Access Across America: Auto 2019 Methodology

Final Report

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ACCESSIBILITY OBSERVATORY

UNIVERSITY OF MINNESOTA

Technical Report Documentation Page

1. Report No. CTS 21-02	2.	3. Recipients Accession No.	
4. Title and Subtitle Access Across America: Auto 2019 Methodology		5. Report Date February 2021	
		6.	
7. Author(s) Andrew Owen and Brendan Murphy		8. Performing Organization Report No.	
9. Performing Organization Name and Address Accessibility Observatory University of Minnesota Minneapolis, MN 55455 United States		10. Project/Task/Work Unit No. CTS 2016016	
		11. Contract (C) or Grant (G) No.	
12. Sponsoring Organization Name and Address Center for Transportation Studies University of Minnesota University Office Plaza, Suite 440 2221 University Avenue SE Minneapolis, MN 55414		13. Type of Report and Period Covered Final Report	
		14. Sponsoring Agency Code	

16. Abstract (Limit: 250 words)

Accessibility is the ease of reaching valued destinations. It can be measured across different times of day (accessibility in the morning rush might be lower than the less-congested midday period). It can be measured for each mode (accessibility by walking is usually lower than accessibility by transit, which is usually lower than accessibility by car). There are a variety of ways to measure 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 Access Across America: Auto 2019 report, which estimates the accessibility to jobs by auto for each of the 11 million U.S. census blocks and analyzes these data in the 50 largest (by population) metropolitan areas.

Travel times are calculated using a detailed road network and speed data that reflect typical conditions for an 8 a.m. Wednesday morning departure. Additionally, the accessibility results for 8 a.m. are compared with accessibility results for 4 a.m. to estimate the impact of road and highway congestion on job accessibility.

Rankings are determined by a weighted average of accessibility, with a higher weight given to closer, easier-to-access jobs. Jobs reachable within 10 minutes are weighted most heavily, and jobs are given decreasing weights as travel time increases up to 60 minutes.

17. Document Analysis/Descriptors accessibility, commuting, work trips, land use, travel time, travel behavior, urban transportation, traffic congestion		18. Availability Statement No restrictions. Document available from: National Technical Information Services, Alexandria, Virginia 22312	
19. Security Class (this report) Unclassified	20. Security Class (this page) Unclassified	21. No. of Pages 16	22. Price

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February 2021

Published by:

Center for Transportation Studies
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Acknowledgements

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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 2019*. An overview of the methodology for the Observatory's 2019 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) 2017 Origin-Destination Employment Statistics (LODES)
    3. TomTom North America, Inc. MultiNet and Speed Profile data products

- **Data Preparation**

    1. Divide the geographical United States into analysis zones for efficient parallelization
    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 - this is a change in scope relative to *Access Across America: Auto 2013*, and aligned the data and calculations with the goals of the Observatory's National Accessibility Evaluation Pooled Fund project. This national scope was first implemented for *Access Across America: Auto 2015*, and continues through the current year. 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. The use of U.S. Census block geometries allows accessibility data to be linked to, and correlated with, Census demographics data and other standardized datasets.

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 2017, the most recent available as of the performance of the 2019 accessibility calculations.

2.3 Auto Network

Data describing the auto travel network across the country were contracted 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 the 5-minute resolution level throughout the day. The data products used in this project contain speed data collected by GPS devices during the June 2017–June 2019 period and averaged. For road segments where speed data are provided separately for different days of the week, data for Wednesday are used.

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[1] https://www.census.gov/geo/maps-data/data/tiger.html
[2] http://lehd.ces.census.gov/data/

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[3] 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.

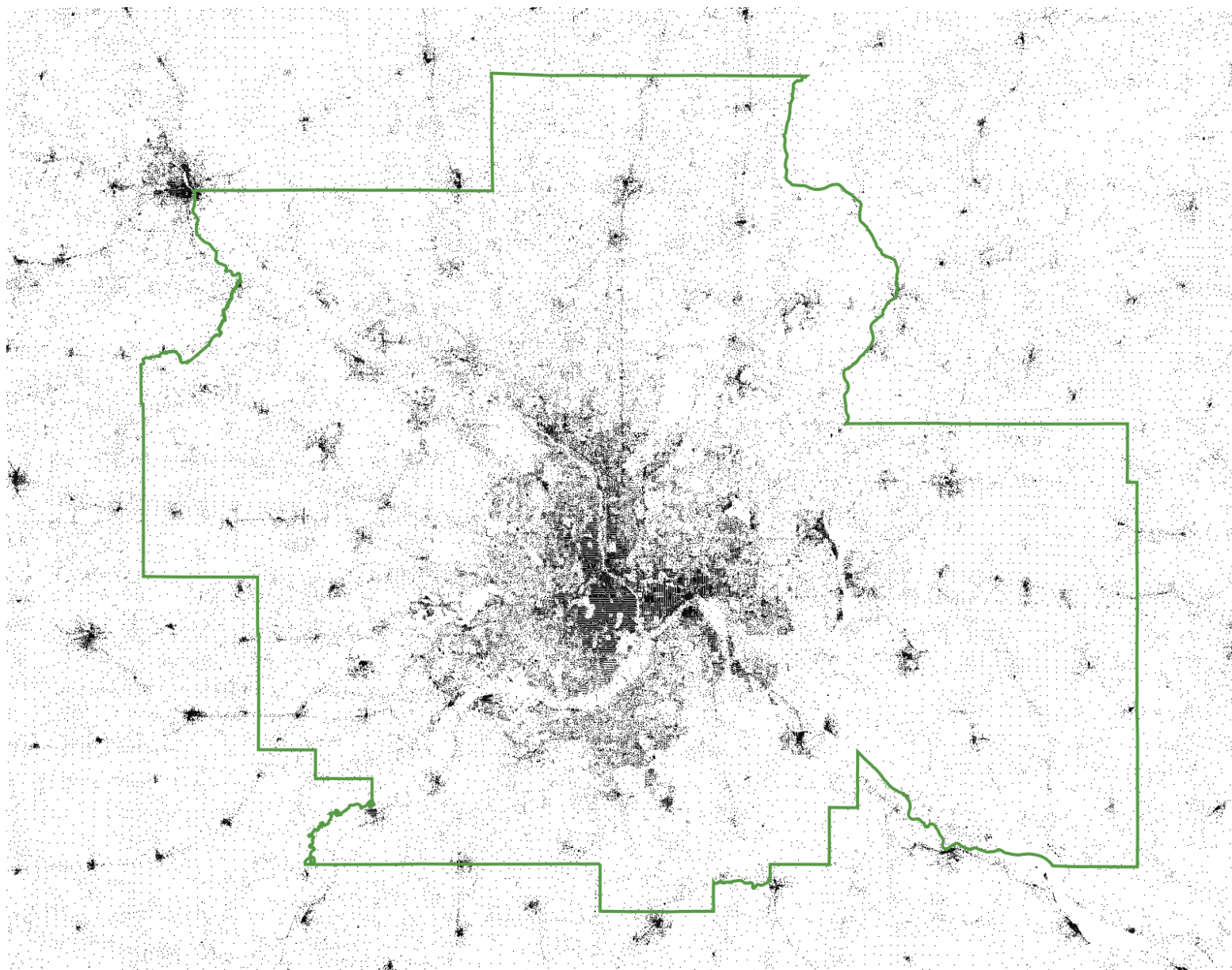[3]http://efele.net/maps/tz/world/tz_world.zip

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

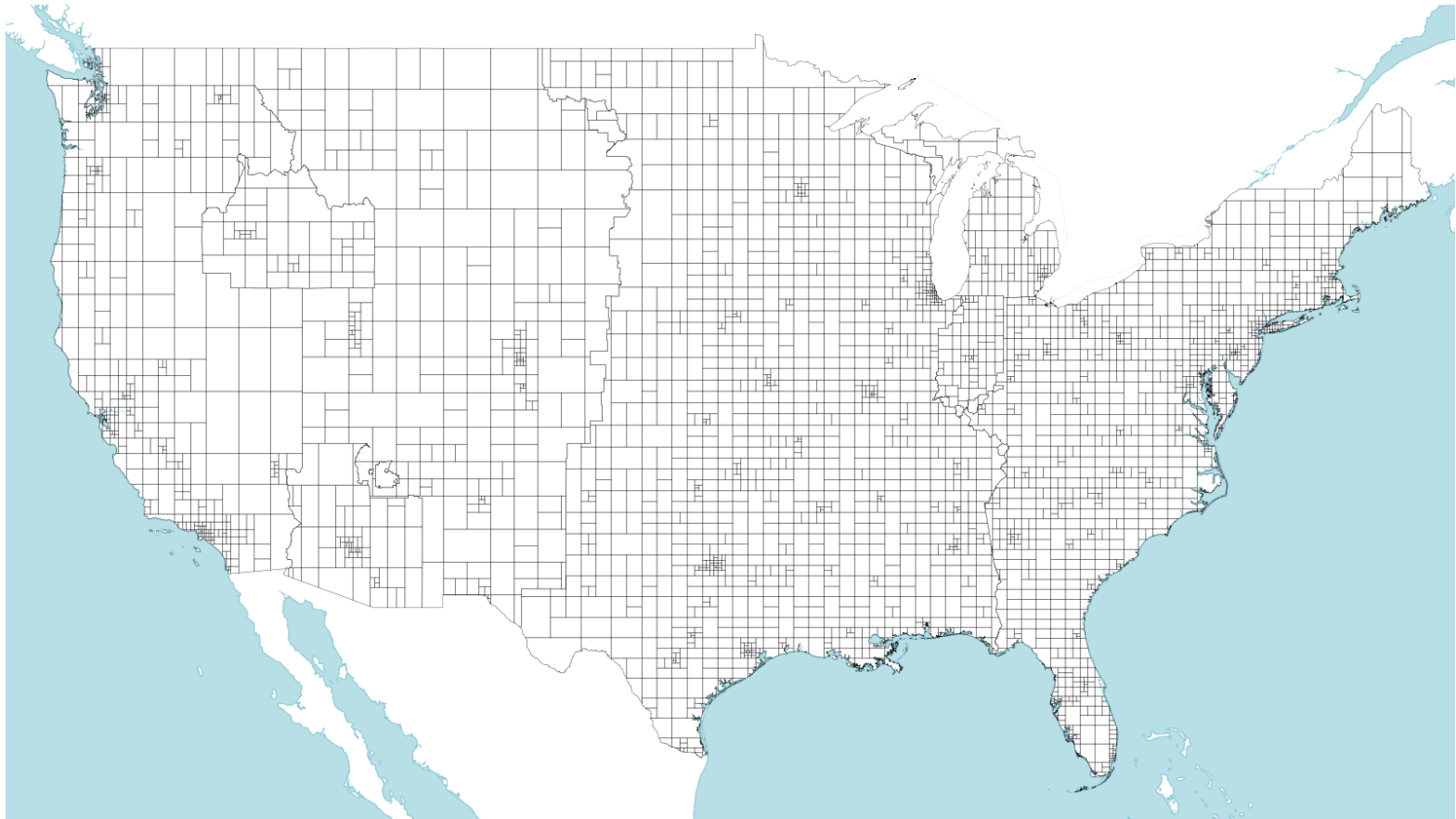Figure 2: The United States divided into analysis zones. Each zone contains a maximum of 5,000 Census block centroids.
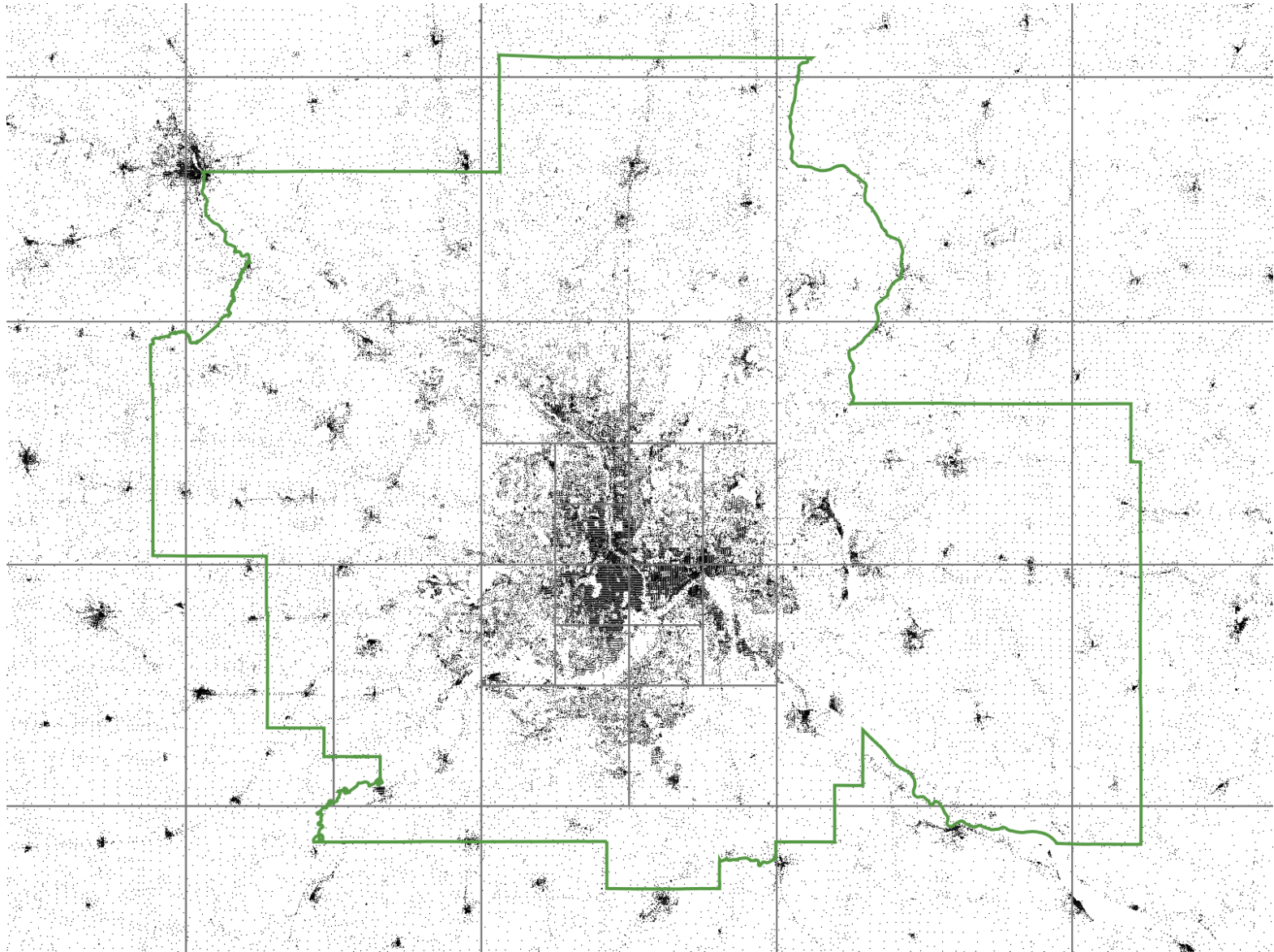
Figure 3: Example of the analysis zone structure within an urban area - Minneapolis & St. Paul, Minnesota
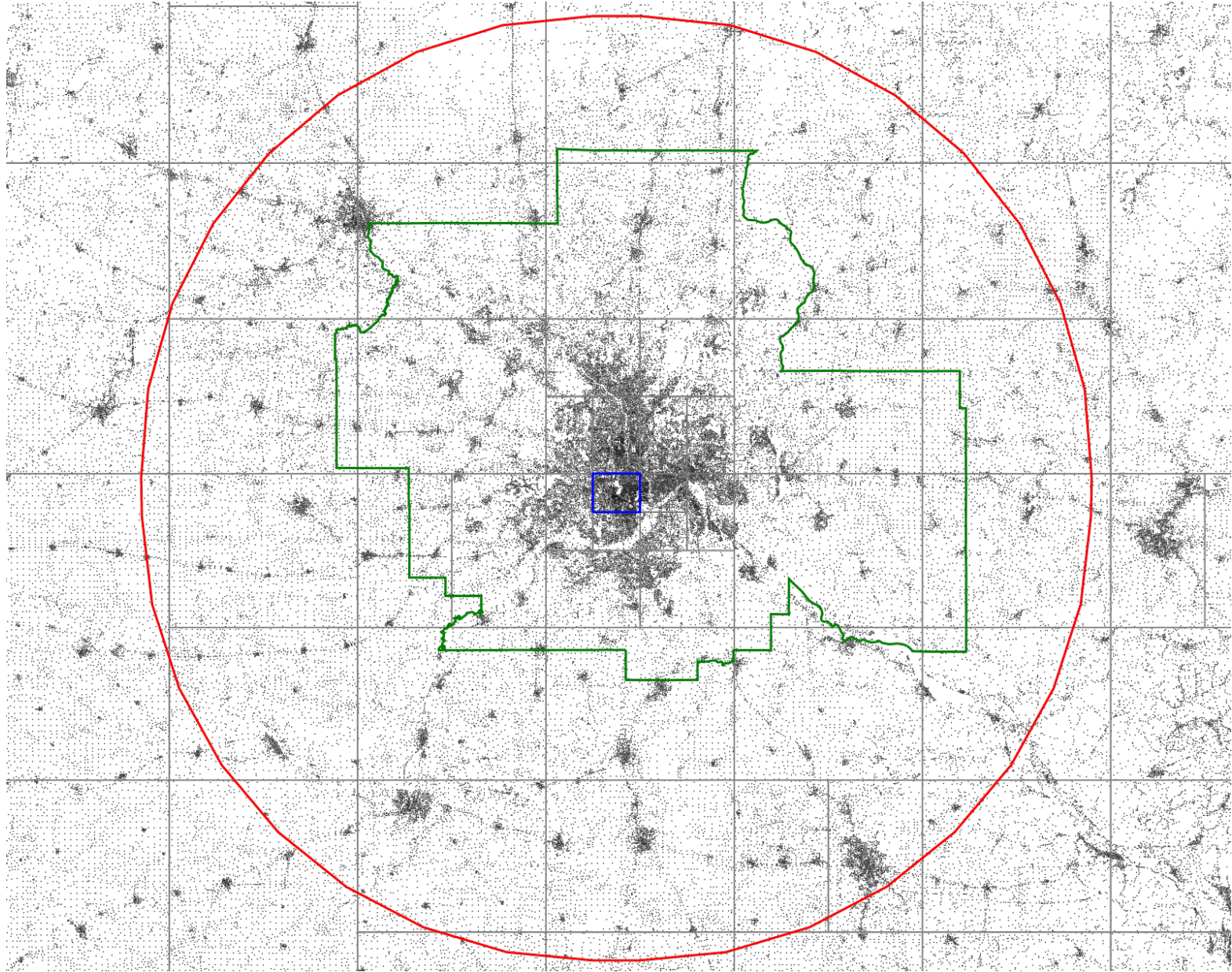
Figure 4: A single origin zone (blue) and its corresponding 120-kilometer destination zone (red). Travel times are calculated from each centroid in the origin zone to each centroid in the destination zone.

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 2019*.

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 **?**. 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 the 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. **?** provide a practical overview of historical and contemporary approaches. Most contemporary implementations can be traced at least back to **?**, 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 (**?**). This makes comparisons between modes, times, and study areas challenging. **?** 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. **?** also note the increased complexity introduced by the cost weighting parameter.

Perhaps the simplest approach to evaluating locational accessibility is discussed by **?** as well as **?**. *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. **?** 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 **?**. 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.).

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

a_w = Weighted accessibility ranking metric for a single metropolitan area

a_t = Worker-weighted accessibility for threshold t

$\beta = -0.08$

4.6 Comparisons With Previous Years

Beginning in data year 2018, federal jobs and federal workers are not included due to changes in underlying datasets from the U.S. Census Bureau. As a result, comparisons between 2018 and 2019 accessibility results are possible, and provide a way to monitor changes in accessibility over time. Comparisons between 2019 accessibility data and data from years earlier than 2018 are less accurate in areas where federal employment is a greater share of total employment.