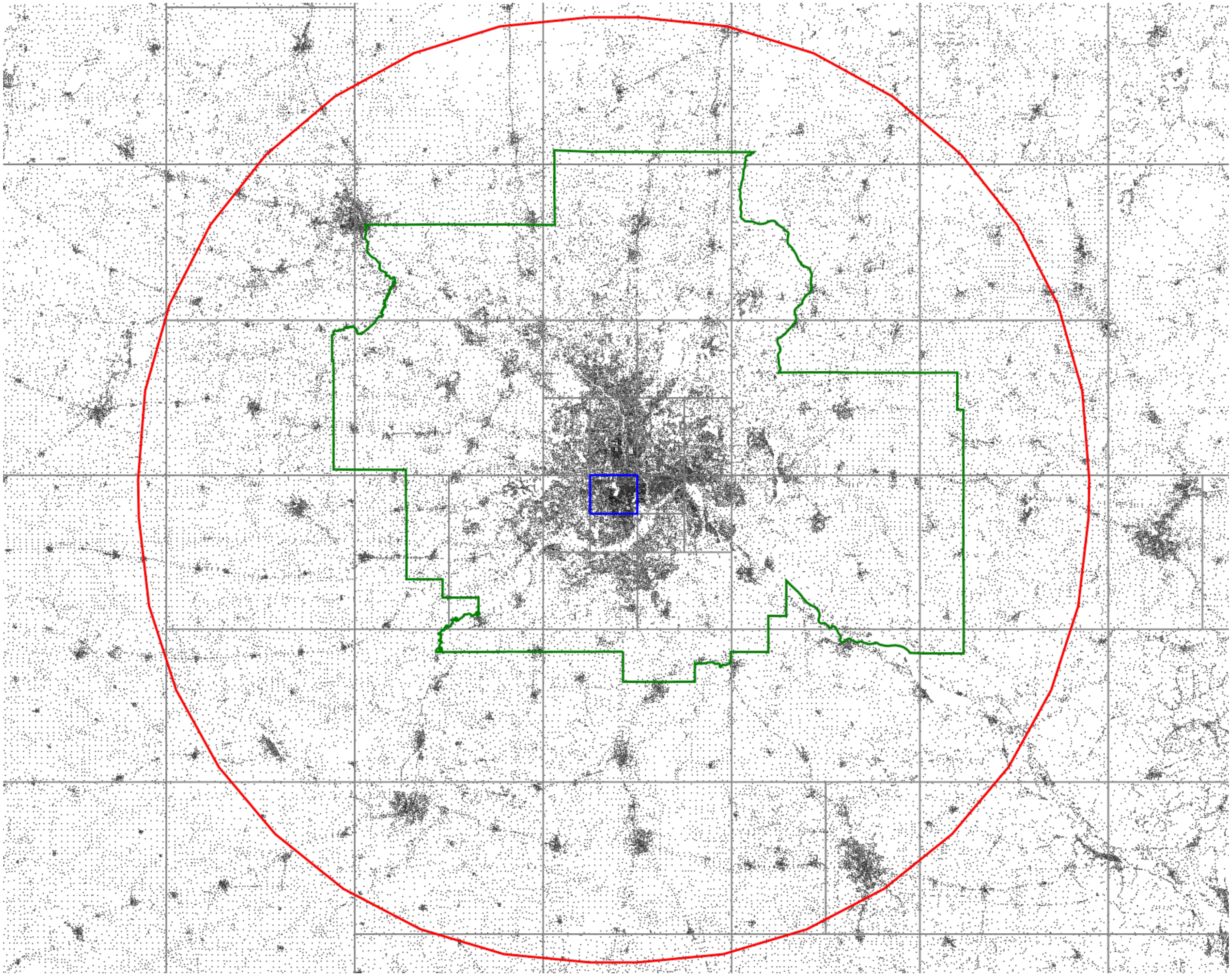

Figure 4: A single origin zone (blue) and its corresponding 120-kilometer destination zone (red). Travel times are calculated from each centroid in the origin zone to each centroid in the destination zone.

Each analysis zone defines a set of origins and a set of destinations. The origins for an analysis zone are simply those Census blocks whose centroids fall within the zone. All Census blocks whose centroids lie within 120km of the boundary of the analysis zone are included as destinations. This corresponds to an average speed of 120 km/hour, which is at or over the speed limit in most metropolitan areas. Figure 4 provides an example of origin and destination selection for a single analysis zone in the Minneapolis area.

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. Custom-built OTP extensions include a graph building function that combines TomTom MultiNet auto travel network data and TomTom Speed Profiles speed data into a single unified graph. A graph is built for each analysis zone. This is combined with origin and destination locations to create a single analysis bundle that contains all data necessary to calculate accessibility values for the blocks in a single analysis zone. These analysis bundles are then easily transmitted for remote computation on computer clusters.

4 Accessibility Calculation

4.1 Overview

Accessibility evaluations rely on an underlying calculation of travel times. Here, auto travel times are evaluated from each Census block centroid based on a detailed auto travel network and link speed data. Travel time calculations are repeated for every departure time at one-hour intervals across the 24-hour period. 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. The accessibility values for all departure times indicate the number of jobs that are reachable departing on each hour from 12:00 AM until 11:00 PM.

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 *Access Across America: Auto 2021*.

4.2 Travel Times

4.2.1 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). OTP's Analyst extension provides efficient and parallelized processing of many paths from a single origin based on the construction of shortest path trees using Dijkstra's Algorithm. Additionally, locally-developed extensions to OTP allow graphs to be built from TomTom MultiNet and Speed Profile data, as well as automated batch processing of accessibility calculations for multiple departure times.

4.2.2 Auto Trip Parameters

The time cost of travel by auto is relatively simple, and 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.

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 5, 10, 15, 20, …, 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 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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