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Metropolitan Chicago Accessibility Mapping Project

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Metropolitan Chicago Accessibility Mapping Project

Final Report

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Disclaimer

Metric Conversion

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
		LENGTH		
in	inches	25.4	millimeters	mm
ft.	feet	0.305	meters	m
yd.	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		VOLUME		
fl. oz.	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
		NOTE: volumes greater than 1000 L shall be shown in m^3		
		MASS		
oz.	ounces	28.35	grams	g
lb.	pounds	0.454	kilograms	kg
T	Short tons (2000 lb.)	0.907	megagrams (or "metric ton")	Mg (or "t")
		TEMPERATURE (exact degrees)		
^oF	Fahrenheit	5 (F-32)/9 or (F-32)/1.8	Celsius	^oC

Technical Report Documentation

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Metropolitan Transportation Support Initiative (METSI)

Metropolitan Chicago Accessibility Mapping Project

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Contents

1 Introduction

Accessibility refers to the ease with which one can reach opportunities. It combines measures of mobility and land use and allows us to see what people can get to rather than how far or with what speed they can travel. Though accessibility and mobility are related ideas, they are not synonymous. As Handy (2002) points out, places of high mobility may have low accessibility on account of the built environment and places of high accessibility may have low mobility on account of substantial congestion. In addition to land use and mobility factors, accessibility measures can also include temporal and individual dimensions as pointed out by Geurs and VAn Wee (2004).

There are various reasons to study accessibility. One is the view that it is not mobility per se that should be the focus of transportation policies but the activities that can be reached. The view of travel as a derived demand is consistent with this view —why travel except for what you are trying to get to? Policy thus should focus on connecting users to as many opportunities as possible rather than focusing on the mobility aspects of travel alone. This forces us to think about not just the transportation system, but also about land use and how the two work in tandem (see for example, Tilahun and Fan (2014) for an application).

There are also other important reasons for studying accessibility. Several authors have looked at accessibility and labor market outcomes and found a connection, particularly for lower income households. Though evidence is mixed, many have found some aspects of accessibility to be related with employment outcomes (e.g. Sanchez (1998); Thakuriah and Metaxatos (2000); Berechman and Paaswell (2001); Kawabata (2003); Ozbay et al. (2006), reduced welfare usage (e.g. Blumenberg and

Ong (1998)), differences in employment rates (e.g. Ihlanfeldt and Sjoquist (1990); Ihlanfeldt (2006)), as well as with commute outcomes (e.g. Levinson (1998)).

A regional look at accessibility allows us to understand urban areas as experienced by their residents. Questions about what activities can be reached by residents of a specific neighborhood in reasonable time by a given mode; changes to accessibility over the course of a day as transit systems adjust their schedules to demand; the spatial equities (or inequities) of transportation availability; as well as changes to accessibility over time as jobs and residences shift or as transportation networks change and whom these changes impact can all be visualized in ways that are easily understood.

In summarizing the different ways of measuring accessibility, El-Geneidy et al. (2006) identify five methods —the cumulative opportunities measure, the gravity type accessibility measure, utility based accessibility measures, constraints based measures, and composite measures. Each measure offers advantages (and disadvantages). Particularly focusing on the first three, one can see that the cumulative measure is the simplest and has the advantage of being easily interpretable. The gravity based measure appropriately discounts opportunities that are further away than closer ones with meaningful impedance/cost measures. The utility based measure has strong theoretical foundations and allows the analyst to attach values to accessibility in a way the other methods don't. As one moves from cumulative measures to others, the intuitive interpretation of the accessibility numbers declines and complexity of the measurement process increases.

Our goal in this project is to provide an online platform that allows users (planners, transportation professionals, policy analysts, etc.) to measure accessibility for the metropolitan area of Chicago and to present the information in the most easily interpretable fashion. We thus adopt the cumulative opportunities measure as our main tool for the measurement of accessibility. This measure reports counts, area, etc. of different opportunities or land uses that can be reached from every origin in the region within some pre-specified travel times (for example, how many manufacturing jobs can you reach within a 30 minute travel time of a given location?). The measures are simple and easily understood. They are presented for a range of opportunities (jobs, parks, schools, groceries, etc.), and at different time thresholds (ranging from 5 minutes to 60 minutes). For transit systems, accessibility is measured for different times of day, reflecting changes in service. Weighted accessibility measures are also presented that reflect the level of resident car ownership at origins. The presentation of the information also allows users to collect data from their location of interest by simply pointing their cursor at it. The goal is to enable a view of accessibility that can be as macro or as detailed as the analyst wishes it to be.

To enable this, a variety of tasks have been undertaken ranging from developing measures of travel time for all origin destination pairs in the metropolitan region for automobile, transit and walk modes, to collecting data from a variety of agencies about land use, and integrating them using a variety of open source tools that are available for organizing as well as presenting this information. In the next section, we will discuss the methodology that was followed in more detail. Section 3 discusses the technical details of implementation as well as the data sources. Section 4 discusses the final product. Finally, section 5 presents future plans for the Metropolitan Chicago Accessibility Explorer[1].

[1]The Metropolitan Chicago Accessibility Explorer can be accessed at http://www.urbanaccessibility.com

2 Methodology

There are multiple ways to measure accessibility. In this project, we used a cumulative opportunity measure to calculate different types of accessibility by different travel type. The cumulative opportunities measure counts the number of opportunities (e.g. jobs) that can be reached in some travel time threshold (e.g. 45 minutes) by a particular mode (e.g. automobile, transit). Accessibility for a given threshold by a particular mode can be calculated as a simple sum of all opportunities in block groups that can be reached within the predesignated time threshold. Mathematically, leaving mode and threshold indexes for simplicity, this can be written as:

$$A_i = \sum_{j=1}^{J} O_j f(T_{ij})$$

where:

> A_i: Accessibility at block group i to activity type O
>
> O_j : Opportunities available in block group j
>
> $f(T_{ij})$: A function that takes a value of 1 or 0 based on whether the travel time from i to j (T_{ij}) is within a given time threshold (1=Yes, 0=No).

Once auto and transit accessibility are computed, we also measure accessibility as a composite of these two measures by using vehicle availability to weigh these values. From the perspective of a resident of a block group, the experience of what is accessible is going to depend on what modes are available for them. The composite measure approximates the expected accessibility for a resident of a randomly chosen household. The weighing would pull accessibility levels to that of transit if many households are car-less; on the other hand, block groups with high percentage of households with cars would have numbers closer to the auto accessibility numbers.

$$A_{Wi} = A_{ai} \cdot p_{i1} + A_{ti} \cdot p_{i2}$$

where:

A_{Wi}: weighted accessibility for block group i

A_{ai}: auto accessibility for block group i

A_{ti}: transit accessibility for block group i

p_{i1}: percentage of household with at least 1 vehicle in block group i

p_{i2}: percentage of household with no vehicles in block group i

The percentages for vehicle ownership (p_{i1} & p_{i2}) come from the 2010 American Community Survey[2]. Since the smallest geography for which data is released is the census tract, we assume that the proportions in a tract apply uniformly to all block groups within in a tract to compute weighted accessibilities.

[2]U.S. Census Bureau; American Community Survey, 2010 ACS 5 year estimates, Table B25044 Tenure By Vehicles Available, generated using American FactFinder December 6, 2014.

3 Data Sources & Implementation

Multiple data sources were used to calculate the various accessibility types the Accessibility Explorer provides. These include accessibility to jobs in general, jobs by sector, earnings and other classifications, and accessibility to points of interest such as parks, libraries, schools, fire stations, hospitals and grocery stores. These accessibilities are provided at different time thresholds ranging from 5 minutes to 60 minutes separated by different travel modes. Accessibilities are computed for using census block group geographies which provide a fairly detailed resolution to assess how well connected a location is to different activities or opportunities. Block group definitions correspond to those used in the 2010 decennial census.

Part of the accessibility data —transit accessibility to jobs —came from the University of Minnesota's Accessibility Observatory[3]. The travel time for transit from the Accessibility Observatory was calculated from the centroid of each block group to all blocks in the metropolitan area along a combined pedestrian and transit service network that reflects schedule times as published by transit providers in the region[4]. Job accessibility is computed for Cook, DeKalb, DuPage, Grundy, Kane, Kendall, Lake, McHenry, and Will counties in Illinois. Automobile accessibility to jobs as well as automobile, transit, and pedestrian accessibilities to the remaining activities were computed using data sources and processes described below.

[3] Accessibility Observatory. http://access.umn.edu. Accessed January 15, 2015

[4] The pedestrian network is derived from the public OpenStreetMap (OSM) database as of April 16, 2014. It includes all OSM features with the "footway," "pedestrian," and "residential" tags. The transit network is derived from GTFS-format schedules published at metrarail.com, www.chicagotransit.com, and www.pacebus.com. These reflect METRA, CTA, and PACE transit service as of January 2014.

3.1 Data Sources

As described in the Methodology section, the inputs to the accessibility matrix are travel times for different modes (in this case block group to block group) and the opportunities or land uses that one wishes to compute access to. The data on opportunities/land uses came from a combination of sources. The number of jobs by sector data is from the Longitudinal Employer-Household Dynamics (LEHD)[5] compiled by the United States Census Bureau. Other land use data besides employment was collected by requesting shapefiles from each metropolitan county's GIS Department or GIS specialist. We also used the City of Chicago's Data Portal[6] to collect data specific to the City. Due to data limitations or unavailability, not every type of land use data is available for all counties. A summary of the data availability is shown in Table 1.

Other types of data that were used in the project include network data for the region to compute travel times. These employed Open Street Maps (OSM)[7] and publicly available General Transit Feed Specification (GTFS)[8] data for the metropolitan region.

[5] Longitudinal Employer-Household Dynamics. http://lehd.ces.census.gov/data/ Accessed February 1,2015

[6] City of Chicago's Data Portal. https://data.cityofchicago.org Accessed February 1, 2015

[7] ©OpenStreetMap contributors. http://www.openstreetmap.org Accessed January 15, 2015

[8] GTFS/Scheduled Service Data. http://www.transitchicago.com/developers/gtfs.aspx Accessed January 15, 2015

Table 1: Availability of accessibility type in each county

Accessibility type	City of Chicago	Cook	DuPage	Kane	Kendall	McHenry	Lake	Will
Jobs	✓	✓	✓	✓	✓	✓	✓	✓
Parks (area)	✓							
Parks (count)	✓	✓	✓	✓	✓	✓	✓	✓
Libraries	✓		✓	✓	✓	✓	✓	✓
Fire stations	✓		✓	✓		✓	✓	✓
Schools (all)	✓	✓		✓		✓	✓	✓
Schools (private)	✓	✓						
Schools (public)	✓	✓						
Hospitals	✓	✓		✓		✓	✓	✓
Grocery stores	✓							✓

3.2 Implementation

Two tools were used to calculate a Travel Time Matrix (TTM), a customized data structure that behaves like a 2D array, but with customized functionality, in which travel time from each block group to all other block groups in the area is stored. The first tool is the Open Source Routing Machine (OSRM)[9]. OSRM is a high-performance routing engine for shortest paths in road networks written in C++. It is used to calculate the TTMs for automobile travel. OSRM has native support for calculating travel time from a list of origins to a list of destinations. As used here, it was slightly modified to suite our needs.

The second tool we used is OpenTripPlanner (OTP)[10]. OTP is an open source platform for multi-modal and multi-agency trip planning written in Java. We used it to produce the TTM for transit. We used a library `[otp-jython]`[11] to write python scripts to do batch processing via Java-written OTP.

In summary, the process is as follows:

- using OTP, together with OSM data and GTFS data, create a 'Graph'.
- writing python scripts that make use of `otp-jython` to calculate TTMs.
- writing python scripts to calculate accessibility (actual counts of opportunities) based on TTM.

Once accessibility is calculated, it was then converted into geojson layers as follows:

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[9] http://project-osrm.org Accessed January 15, 2015

[10] http://www.opentripplanner.org Accessed January 15, 2014

[11] https://github.com/mattwigway/opentripplanner-jython written by Matthew Conway. Accessed January 15, 2015.

- convert accessibility from actual number to percentage (using Python)
- convert them to ‘dbf‘ files (in LibreOffice)
- join our data into shapefile of the area, and change column names (in QGIS)
- convert generated shapefiles to geojson files (using command line tool)

3.3 Rendering Layers

The deployment used:

- Leaflet[12] and Mapbox[13] for online map service and javascript API.
- Amazon EC2[14] for hosting.
- Flask[15] as our framework, providing scalability for future expansion.

12 http://leafletjs.com Accessed January 15, 2015.
13 https://www.mapbox.com Accessed January 15, 2015.
14 http://aws.amazon.com/ec2/ Accessed January 15, 2015.
15 http://flask.pocoo.org Accessed January 15, 2015

4 Product

Current implementation of the Metropolitan Chicago Accessibility Explorer is deployed at http://urbanaccessibility.com. Users have the ability to look into different modal or combined accessibility measures for the Metropolitan area depending on data availability on activity locations. A user would first choose what type of accessibility they are interested in looking at. The options include: jobs, parks (by count or area), schools (private, public, both), grocery stores, hospitals, libraries, as well as fire stations. The most expansive coverage is available for jobs while some are limited to the Chicago area only.

Users are allowed to select which travel type they are interested in. For jobs, three options are available: Auto, Transit and Weighted accessibilities. Auto and transit accessibilities represent percentage of jobs that can be reached at some chosen travel time threshold. Weighted accessibility accounts for the percentage of households that are car-less (applying the same car-less percentage to each block group as is estimated for the Tract by the American Community Survey. At one extreme, if a block group has a 100% car ownership, then the auto accessibility is reported. As the percentage of car owners decreases, the accessibility for a block group will be a weighted combination of what can be reached by transit and auto. This represents what the expected accessibility would be for randomly chosen household in the block group.

The choice of transit presents further choices to the user. Transit schedules and travel times can vary considerably by time of day as operators try to scale operations to demand. As a result, what is reachable in 30 minutes at 8 am, for example, may not be reachable at 8pm. We therefore offer the user the option to look at time of day changes to accessibility by selecting different departure times.

Job accessibility for auto, transit, as well as weighted options are available for multiple classes of jobs. One can select job classes separated by industry, corresponding to the 20 two-digit North American Industry Classification System (NAICS) classes [16]. In addition, jobs accessibility can be visualized by different demographic characteristics as presented in Work Area Characteristics files presented by the Longitudinal Employer-Household Dynamics (LEHD) data. These categories include age, race, ethnicity, earnings, gender, and education level.

Other accessibilities as currently implemented apply to a smaller geography than for jobs. This is primarily because the data based on which accessibility can be computed has gaps as can be seen from Table 1. For that reason, we have opted to include maps for the City of Chicago, with the goal of updating the accessibility maps as more complete coverage can be found.

As currently implemented, the visualization of accessibility uses the Jenks natural breaks classification method(Jenks, 1967) to cluster block groups into 7 classes, and rendered them using a monochromatic green color scheme. Users are also able to bring up CTA and Metra lines onto the map for easier reference of location. CTA and Metra lines are also GeoJSON files converted from shapefiles.

In each of these cases, users interested in measuring accessibility at any given location can hover their mouse at the point of interest and read the accessibility for the block group. The information provided includes the percentage of opportunities that can be reached as well as the regional total that percentage is based on. Along with the user provided inputs on mode, time threshold, activity type, this information allows

[16]See http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012 for these classes.

the user to gather information to allow comparative analysis of a place for different purposes (e.g. job classes) or for different geographical locations.

5 Future Directions

The Metropolitan Chicago Accessibility Explorer is primarily geared to make it easier to use of accessibility in making decisions about transport or land use related change. In its current form, it enables one to perform a comparative assessment of how well a place is connected to opportunities —jobs, schools, groceries, etc. The next step is to allow users to assess potential locations to which they can attract jobs, groceries, or other types of land uses with the goal of increasing accessibility to different areas of the region. This will require, given one knows the location they are interested in, the creation of maps that show what areas can be reached in some time threshold. Our goal is to provide an interface that is able to do this in an easy and speedy manner. Second, the current system allows users to manually look at particular locations and read off accessibility values. In future iterations, we aim to enable selection (e.g. by drawing polygons) and enable users to download reports from the interface that has been created.

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