DEPARTMENT OF TRANSPORTATION

National Accessibility Evaluation: Phase II

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Accessibility Observatory
University of Minnesota

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Research Report
Final Report 2026-14

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16. Abstract (Limit: 250 words)

This project implements activities for the National Accessibility Evaluation (NAE) pooled-fund study, performing accessibility evaluations describing conditions in 2020, 2021, 2022, 2023, and 2024. The National Accessibility Evaluation creates national census block-level accessibility datasets that can be used by partners in local transportation system evaluation, performance management, planning, and research efforts. The project produced a series of annual reports describing accessibility to jobs by driving, biking, walking, and by transit in metropolitan areas across America.

Accessibility calculations rely on detailed travel-time calculations for both driving and transit, using commercially available, GPS-based speed measurements and published transit schedules. Each NAE partner received digital access to the accessibility datasets covering their jurisdictions. These datasets quantify access to jobs, health care, schools, grocery stores, and other essential destinations. The annual Access Across America reports provide summaries of the detailed job accessibility datasets for the 50 most populous metropolitan areas across America. These reports were released to national and local media outlets and supported by publicity and communications efforts.

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National Accessibility Evaluation: Phase II

Final Report

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Table of Contents

List of Figures

List of Tables

List of Abbreviations

LEHD	Longitudinal Employer-Household Dynamics
NAE	National Accessibility Evaluation
LTS	Level of Traffic Stress
R^5	Rapid Realistic Routing on Real-world and Reimagined networks
OTP	Open Trip Planner
GTFS	General Transit Feed Specification
OSM	Open Street Maps
MPO	Metropolitan Planning Organization

Executive Summary

Accessibility is the ease of reaching valued destinations. The simplicity of the concept (what can one travel to?) belies the complexity of calculation across the dimensions of space (origins, destinations), time (departure time of day, length of travel time), and mode (driving an automobile, walking or rolling, riding public transit, or cycling). In the National Accessibility Evaluation Pooled Fund Study, Phase II, the research team undertook the complex task to make accessibility metrics usable and applicable for state Department of Transportation partners.

In this study we estimate the accessibility to jobs, and to other types of destinations, by first calculating the travel times from each origin block in the US Census (8.2 million origin points), to each potentially reachable destinations (those found within 100km). The travel times are calulcated using open-source software customized and implemented by the research team. Travel times to destinations reachable in 60 minutes are retained in the data.

Travel times are calculated for four major modes: personal auto, bicycle, public transportation, and walking/rolling. Within each mode travel networks are built to reflect the possible pathways available to someone using that mode to reach destinations from their block origin.

Travel times are calculated for multiple times per typical weekday, to account for variability due to observed roadway speeds and congestion (for auto) and variation in transit schedules. Pedestrian and bicycle travel times are assumed to be constant across times of day.

Once travel times are calculated, destination access is quantified at each origin block in one of two ways. Cumulative opportunities are measured as the number of destinations reachable in a certain travel time, e.g. the number of job destinations reachable in 30 minutes travel time. Alternatively, we also calculate so-called dual access by fixing the number of destinations (e.g., three grocery stores) and summarizing the time needed to reach that target by each mode at each origin.

The destination types used for accessibility calculations in this study include:

- Employment
  - Enumerated jobs at each census block by sector
- Education
  - Child care centers
  - Public and Private K-12 schools
  - Post-secondary schools and colleges
  - Libraries & Museums
- Healthcare & Services
  - Primary Care Clinics receiving Medicaid
  - Urgent Care
  - Community Access Hospitals
  - Trauma Care Hospitals

    - Social Security Centers
- Food
    - Grocery Stores accepting SNAP payment
- Entertainment
    - Convention Centers
    - Fairgrounds
    - Major Sports Stadiums
- Intermodal Freight
    - Airports with Cargo Facilities
    - Pipeline terminals
    - Rail terminals and roll-on/roll-off transfer
    - Ports

The five years of Accessibility results produced during this study spanned the prior and recovery preiods around the March 2020 outbreak of the COVID-19 pandemic across the USA. The direct and indirect impacts of COVID included altered travel behavior due to stay-at-home orders, economic changes to job availability and distribution, and especially greatly increased rates of telework. In turn, roadway and transit travel times changed in direct (reduced service) and indirect (decreased use) ways. Year-over-year changes in accessibility from 2020 to 2024 thus capture the evolution of access due to these factors, along with economic changes in job opportunity.

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 desired 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. While there are a variety of ways to define this *accessibility*, the number of destinations reachable within a given travel time is the most comprehensible and transparent — as well as the most directly comparable across places.

Accessibility 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 accessibility access across multiple metropolitan and rural areas, by a variety of modes. Some transportation agencies have also begun using access evaluation in their project selection and prioritization processes.

This pooled fund project implemented multiple measurements of accessibility, including access to jobs and access to other types of essential destinations, 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 every Census block, travel times were estimated to additional specific destination types in the categories of health care, education, services, entertainment, and freight. This combined evaluation produced detailed job accessibility datasets covering 2020 through 2024, and access to essential destinations in travel years 2022 through 2024. A series of annual reports summarizing the access datasets for each participating state DOT, as well as summaries by modes for metropolitan areas across the country were produced. Access to jobs data for transit, driving, and biking are available for all five years, while walk access to jobs data are available for 2022-2024.

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, including download links, and Chapter 5 discusses lessons learned and considerations for future accessibility evaluations and research.

1.1 Impacts of COVID-19

Beginning in March 2020, the worldwide COVID-19 pandemic strongly impacted daily travel throughout the U.S., as stay-home orders and business closures changed commutes. The data series created by the NAE (Phase I and this Phase II) spans the time before, during, and after the pandemic began and subsided. Thus this project traced the evolution of impacts, direct and indirect, of travel behavior changes resulting from COVID-19, as well as measuring the longevity of these changes. Impacts on auto access (mediated by changes in congestion) and transit access (mediated by changes in service provision) were especially notable.

Chapter 2: Data Sources

Effective calculation of destination access metrics relies on components of three data categories: origins, networks, and destinations. The details of each data source, the set of which differs by mode and access type, are described here.

2.1 Origin Data

2.1.1 Geography of origins

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. This project uses the geography definitions established for the 2010 decennial census for the 2020 and 2021 travel years (calculated before updated decennial census data were available), and 2020 decennial census information for the 2022 – 2024 travel years.

2.1.2 Residential worker populations at origins

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).[1] The LEHD Origin-Destination Employment Statistics (LODES) dataset, which is updated annually, provides Census block-level estimates of the number of workers residing in each place. These data are used to person-weight the access calculations. Due to the time needed to process and release LODES data by the Census, the residential worker estimates lag the travel year by two stated calendar years (e.g. the 2023 travel year uses 2021 LODES data).

2.2 Network Data

Network data represent the potential connections travelers can make from their origins to destinations. The digital representation of these connections differs by mode, and in some cases involves multiple modes, such as with pedestrian and transit network information.

[1] https://lehd.ces.census.gov/data/

2.2.1 Pedestrian network

Data describing the pedestrian network across the country were obtained from OpenStreetMap (OSM)[2], an open-access online database of transportation network structures, maps, and other spatial information. OSM 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 annually from OSM as existed in January of the travel year. 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.

2.2.2 Bicycle networks and Level of Traffic Stress

Data describing the bicycle network across the country were obtained from the same OSM extract used for the pedestrian network. 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 bicycle network elements include OSM tag data, which describe attributes such as the presence of bike lanes or off-street facilities. These tags are used as the basis for LTS classification described in 3.3.2.1

2.2.3 Transit routes and schedules

The ability to reach destinations via transit is heavily influenced by the transit service, in particular the geographic coordination between transit stops and destinations, but even more importantly the frequency with which vehicles serve stops, and speed of the transit vehicles. All of this information is captured in the detailed transit schedules. An industry standard format called GTFS[3] organizes the detailed schedule of a transit provider into machine-readable files useful for trip routing. These are published to allow apps (websites, mobile phone maps) to provide trip planning to customers, but they are similarly useful for calculating travel times to many destinations, as we use them here.

For each travel year in the dataset, we collected GTFS feeds using the curated service TransitLand.[4] We collected all published feeds from U.S. transit agencies with service during the appropriate year. By the 2023 travel year this was well over 1000 individual schedule feeds. Feeds are run through quality control checks using a validator provided by GTFS.org, and through custom code to ensure the service being provided on the travel date is the highest weekday service available.

[2] https://www.openstreetmap.org

[3] https://gtfs.org/

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

Transit schedules change often. For consistency of calculating travel times via walk and transit, schedules are downloaded that correspond to the service offered on the Wednesday in the third week of January. 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.

2.2.4 Road network and segment 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 travel year, which reflects speed sample data collected by GPS devices over the preceding 24 months. For instance, the speeds used in the 2023 calculations reflected conditions averaged over June 2021 – June 2023, meaning reductions to peak congestion due to the influence of the COVID-19 pandemic might be stronger than would be expected using other sources. For road segments where speed data are provided separately for different days for the week, data for Wednesday are used.

2.3 Destination Data

2.3.1 Jobs destinations

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).[5] The LEHD Origin-Destination Employment Statistics (LODES) dataset, which is updated annually, provides Census block-level estimates of the number of jobs located in each workplace. These jobs are assigned to the centroid of the containing census block shape, and used as destinations. Due to the time needed to process and release LODES data by the Census, the residential worker estimates lag the travel year by two stated calendar years (e.g. the 2023 travel year uses 2021 LODES data).

2.3.2 Essential destinations

While jobs data contain locations of economic activity and include many types of destinations, it is important for agencies to consider particular categories of destinations when evaluating how well the transportation system is connecting residents to their needs. Here we examine a set of "essential" destinations, all of which have consistent and national coverage, and are publicly available.

[5] https://lehd.ces.census.gov/data/

2.3.2.1 Health care

RURAL HEALTH CLINICS

As defined by the Center for Medicare and Medicaid Services, a rural health clinic is a clinic located in a rural area designated as a shortage area, is not a rehabilitation agency or a facility primarily for the care and treatment of mental diseases. RHCs operate exclusively for the purpose of providing primary care services to Medicare patients located in rural and shortage areas. This dataset is a subset extracted from the CMS Approved Facilities ArcGIS REST Server.

FEDERALLY QUALIFIED HEALTH CENTERS

A Federally Qualified Health Center (FQHC) is a reimbursement designation from the Bureau of Primary Health Care and the Centers for Medicare and Medicaid Services of the United States Department of Health and Human Services. FQHCs provide primary care services and dental care services to rural/urban areas and shortage areas. This dataset is a subset extracted from the CMS Approved Facilities ArcGIS REST Server.

URGENT CARE

Urgent care is defined as the delivery of ambulatory medical care outside of a hospital emergency department on a walk-in basis without a scheduled appointment; does not include locations co-located within hospitals.

TRAUMA CENTERS

Generally, a trauma center is a unit within a hospital that is equipped and staffed to provide care for patients suffering from major traumatic injuries. Trauma center levels range from I (most capable) to IV.

2.3.2.2 Education

CHILDCARE SERVICES

The dataset only includes center-based child day care locations (including those located at schools and religious institutes) and does not include group, home, and family-based child day cares.

K-12 PUBLIC SCHOOLS

All public schools (K-12) in the United States as defined by the U.S. Department of Education. Schools were filtered by the status field to only include schools that are currently operational: School was operational at the time of the last report and/or is currently operational.

K-12 PRIVATE SCHOOLS

A private school is not supported primarily by public funds, provides classroom instruction for one or more of grades K-12 or comparable ungraded levels, and has one or more teachers. Organizations or institutions that provide support for homeschooling without offering classroom instruction for students are not included. Schools were filtered by the status field to only include schools that are currently operational: School was operational at the time of the last report and is currently operational.

POST-SECONDARY SCHOOLS

Contains data about every college, university, and technical and vocational institution that participates in the federal student financial aid programs. Specifies whether the institution has less than 2 year, 2 year, 4 year, or 4 year or higher program offerings.

LIBRARIES

The Public Libraries Survey (PLS) provides comprehensive annual data on public libraries across the United States, offering insights into how library services adapt to meet public needs. Libraries from all 50 states, the District of Columbia, and U.S. territories. Approximately 9,000 public libraries and 17,000 individual outlets, including main libraries, branches, and bookmobiles.

MUSEUMS

The Museum Data Files consist of locations categorized by museum discipline. This dataset provides categorized records of various types of museums and cultural institutions. The three disciplines are: (1) Art, history, science and nature; (2) General museums; (3) Historical societies and historical preservation.

2.3.2.3 Food & Services

SNAP RETAILERS

The Supplemental Nutrition Assistance Program (SNAP) is a federal program that provides nutrition benefits to low-income individuals and families that are used at stores to purchase food. The program is administered by the USDA Food and Nutrition Service (FNS) through its nationwide network of FNS field offices. Local FNS field offices are responsible for the licensing and monitoring of retail food stores participating in SNAP. This dataset uses SNAP retailer location data.

SOCIAL SECURITY ADMINISTRATION OFFICES

Field offices where public services were provided, as of 2023.

2.3.2.4 Entertainment

MAJOR SPORTS VENUES

Facilities within the United States, Canada, and Mexico that host events for the National Association for Stock Car Auto Racing (NASCAR), Indy Racing League (IRL), Major League Soccer (MLS), Major League Baseball (MLB), National Basketball Association (NBA), Women's National Basketball Association (WNBA), National Hockey League (NHL), National Football League (NFL), Professional Golfers Association

(PGA) Tour, National Collegiate Athletic Association (NCAA) Division 1-Football Bowl Subdivision (FBS), National Collegiate Athletic Association (NCAA) Division 1 Basketball, Minor League Baseball (MiLB) Class Triple-A, and thoroughbred horse racing.

FAIRGROUNDS/CONVENTION CENTERS

Locations of convention centers, conference centers, exposition centers, and fairgrounds for the 50 US States, the District of Columbia, and the territory of Puerto Rico, large enough to house a convention, trade show, or fair.

2.3.2.5 Freight

AIRPORTS WITH CARGO FACILITIES

The Airports dataset includes all official and operational aerodromes and is part of the U.S. Department of Transportation (USDOT)/Bureau of Transportation Statistics (BTS) National Transportation Atlas Database (NTAD).

MARINE ROLL-ON/ROLL-OFF (RORO)

Every facility is associated with a port served by both marine and truck, and those facilities which support rail operations, the reporting code for the operating rail company is also identified.

RAIL TOFC/COFC

Trailer on flat car / Container on flat car facilities. Every facility is assumed to be served by both rail and truck, and those facilities which support port operations, the name of the port is also identified. The dataset also includes the services provided at each facility (TOFC only, COFC only, or both TOFC and COFC), and the Station Point Location Code (SPLC) associated with the rail facility. This dataset is one of several layers in the Bureau of Transportation Statistics (BTS) Intermodal Freight Facility Database.

PIPELINE TERMINALS

Pipeline terminals interface between pipeline mode and other transportation modes. They have the ability to receive or deliver freight commodities via pipeline and truck/rail/water. The data consists of location information, truck/rail/water mode connections, storage capacity, and a list of commodities handled at the terminal. Geographical coverage includes the United States and U.S. territories.

PRINCIPLE PORTS

The Major Ports are politically defined by port limits or Corps projects, excluding non-Corps projects not authorized for publication. The determination for the published Major/Principle Ports is based upon the total tonnage for the port for the particular year; therefore the top 150 list can vary from year to year. These data show Major Ports in 2016. The Principal Port dataset contains USACE port codes, geographic locations (longitude, latitude), names, and commodity tonnage summaries (total tons, domestic, foreign, imports and exports) for Principal USACE Ports.

Chapter 3: Access Calculations

3.1 Overview

3.1.1 Methods changes by year

As the NAE Phase II progressed, changes to capabilities of software, expertise of staff, and goals of efficiency led to changes in how access was calculated. The full calculation approaches are described in the following sections. Table **{XX}** provides a summary of the methods for each data year in Phase II. In addition to slight changes in expected travel times by using a different routing software package beginning in the 2022 travel year, the methods for calculating transit access became different as well.

Table 3.1 Key access calculation methods changes by NAE travel year

Travel year	Auto routing software	Walk/bike/transit routing software	Transit job access metric
2020	OTP*	OTP*	Average job access of 120 measurements 7 – 9am
2021	OTP*	OTP*	Average job access of 120 measurements 7 – 9am
2022	OTP*	R^5	Job access at 15th percentile of 120 travel times 7 – 9 am
2023	OTP*	R^5	Job access at 15th percentile of 120 travel times 7 – 9 am
2024	OTP*	R^5	Job access at 15th percentile of 120 travel times 7 – 9 am

* Accessibility Observatory custom fork of Open Trip Planner v1

3.2 Software

To calculate access data for each origin, we used a two-step process. First, travel times are calculated from each origin to all reachable destinations in the destination set (reachable within 60 minutes of total travel time on the given mode). Second, access metrics are developed from the travel time matrix (see Section 3.4). The software used to calculate travel times is called a "routing engine" and we utilized two:

Open Trip Planner, and R^5. Both are java-based compiled software that take in representations of networks, origins, and destinations, and return the appropriate travel times from each origin to each reachable destination given a set of parameters about the trip.

3.2.1 Open Trip Planner

All auto, and 2020-2021 walk/bike/transit 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 v1.5 is available at https://github.com/opentripplanner/OpenTripPlanner/releases/tag/v1.5.0 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 R^5

All travel time calculations for walk, bike, and transit modes for travel years 2022-2024 are performed using the Rapid Realistic Routing on Real-world and Reimagined networks, or R^5. R^5 is available at https://github.com/conveyal/r5 and is provided as an open-source engine by Conveyal, commercially available accessibility calculation software. We used R^5 version **X.X** for the calculations 2022-2024 to maximize comparability and consistency in output from year to year.

3.2.3 Python, git, GitHub

Data processing, handling, aggregation, and interface with the routing engines was handled using custom functions developed in python v13, packaged into custom modules, developed and deployed collaboratively using git and GitHub repositories.

3.3 Travel time calculations

3.3.1 Pedestrian routing parameters

Walk travel times is calculated using pedestrian network data from OpenStreetMap (see 2.2.1) and a constant walking speed of 3.1 mph (5 km/h). The same speed and input networks were used in OTP and R^5 routing.

3.3.2 Bike routing parameters

3.3.2.1 Level of Traffic Stress

This project uses a bicycle network classification based on the Level of Traffic Stress (LTS) framework to produce job access metrics reflecting different tolerances for bicycle travel stress. LTS a way 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.

3.3.2.2 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.

3.3.2.3 LTS 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.

3.3.3 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 egress 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 summarizing calculations at each minute over a departure time window.

3.3.3.1 Transit stop access and egress

This analysis makes the assumption that all walk and roll portions of a transit trip—initial, transfer(s), and destination—take place by walking at a speed of 3.1 mph (5 km/hour) along designated pedestrian facilities, equivalent to the pedestrian travel time parameters in 3.3.1.

3.3.3.2 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.

3.3.3.3 Handling service frequency

Unlike the other modes considered here (walking, biking, driving), transit trips face a time-coordination problem between the traveler and the vehicle. A traveler can depart their origin at any time, but upon arriving at a transit stop, must await the departure of the next appropriate vehicle. In the meantime, the travel time clock is progressing towards the 60 minute limit. How well the coordination is performed can have large impacts on the resulting access (Figure 3.1).

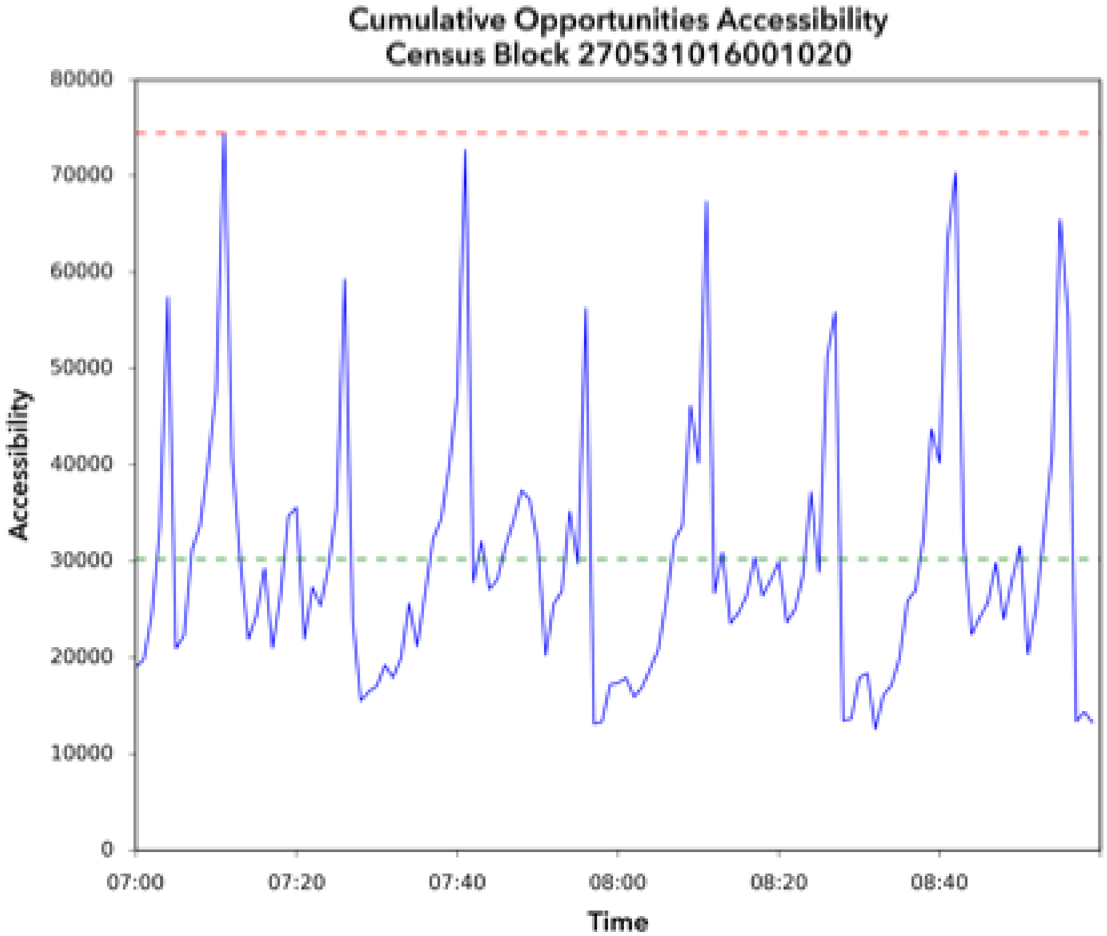

Figure 3.1 Transit access between 7:00 a.m. and 9:00 a.m. for a single Census block. The top (red) dashed line indicates maximum access value; the bottom (green) line indicates average access value.

To account for this, two approaches which differ slightly were used over the course of the project. In 2020-2021, using the OTP router, transit travel times were 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 were averaged to represent the expected access value that a traveler departing at a random time in this interval would experience (Owen & Levinson, 2015). In the 2022-2024 data years, the R^5 router was used to calculate travel times repeatedly for each origin-destination pair departing each minute between 7:00 and 9:00 AM. These values are reduced to a single representative travel time between each origin-destination pair, and an access value calculated from that single representation. In testing consistency across methods and routers, we found it best to use the 15th percentile fastest travel time as the single representation between each origin-destination pair. The represents something like the expected access value of a traveler who departed their origin with knowledge of the transit schedule.

3.3.3.4 Transit access without using transit vehicles

Just as there is no upper limit on the number of vehicle boardings, there is no lower limit either. Transit and walking or rolling 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 service, the transit access results equal the walking access results.

3.3.4 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 destination. 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.

3.4 Access metric calculations

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
$C_{ij} =$ time cost of travel from i to j

$$f\left(C_{ij}\right) \; = \; \text{weighting function}$$

The specific weighting function $f\left(C_{ij}\right)$ used has an impact on the resulting accessibility 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.

3.4.1 Cumulative job 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:

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

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

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 3.3, cumulative opportunity access values are calculated for each Census block using thresholds of 5, 10, 15, 20, …, 60 minutes.

3.4.2 “Dual” access metrics

In contrast to cumulative measures of job accessibility (El-Geneidy and Levinson 2006), quantifying the access to particular types of destinations requires a different approach. Cui and Levinson (2019) recommend the name “Dual Access” for the approach of fixing the number of destinations and estimating the travel time to reach them. This inverts the cumulative measurement by fixing the destinations rather than the travel time:

$$A'_i \; = \; max\ Q_{ij}C_{ij}$$

that satisfies

$$\min_{Q} \sum_{j} O_j Q_{ij} C_{ij}$$

subject to

$$\sum_j O_j\, Q_{ij} \geq \Omega$$

$$Q_{ij} \in \{0,1\}$$

where

A'_i = dual access for location *i*

O_j = the number of opportunities in destination *j*

Q_{ij} = cells in incidence matrix Q: 1 if destination *j* is included in the category set; 0 otherwise

C_{ij} = time cost of travel from *i* to *j.*

In other words, the dual measure finds the cost of the farthest destination in the set of "nearest" (lowest cost) destinations that contain desired opportunities.

The key decision in calculating dual metrics is how many potential destinations should be considered as part of the evaluation set. These could differ strategically by destination type, reflecting the ability of travelers to choose specific opportunities. For instance, performance of the system might be evaluated by travel time to the nearest trauma center hospital, but a school travel metric might want to consider a choice set of public elementary schools. To accommodate the flexible use of the dual metrics, the data provide the travel time to the 5th nearest location for each category from each origin block, or the maximum number reachable in 60 minutes of travel time, whichever is greater.

3.5 Aggregations of metrics

3.5.1 Person-weighting

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.

For dual access metrics, because they are measured in time rather than number of jobs, it is suggested to use the median (50^{th} percentile) as a statistical descriptor of typical access. The aggregated dual access at any area will be the population-weighted median of the travel time to the *N*th closest destination, where *N* is a specified parameter. This is interpreted as the access experienced by the typical resident of the area, where half have faster travel times, and half have longer travel times.

3.5.2 Time-weighted 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: Data 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

The datasets produced by this project include data provided to partners in the pooled fund study, and data generated for broader research use, especially in the Access Across America reports. The data deliverables discussed below use Minnesota (MnDOT) as an example, though equivalent datasets were provided to each partner.

4.1.1 Data structure and format

4.1.1.1 Access to jobs by origin block

Geospatial data files combine geometry (shape) information with attributes of interest. The main data provided to each state is the complete access data for that travel year, reported per individual Census block. Each record is uniquely identified by its 15-digit id field, which corresponds to an individual block's GEOID code based on the U.S. Census Bureau's 2010 or 2020 geography definitions. Data files include a geometry for each record that describes the geographical boundary of the corresponding Census block. This is based on 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 travel time threshold, and job access counts for a variety of job categories reachable in that travel time for that mode at that departure time from that origin block. The job categories correspond to those used by the LEHD LODES employment datasets discussed in Section 2.3.1 These geospatial data files are delivered one for each mode, in each travel year.

4.1.1.2 Summary and express datasets

To facilitate ease of use and creation of summary information, additional processing and aggregation produces two other categories of job access data. Summary tables that are created in the reporting (see Section 4.2) are also delivered as stand-alone data products. For instance, a table of the person-weighted average jobs reachable by travel time threshold within each MPO that intersects Minnesota is included in the report, and also as a stand-alone table.

Express datasets take a single jobs variable (total jobs) and summarize cumulative access to those jobs for each mode, departure time, travel time threshold, and network. These data are shared in non-spatial form but with the spatial identifier to match the Census geography. For instance, Minnesota access to total jobs via bicycling on LTS 2 networks is reported in an express table at the block level, but also weighted according to residential workers in each block, to be the average job access at the block group, tract, county, and overall state access.

4.1.1.3 Access to essential destinations (dual access)

Dual metrics capture travel times from each origin block to different destination categories. These data are delivered in tabular, non-spatial form. Each record is of a block-destination category combination, along with a cumulative order. For the order 1 through 5, the travel time in minutes is reported for that mode from that block to that destination type. For instance, the 3rd grocery store can be reached in 13 minutes, the 4th in 20 minutes, and the 5th in 44 minutes from the indicated origin block using the indicated mode. Where there are not 5 examples of each category reachable in 60 minutes, only the number reachable are included in the dual data table. One table is produced per state per mode per travel year of evaluation.

4.2 State reports

Partner states receive annual reports which summarize their jurisdiction in terms of job access overall, and within the counties of the state, and the MPOs which are in or intersect the state. One report is issued per mode per reporting year, to accompany the data delivered to the state partners. An example of a state report for Minnesota for one mode in one year is given in Appendix B.

4.3 Access Across America reports

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. In reporting years 2020 and 2021 there were Access Across America reports published for auto, transit, and bike; in years 2022-2024 there were annual reports for auto, transit, bike, and walk access. Links to each Access Across America report can be found at https://www.cts.umn.edu/programs/ao/aaa.

Chapter 5: Lessons and Future Research

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 the impact of COVID-19 and aftermath

Beginning in March 2020, the worldwide COVID-19 pandemic strongly impacted daily travel throughout the U.S., as stay-home orders and business closures changed commutes. The data series created by the NAE (Phase I and this Phase II) spans the time before, during, and after the pandemic began and subsided. Thus this project traced the evolution of impacts, direct and indirect, of travel behavior changes resulting from COVID-19, as well as measuring the longevity of these changes. Impacts on auto access (mediated by changes in congestion) and transit access (mediated by changes in service provision) were especially notable.

Measuring access to jobs by auto provides a view into how the congestion impacts have differed across areas. Where in pre-COVID times congestion limited jobs accessible in 30 minutes by auto in the AM peak period, in 2021 (the first full COVID-era time period measured in this study) access to jobs soared in all of the top 50 urban areas (Figure 5.1). As daily travel increased again in the 2022 travel year and beyond, the average access declined differently in different urban areas. Some returned almost immediately to pre-COVID levels; others declined much less and had accessibility gains over 2019 through the 2023 travel year.

The transit time series tells a slightly different story (Figure 5.2). As the COVID-19 pandemic erupted, many transit agencies were forced to alter service and even reduce capacity to maintain social distance, rules that remained in place well into 2022. At the same time, the drop in regular commute ridership precipitated a financial challenge due to fare revenue loss. While emergency federal funding solved the problem temporarily, the long-term challenge (and other challenges, such as in hiring and retaining drivers and mechanics) led agencies to reduce service offerings over time during the COVID era. Because of the importance of frequency in supporting access, the result has been a decline in access to jobs via transit overall since 2021.

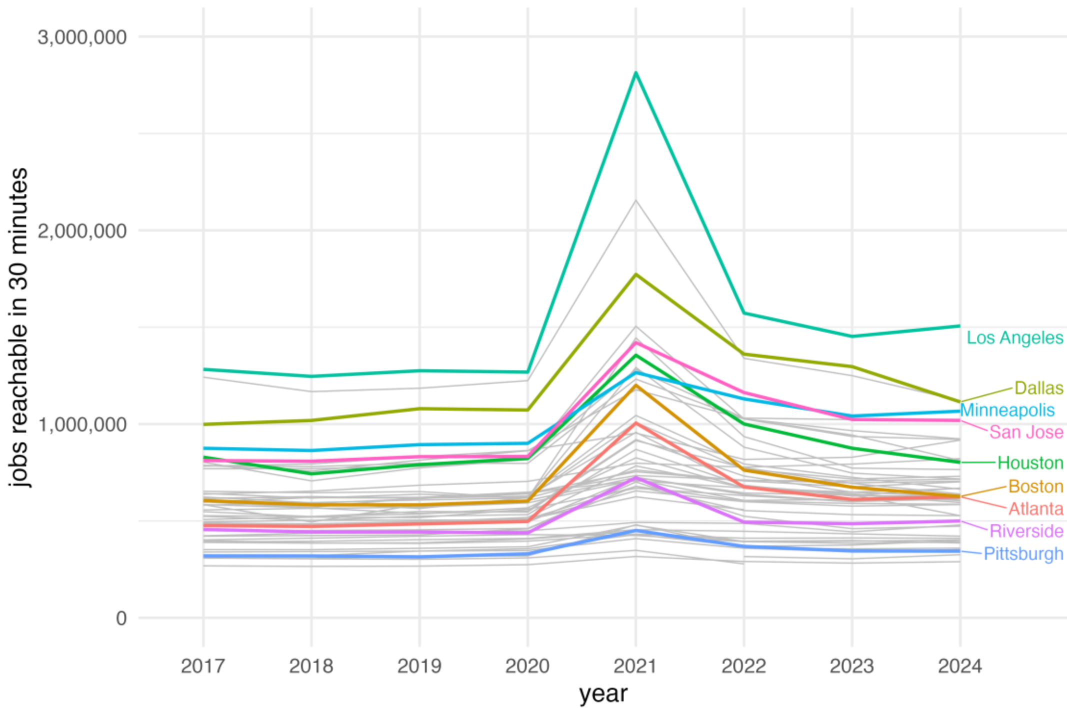

Figure 5.1: Impact of the COVID-19 pandemic through changes in travel behavior and congestion on auto access to jobs in 30 minutes, top 50 U.S. urban areas. Lines represent time series of individual CBSAs, with examples highlighted.

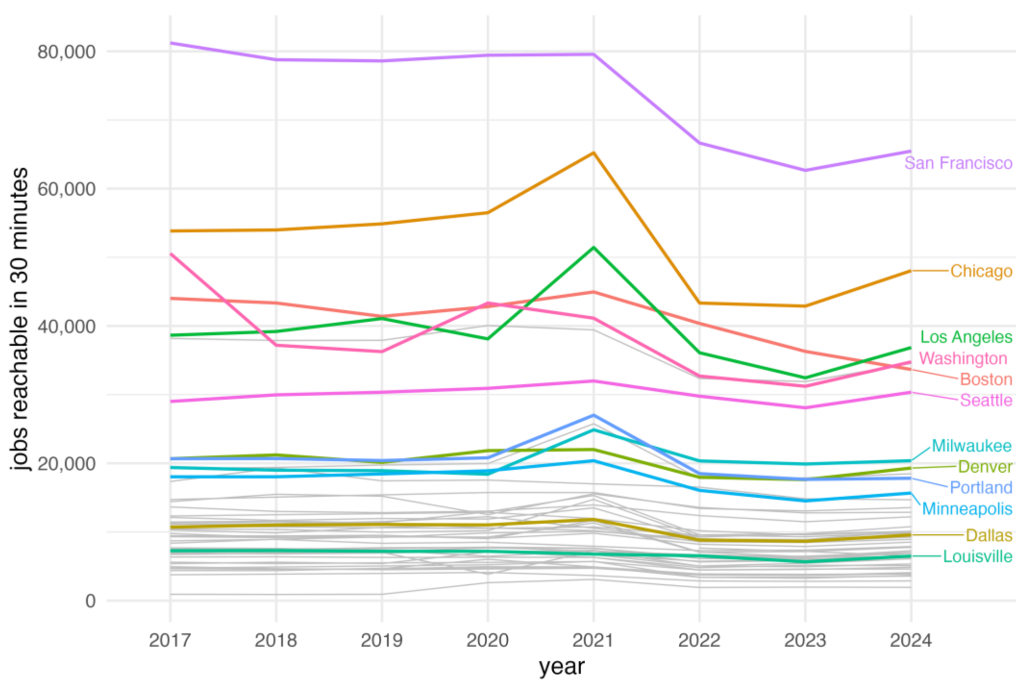

Figure 5.2: Impact of the COVID-19 pandemic through changes in travel behavior and congestion on transit access to jobs in 30 minutes, top 50 U.S. urban areas. Lines represent time series of individual CBSAs, with examples highlighted. New York City urban area is omitted to ensure a comparative scale.

5.2 Effectively using dual access metrics

While collecting the appropriate input data and constructing the data pipeline to produce travel time dual access metrics was a large effort, in some ways it was more straightforward than the application of the resulting data. Any set of geographic points with a description of what kind of place it is, can be used to generate cumulative or dual access metrics. How should the resulting information be used?

One effective way to isolate the impact of transportation in broader research questions is to pair a domain-specific set of outcome data to the corresponding travel times which might influence those outcomes. Do people with longer travel times to hospitals have worse health outcomes? Are students with lower access to multiple school options more likely to end their formal schooling earlier? These and other related questions can help bring context to what it means to have a travel opportunity available to someone.

Another use is in constructing metrics for transportation-land use evaluation. Dual metrics can be used either to evaluate whether certain needs are being met in a reasonable time (a binary, yes/no score), or to evaluate many potential destinations together in a sort of index. One popular conception of the former approach is in the "fifteen minute city," where walk or bike travel times to a set of key destinations are evaluated and if all the desired categories can be reached, that origin is included in the designation. This requires decisions about what the key destinations are, and whether having one or more destinations unavailable truly invalidates the entire description of a high-access place. On the other hand, indexes such as a "walk score" can combine the travel times to particular destinations or destination sets, to give a relative performance of an origin in multiple destination categories. While useful to have a single representative number for scoring locations, the index approach done well requires external information about the expectations and priorities of residents for whom the access measurements are supposed to apply. In all the above cases, it is critical to understand that the calculation of travel times from origins to destinations only begins the evaluation process. Expertise of planners and experience of residents and others must be included to maximize the utility of the data.

5.3 Comparing access to opportunities with observed travel

Access metrics describe what is *possible* for travelers to reach from their origin. There are a number of advantages to evaluating the transportation and land use systems this way. Most importantly, transportation agencies have much more control over what opportunities are accessible, than they do over which of those opportunities people choose to utilize. However, understanding how people do travel can inform planning and performance management at agencies as well. With the rise of high-frequency, granular trip data from commercial providers, there is a new research area combining access and observed trip making. Most fundamentally, how does the number or type of opportunities predict the day to day travel of residents? Do these differ by mode, or by destination? Combining or fusing granular trip making data with granular access metrics promises to reveal new insights for transportation agencies in the years ahead.

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Appendix A
Accessibility Data in UMN Data Repositor

The table below provides descriptions of the publicly available datasets produced by the National Accessibility Evaluation. These datasets are archived in the University of Minnesota Digital Conservancy and can be found at the permanent collection address https://hdl.handle.net/11299/200592.

Travel year	Mode	Geographic span	Content
2020	Auto	Top 50 Urban Areas	Total job accessibility by block for the top 50 US Urbanized areas
2020	Transit	Top 50 Urban Areas	Total job accessibility by block for the top 50 US Urbanized areas
2020	Biking	Top 50 Urban Areas	Total job accessibility by block for the top 50 US Urbanized areas
2021	Auto	NAE partner states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2021	Transit	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2021	Biking	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2022	Auto	NAE partner states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2022	Transit	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2022	Biking	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2022	Walk	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2023	Auto	NAE partner states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2023	Transit	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2023	Biking	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2023	Walk	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2024	Auto	NAE partner states	Total jobs accessible at Census block, and weighted averages for Census hierarchy

2024	Transit	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2024	Biking	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy
2024	Walk	All U.S. states	Total jobs accessible at Census block, and weighted averages for Census hierarchy

Appendix B

Example State Report: MN 2024 Auto Accessibility

https://ao-nae-reports-2024.s3.us-east-2.amazonaws.com/state_reports/auto/MN-2024-Auto-Accessibility-Report.pdf