Technical Report Documentation Page

1. Report No. MN/RC 2019-XX	2.	3. Recipients Accession No.
4. Title and Subtitle National Accessibility Evaluation Phase I		5. Report Date
		6.
7. Author(s) Andrew Owen, Brendan Murphy, and Kristin Carlson		8. Performing Organization Report No.
9. Performing Organization Name and Address Center for Transportation Studies University of Minnesota University Office Plaza, Suite 440 Minneapolis, MN 55414		10. Project/Task/Work Unit No.
		11. Contract (C) or Grant (G) No.
12. Sponsoring Organization Name and Address Minnesota Department of Transportation Office of Research & Innovation 395 John Ireland Boulevard, MS 330 St. Paul, Minnesota 55155-1899		13. Type of Report and Period Covered
		14. Sponsoring Agency Code

15. Supplementary Notes

http://mndot.gov/research/reports/2019/2019XX.pdf

16. Abstract (Limit: 250 words)

Transportation exists to provide travelers the opportunity to reach destinations, and this potential for interaction can be regarded as the fundamental product of transportation systems. This project implemented a measurement of access to jobs across the entire U.S. For every Census block, it calculated the number of jobs that can be reached, by auto, transit, biking, or walking, within various travel time thresholds. This evaluation produced detailed destination access datasets covering 2015 through 2019, as well as a series of annual reports summarizing the access datasets for metropolitan areas across the country. Travel time calculations were performed using an open-source, multi-modal trip planning and analysis tool. The calculations for each travel mode vary in ways that reflect specific technical differences among them and their data sources. The resulting datasets and reports provide a highly detailed look at job access across America, and track how job access evolved between 2015 and 2019.

17. Document Analysis/Descriptors Accessibility, performance management, planning		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	22. Price

National Accessibility Evaluation Phase I

FINAL REPORT

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March 2021

Published by:

Minnesota Department of Transportation
Office of Research & Innovation
395 John Ireland Boulevard, MS 330
St. Paul, Minnesota 55155-1899

ACKNOWLEDGMENTS

The National Accessibility Evaluation was made possible by sponsorship and technical guidance from the following organizations:

- Arkansas State Highway and Transportation Department
- California Department of Transportation
- District of Columbia Department of Transportation
- Federal Highway Administration
- Florida Department of Transportation
- Illinois Department of Transportation
- Iowa Department of Transportation
- Maryland Department of Transportation
- Massachusetts Department of Transportation
- Metropolitan Council (Minnesota)
- Minnesota Department of Transportation
- North Carolina Department of Transportation
- Tennessee Department of Transportation
- Virginia Department of Transportation
- Washington State Department of Transportation
- Wisconsin Department of Transportation

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EXECUTIVE SUMMARY

Transportation exists to provide travelers the opportunity to reach destinations, and this potential for interaction can be regarded as the fundamental product of transportation systems. Destination access metrics directly reflect the ability of travelers to reach critical destinations. They combine network travel times with the locations and value of the many origins and destinations served by a multimodal transportation system.

This project implemented a measurement of access to jobs across the entire U.S. For every Census block, it calculated the number of jobs that can be reached, by auto, transit, biking, or walking, within various travel time thresholds. For example, from a given Census block it may be possible to reach 150,000 jobs by driving within 20 minutes, or 20,000 jobs by transit within 30 minutes. This evaluation produced detailed job access datasets covering 2015 through 2019, as well as a series of annual reports summarizing the access results for metropolitan areas across the country.

This project was sponsored by state and federal transportation agencies, but the concept of accessibility combines detailed transportation analysis with detailed land use analysis. The year-to-year access changes revealed through this evaluation reflect changes in land use patterns — where workers live and where jobs are located — as much as they do changes to transportation networks.

DATA

The project involved several national-scale data sources:

- LEHD Origin-Destination Employment Statistics (LODES) datasets from the U.S. Census Bureau
- National-scale pedestrian network from OpenStreetMap
- National-scale bike network from OpenStreetMap
- National road network and speeds licensed from TomTom, Inc.
- Transit schedule datasets collected from hundreds of transit operators

ACCESS CALCULATIONS

Access evaluations rely on an underlying calculation of travel times. In this project, travel times are calculated for each mode based on detailed network and speeds data, using each Census block as an origin. These travel times are the basis of a cumulative opportunities accessibility measure that counts the number of opportunities that are reachable from each origin within travel times of 5 through 60 minutes, at 5-minute increments. All travel time calculations are performed using OpenTripPlanner, an open-source, multi-modal trip planning and analysis tool. The calculations for each travel mode vary in ways that reflect specific technical differences among them and their data sources.

Bike

This project uses a bicycle network classification framework based on the Level of Traffic Stress (LTS) metric to produce access metrics reflecting different tolerances for bicycle travel stress. LTS a metric used to evaluate how “stressful” a given street or path is to bike on, based on physical attributes of the roadway and any bicycle facilities present. The research team developed a method for assigning LTS values to individual bike network segments based on OpenStreetMap data.

Transit

Transit access calculations use detailed routes and timetables, and include time spent accessing a stop or station, waiting for a trip to depart, transferring, and accessing the final destination. The impact of service frequency is reflected by repeating access calculations at each minute to capture how access varies as trips arrive and depart.

Auto

Auto access calculations make use of detailed speed data to evaluate travel times at each hour of the day. This allows an evaluation of how congestion impacts destination access.

Walk

Walk access is calculated using pedestrian network data from OpenStreetMap and a constant walking speed of 3.1 mph (5 km/h).

LESSONS AND FUTURE RESEARCH

The project team and advisory panel identified lessons that can be applied to future access evaluation efforts, as well as areas where additional research or development would be useful.

- Advancements in understanding changes in access could provide useful insights into the relative impact that typical annual transportation network changes or land use changes have on destination access, and potentially help guide policy or planning decisions.
- Destination access evaluation requires detailed, consistent data describing transportation network and land use patterns, and access results are extremely sensitive to changes in the input data. The project was impacted by two significant changes to input datasets. Carefully selecting and maintaining input datasets will be important in future access evaluation work.
- It will likely be useful to include additional destination types in future access evaluation efforts. The advisory panel identified education, healthcare, and food/grocery locations as particularly interesting. An effort to include additional destination types will need to focus on identifying appropriate data sources.

CHAPTER 1: INTRODUCTION

Transportation exists to provide travelers the opportunity to reach destinations, and this potential for interaction can be regarded as the fundamental product of transportation systems. Destination access metrics directly reflect the ability of travelers to reach critical destinations. They combine network travel times with the locations and value of the many origins and destinations served by a multimodal transportation system.

Access can be measured for a wide range of transportation modes, to different types of destinations, and at different times of day. There are a variety of ways to define destination access; 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.

Destination access is not a new idea. Historically, however, implementations of access evaluation have typically focused on individual cities or metropolitan areas. Recent work has demonstrated the feasibility and value of systematically evaluating access across multiple metropolitan areas, by a variety of modes. Some transportation agencies have also begun using access evaluation in their project selection and prioritization processes.

This project implemented a measurement of access to jobs across the entire U.S. For every Census block, it calculated the number of jobs that can be reached, by auto, transit, biking, or walking, within various travel time thresholds. For example, from a given Census block it may be possible to reach 150,000 jobs by driving within 20 minutes, or 20,000 jobs by transit within 30 minutes. This evaluation produced detailed access datasets covering 2015 through 2019, as well as a series of annual reports summarizing the access datasets for metropolitan areas across the country. Access data for transit and driving are available for all five years, while bike and walk access data are available for 2017–2019.

This project was sponsored by state and federal transportation agencies, but the concept of accessibility combines detailed transportation analysis with detailed land use analysis. The year-to-year job access changes revealed through this evaluation reflect changes in land use patterns — where workers live and where jobs are located — as much as they do changes to transportation networks.

Chapters 2 and 3 of this report describe the data sources and methodology used to evaluate job access for each mode. Chapter 4 describes the resulting datasets and reports produced during the project, and Chapter 5 discusses lessons learned and considerations for future accessibility evaluations and research.

CHAPTER 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 calculations, which are performed for every census block (excluding blocks that contain no land area) in every state in the United States. Block-level access results are then aggregated across core-based statistical areas (CBSAs) for metropolitan-level analysis in the *Access Across America* series of reports. 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 throughout the U.S. 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 2013 through 2017, with the most recently-available LODES dataset included in each annual job access update.

2.3 PEDESTRIAN NETWORK

Data describing the pedestrian network across the country were obtained from OpenStreetMap[3] (OSM), an open-access online database of transportation network structures, maps, and other spatial information. OpenStreetMap, like Wikipedia, is composed of contributions from many individuals and organizations. In urban areas, it typically provided 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 August 31, 2015. Specifically, the pedestrian network is composed of OSM features with the "footway," "pedestrian," and "residential" tags. This includes designated pedestrian crosswalks and similar facilities, and excludes roadways where pedestrian use is prohibited.

2.4 BICYCLE NETWORK

Data describing the bicycle network across the country were similarly obtained from OSM. The data used for bicycle access calculations were refreshed for each annual update. Specifically, the bicycle network is composed of all roadway features that are not restricted-access (e.g. interstate and other highways), as well as all separated facilities and off-street paths on which bicycles are permitted. The

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[1] https://www.census.gov/geographies/mapping-files/time-series/geo/tiger-line-file.html
[2] https://lehd.ces.census.gov/data/
[3] https://www.openstreetmap.org

bicycle network elements include OSM tag data, which describe attributes such as the presence of bike lanes; these tag data are used in the LTS-based classification procedure described in Section 3.2.2.

2.5 TRANSIT ROUTES AND SCHEDULES

Detailed digital transit schedules in a consistent format are a critical component of this project, and the widespread availability of such data were a relatively recent development when the project began. The General Transit Feed Specification[4] (GTFS) was developed by Google and Portland TriMet as a way to provide transit schedules for use in traveler routing and information tools.

Despite their importance and digital nature, the collection of GTFS datasets can be inconsistent and error-prone. While the format of GTFS itself is standardized, practices for the digital publication and distribution of the datasets vary widely across transit operators. A majority of operators among medium and large metropolitan areas provide GTFS datasets via a direct download link. However, even among these, variations in data archiving practices pose challenges for systematic retrieval. Other operators allow GTFS dataset downloads only after users interactively submit a form or agreement. Still others generate GTFS datasets and provide them directly to Google for use in its popular online routing tools, but release them to the public only in response to direct requests.

These issues are somewhat mitigated by websites that collect and archive transit schedules in GTFS format.[5] These websites publish official GTFS feed information for agencies wherever available, and in such cases files are downloaded directly from agencies.

Transit schedule collection began in January 2014 and is ongoing, with weekly, monthly, and quarterly update schedules to match the data release practices of various transit operators. Often, multiple schedule updates are collected for a single transit operator. In each annual update, schedules for the third Wednesday in January are used to calculate transit travel times.[6] This date scheme was selected in order to reflect typical non-holiday weekday service when schools are in session. When a schedule for that date is not available for a given transit operator, the schedule that comes closest to including it is used.

2.6 ROAD NETWORK AND SPEEDS

Data describing the road and highway network throughout the U.S. were obtained under license 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 throughout the day. Each annual update uses the June data release for that

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[4] https://gtfs.org/

[5] E.g. http://transitfeeds.com/

[6] Exceptions are made for the D.C. metro area during presidential inaugural years.

year, which reflects speed sample data collected by GPS devices over the preceding 24 months. For road segments where speed data are provided separately for different days for the week, data for Wednesday are used.

2.7 ANALYSIS ZONE DEFINITION

This project relies on the efficient calculation of shortest paths between a very large number of origin–destination pairs, repeated for many departure times. In order to efficiently parallelize these calculations, the geographical U.S. is divided into 4,879 “origin zones,” each including no more than 5,000 Census blocks. Figure 2-1 shows the Census block and origin zone structure for the Minneapolis–Saint Paul, MN region as an example, and Figure 2-2 illustrates the same analysis zone structure at the national scale. Origin zones are paired with “destination zones” containing all Census blocks within a 60-km buffer around the origin zone, illustrated in Figure 2-3.

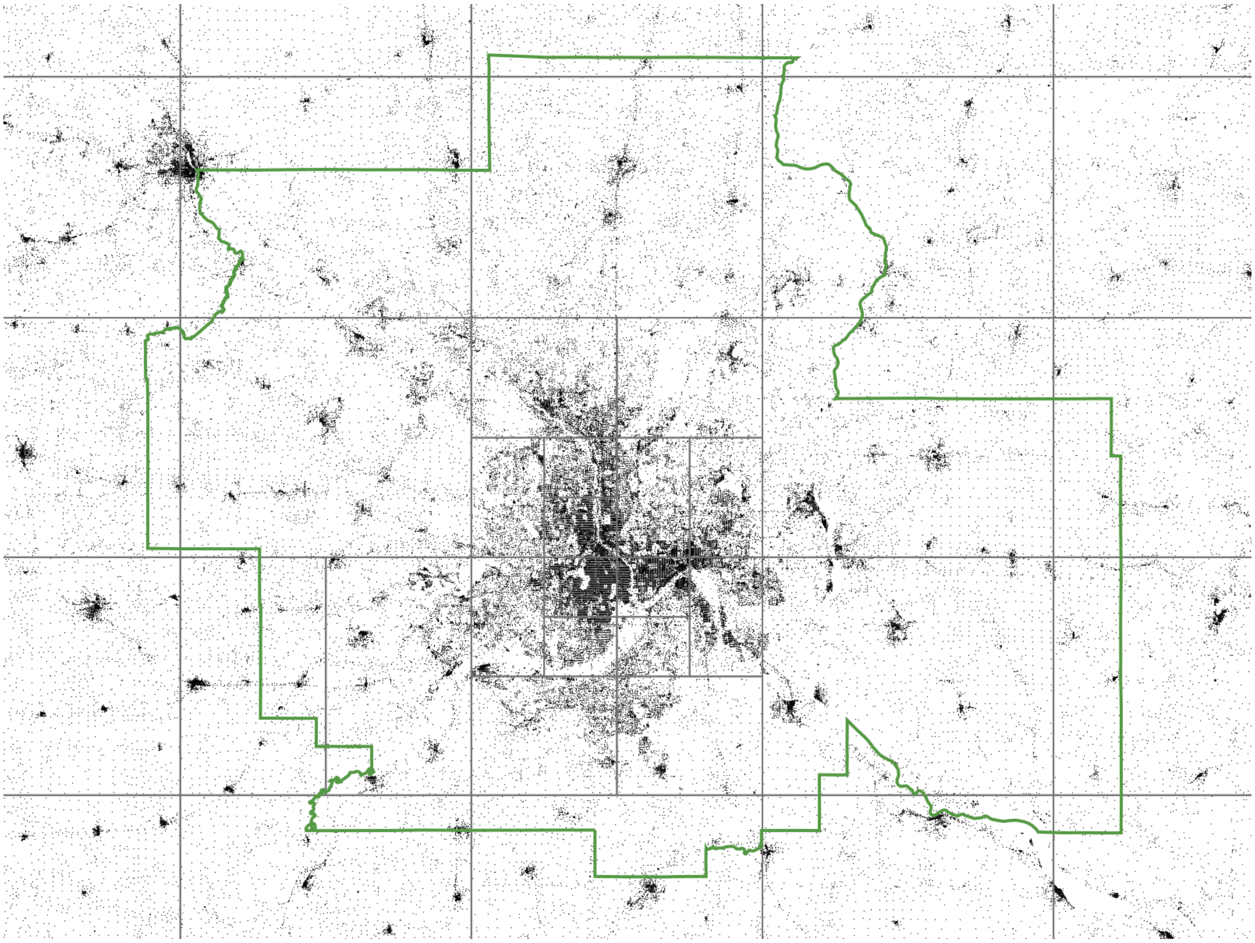

Figure 2-1: Boundary and Census blocks for the Minneapolis–Saint Paul, Mn CBSA. Each dot represents the centroid of a single Census block. The region is divided into analysis zones containing no more than 5,000 blocks each.

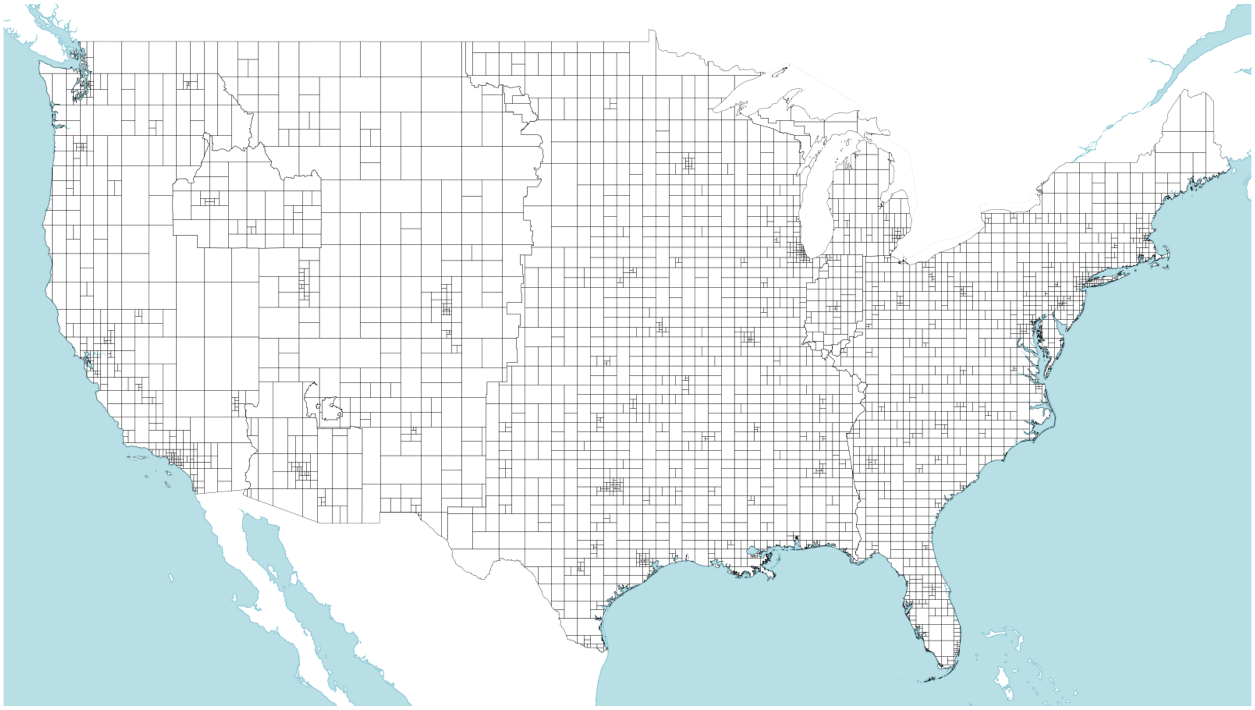

Figure 2-2: The United States divided into analysis zones. Each zone contains a maximum of 5,000 Census block centroids.

To simplify the calculation of local time, which is necessary to determine average roadways speeds on specific segments for a given minute of the day, time zone geometries based on U.S. Census data were used as parent geometries of the analysis zone areas. This way, all of the origin blocks in each analysis zone are guaranteed to have a single associated time 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. Destination blocks are included based on distance from the boundary of each analysis zone. For pedestrian, bicycle, and transit analyses, all Census blocks whose centroids lie within 37.3 miles (60 km) of the analysis zone are included as destinations. This corresponds to an average speed of 37.3 mph (60 km/h); in 2011, U.S. bus service operated at an average speed of 12.7 mph (20.4 km/h), heavy rail operated at an average speed of 20.0 mph (32.2 km/h), and commuter rail operated at an average speed of 32.7 mph (52.6 km/h). (Dickens, 2013)

For auto analyses, all Census blocks whose centroids lie within (120 km) of the analysis zone are included as destinations. This corresponds to an hour of travel at 74.5 mph (120 km/h), which is at or above the speed limit in most metropolitan areas.

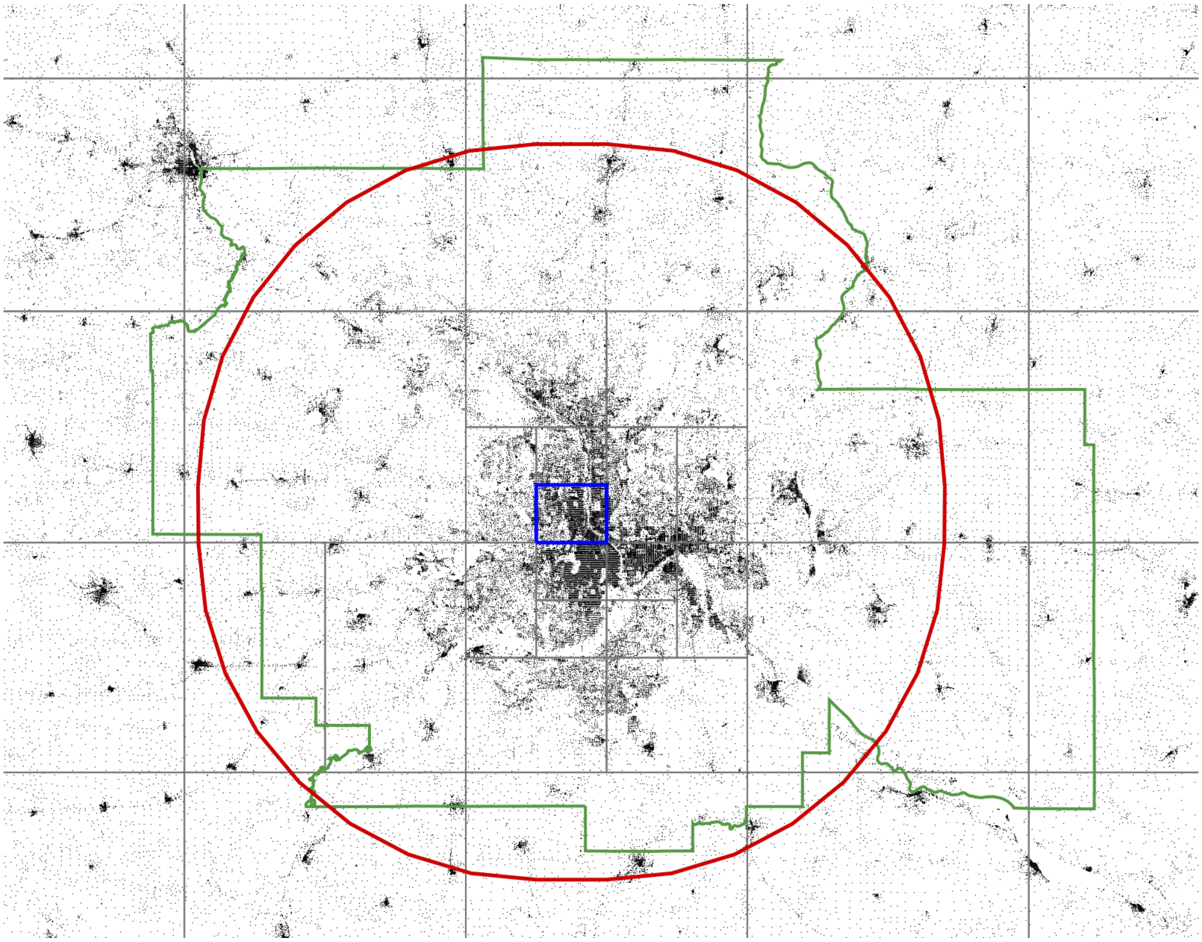

Figure 2-3: Example of the analysis zone structure within an urban area — Minneapolis–Saint Paul, MN. A single origin zone is shown in blue and its corresponding 60-km destination zone in red. Travel times are calculated from each centroid in the origin zone to each centroid in the destination zone.

CHAPTER 3: ACCESS CALCULATION

3.1 OVERVIEW

Destination access evaluations rely on an underlying calculation of travel times. In this project, travel times are calculated for each mode based on detailed network and speeds data, using each Census block as an origin. These travel times are the basis of a cumulative opportunities access measure that counts the number of opportunities (in this case, jobs) that are reachable from each origin within travel times of 5 through 60 minutes, at 5-minute increments. The calculations for each travel mode vary in ways that reflect specific technical differences among them and their data sources; these are described below in Section 3.2.

This block-level cumulative opportunity dataset provides a *locational* measure of access — it indicates how many jobs can be reached from individual Census block locations. This locational measure is then weighted by the number of workers residing in each Census block and averaged across entire metro areas to produce *worker-weighted* access. This metric indicates the job access that is experienced by the average worker in a metropolitan area. This approach can be applied to any aggregation of Census blocks. Finally, the worker-weighted average job access values across the 5- through 60-minute thresholds are averaged for each metropolitan area to produce a weighted job access ranking score used in the *Access Across America* series of reports.

Section 3.3 discusses the cumulative opportunity metric in more detail and describes how it is used to create more nuanced metrics that reflect regional averages, population weights, and annual change.

3.2 TRAVEL TIMES

3.2.1 Software

All travel time calculations are performed using OpenTripPlanner (OTP), an open-source, multi-modal trip planning and analysis tool. OTP provides a multimodal routing system that operates on a unified network including links that represent road, pedestrian, bicycle, and transit facilities and services. OTP is available at http://opentripplanner.org and is described and evaluated by 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. Additionally, locally-developed extensions to OTP allow automated batch processing of access calculations for multiple departure times and origins, as well as organization of analysis zones.

3.2.2 Walk Routing Parameters

Walk access is calculated using pedestrian network data from OpenStreetMap and a constant walking speed of 3.1 mph (5 km/h).

3.2.3 Bicycle Routing Parameters

3.2.3.1 Level of Traffic Stress (LTS)

This project uses a bicycle network classification framework based on the Level of Traffic Stress (LTS) metric to produce job access metrics reflecting different tolerances for bicycle travel stress. LTS a metric used to evaluate how “stressful” a given street or path is to bike on, based on physical attributes of the roadway and any bicycle facilities present. LTS evaluation is outlined by Mekuria et al. (2012) and Furth et al. (2016), and is identified as a data-driven performance metric in Cesme et al. (2017). The LTS classification process uses a variety of roadway characteristics, such as the presence or absence of bicycle facilities, number of motor vehicle lanes, and roadway speeds, and assigns a value of 1 (lowest stress) to 4 (highest stress) to network segments based on these characteristics.

Bicycle access evaluations have been performed previously on low-stress and LTS-labeled networks; Lowry et al. (2016) included a full LTS assignment procedure in Seattle within an access evaluation, and Kent and Karner (2018) analyzed access to banks, supermarkets, pharmacies, and public libraries from neighborhoods in Baltimore, coupled with implementation of 106 different proposed bicycle projects. People for Bikes (2017) built a Bike Network Analysis tool to evaluate bicycle access to a variety of destination types within metropolitan areas on low-stress bicycle networks and performed evaluations in many cities in the United States. The National Accessibility Evaluation includes a few key enhancements beyond earlier and other current work: the evaluation is fully national (i.e., it includes the entire United States, both within and outside of metropolitan areas), and it provides job access metrics for multiple travel time thresholds, rather than selecting a single threshold.

In order to calculate access to destinations by bicycle, on low-stress bicycle routes, the low-stress facilities must first be identified. The bicycle LTS assignment heuristics employed in this study consist of a set of hierarchical classification rules that assign bicycle LTS ranks to both street segments and intersections, based upon OSM tag data; this work is based on previous work by Conway (2015) and People for Bikes (2017).

Limited-access roadways that disallow bicycles, such as interstates, are not considered for routing; only street segments where bicycles are either expressly permitted or not disallowed are considered for the LTS ranking process. Information regarding the type of bicycle facility present is first used, such as the presence of a protected bike lane. As information regarding bicycle facilities, number of lanes, and roadway speeds does not exist for some roadway segments in the OSM database, hierarchical classification of roadways as “primary,” “secondary,” and “tertiary” is used later in the LTS assignment process as a proxy for physical roadway design characteristics that influence LTS rank.

3.2.3.2 Intersections

Intersections are handled in such a way that their LTS rank is dependent upon the LTS ranks of their approaching roadway segments. If an intersection is controlled by traffic signal devices, the LTS rank of the intersection is set to the lowest-stress rank of all approaching roadways; if an intersection is uncontrolled, the LTS rank of the intersection is set to the highest-stress rank of all approaching roadways. This approach acknowledges the importance of complete routing when considering bicycle traffic—that is, a single stressful intersection crossing along an otherwise low-stress route may deter riders from using the facilities.

A dummy category of "LTS 5" is used in the special cases of "motorways" and "motorway links", which designate restricted-access roadways such as interstates, as well as in the rare case of "raceways" — these "ways" should never be routable for bicycles unless explicitly designated, but if another roadway crosses one with a signal, crossing is allowed at the stress factor of the crossing roadway. If there is no signalization, then the "LTS 5" label disallows crossing in all bicycle routing cases.

Intersections are coded in a few different ways in OpenStreetMap, depending on whether an intersection is signalized or not. Traffic signals may or may not be located on the intersection's central node; if not, a proximity search within a 35 meter radius is performed, to determine whether there are nearby signals likely to be associated with the central intersection node. The number of nearby signals, in combination with OSM tag information, allows accurate determination of the signalized status of an intersection in a variety of encoding cases.

3.2.3.3 Departure Times

Travel time calculations for bicycle analysis are performed for one departure time only — noon — as bicycle trips were not modeled to be dependent on departure time.

3.2.3.4 Routing

When applying LTS classification to bicycle access analysis, a maximal LTS tolerance is set — e.g. if a bike trip may be composed of streets and intersections of at most LTS 3, then the routing software may use only facilities classified as LTS 1, 2, or 3. The time cost of travel by bike is composed of a few different components. *Initial access time* refers to the time cost of traveling by foot from the origin to a nearby segment 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 the 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 bicycle travel times. Bicycle travel times vary significantly depending on the maximal LTS tolerance value set, with the routes between some origin-destination pairs becoming very circuitous or impossible at lower LTS values.

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 3.1 mph (5 km/h) along designated pedestrian facilities such as sidewalks, trails, etc. On-bicycle travel time is calculated with an assumed bicycle speed of 11.2 mph (18 km/h). Bicycle travel was also assumed to be insensitive to departure times and the time of day, and thus not subjected to significant congestion effects or other factors that may render bike speeds slower at certain times of day than others. On a bicycle network with significant amounts of separated infrastructure, it is reasonable to assume mixed-traffic congestion during peak periods would have a negligible effect on bicycle travel speed. Without bike infrastructure, bicycle travel times would be negatively impacted by automobile congestion, particularly where lane-splitting is uncommon — however, datasets sufficiently detailed to model this effect are not available at a national scale. Weather and climate effects were also not accounted for, as this study constitutes a snapshot evaluation of bicycle access under conditions when people are most willing to bike.

3.2.4 Transit Routing Parameters

The time cost of travel by transit is composed of several components. Initial access time refers to the time cost of traveling 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. On-vehicle travel time is derived directly from published transit timetables, under an assumption of perfect schedule adherence. 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. Additionally, the access effects of service frequency are reflected by averaging access calculations at each minute over a departure time window.

3.2.4.1 Access & Egress

This analysis makes the assumption that all access portions of a transit trip—initial, transfer(s), and destination—take place by walking at a speed of 5 km/hour along designated pedestrian facilities such as sidewalks, trails, etc.

3.2.4.2 Transfers

An unlimited number of transfers are allowed. This is somewhat unusual among evaluations of access by transit. In many cases trips are specifically limited to those involving no more than one or two transfers; this is justified by the observation that in most cities a very large majority (often over 90%) of observed transit trips involve no more than two transfers. However, the shortest-path algorithms typically employed in these evaluations are single-constraint algorithms: they are guaranteed to find the shortest path only when given a single constraint (typically, travel time). When the available paths are limited based on an additional constraint such as number of transfers (or, in some cases, transfer wait time), these algorithms provide no insurance against a shorter trip, requiring additional transfers, remaining among the restricted paths (Korkmaz and Krunz, 2001; Kuipers et al., 2002).

Given the realities of transit networks, it likely that cases where (for example) a three-transfer itinerary provides a faster trip than a two-transfer itinerary are relatively rare. However, given the goal of evaluating the full access available from a transit system rather than simply the access that is likely to be utilized, this analysis prefers the algorithmically correct approach of using travel time as the single routing constraint and leaving the number of transfers unconstrained.

3.2.4.3 Service Frequency

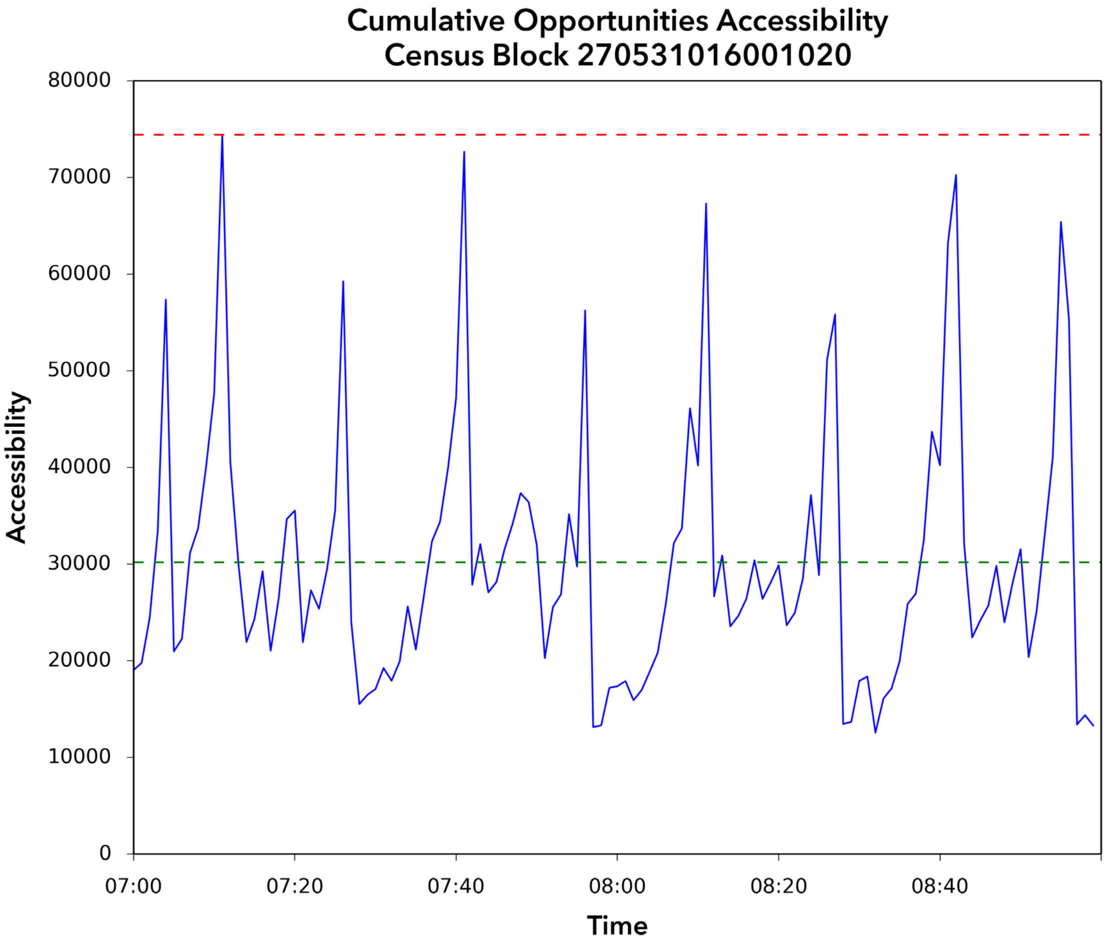

Figure 3-1: Transit access between 7:00 a.m. and 9:00 a.m. for a single Census block. The red line indicates maximum access value; the green line indicates average access value.

Access by transit is strongly dependent on departure time because of the scheduled nature of transit service. For example, if a transit route's service frequency is 20 minutes, then immediately after a vehicle departs all destinations become 20 minutes "farther away." Figure 3-1 illustrates the fluctuations in access at a single Census block in the Minneapolis–Saint Paul, MN metropolitan area between 7:00 and 9:00 AM. This project reflects the impact of transit service frequency in two ways. First, as discussed above, it includes waiting time in shortest-path calculations for transit. Second, travel times are calculated repeatedly for each origin-destination pair using each minute between 7:00 and 9:00 AM as the departure time, and an access value is calculated using each travel time result. The access results are averaged to represent the expected access value that a traveler departing at a random time in this interval would experience. (Owen & Levinson, 2015)

3.2.4.4 Transit + Walking

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 that provides no trips that 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. Thus, for areas without transit service of where GTFS data were not available for actual transit serfice, the transit access results equal the walking access results.

3.2.5 Auto Routing Parameters

The time cost of travel by auto is simple to represent, relative to other modes, and is composed of one primary component — travel time spent driving 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 that the end of an auto trip can be equated with the final destination. The time cost of auto travel on each network segment is dependent on the time of day, and TomTom’s Speed Profile data provide average roadway speed information at a 5-minute resolution. As the OTP routing process traverses the network, speed information is updated every 5 minutes to provide a travel time informed by historical average roadway traffic speed variations. Travel time calculations are repeated for every departure hour at one-hour intervals throughout a 24-hour day. The resulting access values indicate the number of jobs that are reachable when departing on each hour from 12:00 AM until 11:00 PM.

3.3 ACCESS METRICS

Many different implementations of access measurement have been proposed, and many have been implemented to varying degrees of success. 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:

$$A_i = \sum_j O_j f(C_{ij})$$

$A_i =$ access for location i
$O_j =$ number of opportunities at location j

$$C_{ij} = \text{ time cost of travel from } i \text{ to } j$$
$$f(C_{ij}) \; = \; \text{weighting function}$$

The specific weighting function $f(C_{ij})$ used has a tremendous impact on the resulting access 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 access; 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.

3.3.1 Cumulative Opportunities

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

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

$$t \; = \; travel\ time\ threshold$$

Access 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 access evaluation process developed for the Minnesota Department of Transportation. Using the results of the travel time calculations described in Section 3.2, cumulative opportunity access values are calculated for each Census block in each CBSA using thresholds of 5, 10, 15, 20, …, 60 minutes.

3.3.2 Person-Weighted Access

The access calculation methods described in the sections above provide a *locational* access metric—one that describes accessibility as a property of locations. The value of access, however, is only realized when it is experienced by people. To reflect this fact, access 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 access experienced by an average worker in that CBSA. These CBSA-level summaries form the basis of the metro-area comparisons and evaluations found in the *Access Across America* series of reports. This approach can be used to apply the block-level access datasets produced by this project to other statistical areas or population groups.

3.3.3 Weighted Access Rankings

The metropolitan area rankings presented in the *Access Across America* series of reports are based on an average of person-weighted job access for each metropolitan area over all travel time thresholds. In the weighted average of access, 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, travel times are grouped 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 access ranking metric for a single metropolitan area
$a_t =$ Worker-weighted access for threshold t
$\beta = -0.08$

CHAPTER 4: RESULT DATASETS AND REPORTS

The detailed access datasets produced in this project were provided directly to sponsor organizations and used as the basis for the *Access Across America* series of reports. The following sections discuss the structure and format of the datasets and provide links to the *Access Across America* reports.

4.1 DATASETS

4.1.1 Datasets

For each year and each mode, access datasets were assembled for each sponsor organization corresponding to its geographical jurisdiction. Appendix A provides links to all state-level data files.

4.1.2 Data Structure and Formats

The data files provide access records for individual Census blocks. Each record is uniquely identified by its 15-digit "geoid" field, which corresponds to an individual block's GEOID code based on the U.S. Census Bureau's 2010 geography definitions. Data files include a geometry for each record that describes the geographical boundary of the corresponding Census block. This is based on 2010-vintage TIGER/Line data from the U.S. Census Bureau, and is stored in the WGS84 coordinate system. Data are provided for each block that include any amount of land area. Blocks with a land area of zero (e.g. blocks that are entirely water) are omitted.

Data fields within each record identify the origin Census block, the departure time, the maximum travel time threshold, and job access counts for a variety of job categories. These categories correspond to those used by the LEHD LODES employment datasets discussed in Section 2.2.

Appendix B provides detailed data documentation for each evaluation year.

4.2 *ACCESS ACROSS AMERICA* REPORTS

Twelve "Access Across America" reports published during the project provided a national view of job access across the top 50 metropolitan areas by population. These reports provide metro-level summaries and rankings of job access, as well as detailed job access maps for each metro area. Links to each Access Across America report are provided below. Note that while the relevant data were calculated, national reports for walk access were not produced; similarly, a national report for bike access was omitted in 2018 due to timing of the data availability.

- 2015
  - Auto
  - Transit
- 2016
  - Auto
  - Transit

- 2017
    - Auto
    - Transit
    - Bike
- 2018
    - Auto
    - Transit
- 2019
    - Auto
    - Transit
    - Bike

CHAPTER 5: LESSONS AND FUTURE RESEARCH DIRECTIONS

In the process of developing and refining a process for national-scale evaluation of job access, the project team and TAP members identified lessons that can be applied to future destination access evaluation efforts, as well as areas where additional research or development would be useful.

5.1 UNDERSTANDING CHANGES IN ACCESS

The project's core focus was to develop annual datasets that track multimodal access to jobs throughout the U.S. These datasets reveal *how* access changed year-to-year, but do not explicitly identify *why* it changed. Because access reflects both transportation and land use, additional effort is needed to understand whether an observed change in access is due to changes in the transportation network, changes in land use patterns, or both.

In 2018, the project took initial steps in this direction by including both the current and the previous year's land use data in access calculations. When continued over multiple years, this approach provides an opportunity to cross-compare access results by varying a single factor — transportation or land use. Comparing these single-variant results to the actual results allows a simple estimation of the access change that can be attributed to the individual factors.

While these data have been calculated for 2018 and 2019, they have not been rigorously analyzed or reported on. Continuing this line of inquiry could provide useful insights into the relative impact that typical annual transportation network changes or land use changes have on access, and potentially help guide policy or planning decisions.

5.2 INPUT DATA CONSIDERATIONS

Destination access evaluation requires detailed, consistent data describing transportation network and land use patterns, and access results are extremely sensitive to changes in the input data. On two notable occasions, the research team encountered challenges related to input datasets.

Ahead of the 2017 data release, TomTom, Inc. — provider of the road network and speed data — announced a change in its speed data procedures that made its data more accurate. On average, the more accurate speeds were approximately 5% lower than in previous data releases, though the exact magnitude of the change varied widely across location and across roadway types. This speed "decrease" was factored into the 2017 access data results. But because TomTom's data processing change could not be isolated from other factors — real speed changes, road network changes, and land use changes — it was not possible to determine or estimate how much of the annual change in access was due to the data processing change. As a result, the research team decided to omit year-to-year access change analysis from the 2017 report.

In another instance, LODES datasets from the U.S. Census Bureau were changed in 2018 to no longer include federal jobs. The impacts of this change varied across locations; in some cities, federal jobs are a significant share of total employment, while in others they are negligible. In locations with high shares of federal jobs, it again became difficult to appropriately interpret year-to-year access changes.

Carefully selecting and maintaining input datasets will be important in future destination access evaluation work. It is inevitable that input data sources will change in some ways; when this happens, researchers should be cautious in interpreting the resulting access changes.

5.3 ADDITIONAL DESTINATION TYPES

This project focused on evaluating access to jobs. While commute trips are typically reported to be the single largest trip purpose, they do not make up a majority of all trips. Behaviors such as mode choice, residential location choice, and vehicle purchasing depend on the perception of access to a much wider range of destination types. Because of this, it will likely be useful to include additional destination types in future access evaluation efforts. This project's TAP identified education, healthcare, and food/grocery locations as particularly interesting. The access evaluation framework developed in this project is very flexible with respect to destination data — any point data, with optional count values, could be used as the destination dataset. An effort to include additional destination types will need to focus on identifying appropriate data sources.

Additionally, it may be useful to develop or adopt different approaches to summarizing access across different destination types. For jobs, which often number in the hundreds of thousands, it is reasonable to report access as a count of reachable destinations. For destination types where far fewer physical locations each serve the needs of many users, this approach may not be as useful. For example, a metropolitan area might host dozens of high schools. It seems less meaningful to calculate how many high schools can be reached in e.g. 30 minutes — what is the value of the 8th high school that can be reached? Instead, it may be more useful to establish a target number of destinations — say, two high schools — and then evaluate how easy is it to reach that target number. For example, from one location there may be two high schools within 18 minutes by auto, while from another it might take a minimum of 27 minutes to reach two high schools. The first location has better access to high schools; the target number of high schools can be reached at a lower travel time cost.

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APPENDIX A

ACCESSIBILITY DATASET DOWNLOAD LINKS

APPENDIX B
ACCESSIBILITY DATA DOCUMENTATION