

Geospatial Processing Tools to Enhance Longitudinal Employer-Household Dynamics Commute Data

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The views expressed in this article are those of the authors and do not represent the official positions or policies of the East-West Gateway Council of Governments.

Abstract

This article introduces ETURAS, a suite of software tools designed to analyze commute patterns using Longitudinal Employer-Household Dynamics (LEHD) data. LEHD offers detailed information on workforce housing patterns, job locations, and transportation connections between home and work. ETURAS enhances the analysis of changing commute patterns by linking LEHD to road network files, allowing estimates of commute distance. ETURAS also offers visualization tools, including the generation of dot density maps showing changes in the place of work for residents of any user-defined geography (UDG) and changes in the place of residence for workers in any UDG. This article will demonstrate ETURAS's output using two analysis areas as examples. Case studies offer two main conclusions: (1) ETURAS enhances the ability of planners to analyze locational affordability and balancing jobs and housing; and (2) although LEHD is a powerful tool for analyzing commute patterns, it is necessary to validate LEHD using other data sources and local knowledge.

Introduction

Detailed information about commute patterns is useful in various planning-related fields, including transportation, community development, and housing. Because it offers Origin-Destination (OD) data at a block level, the Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics (LODES) data set (U.S. Census, 2019a) is used by a growing number of planning agencies (NYC Planning, 2019; Schroeder, 2017). Housing analysts use LODES to analyze the balance between housing and jobs, with an aim toward identifying places in need of additional workforce housing (Benner and Karner, 2016; Kneebone and Holmes, 2015). In addition, the

recently passed Infrastructure Investment and Jobs Act authorizes Metropolitan Planning Organizations (MPOs) to “develop regional goals for the integration of housing, transportation, and economic development strategies to better connect housing and employment while mitigating commuting times.”¹ An understanding of commute patterns is useful for developing strategies to connect housing and employment.

The Longitudinal Employer-Household Dynamics (LEHD) provides OnTheMap (U.S. Census, 2022), an online tool that is useful for analyzing LODES and downloading the analysis results and data. Two key features of OnTheMap are (1) the ability to upload a shapefile of any user-defined geography (UDG) and (2) the Distance/Direction analysis.

For example, using OnTheMap, an analyst could upload a shapefile of a local residential development area and then run the Distance/Direction analysis to calculate the number of jobs that are within 10 miles, 10–24 miles, 25–50 miles, and more than 50 miles away. To generate a histogram of commute distances (for example, at 1-mile increments), however, more granular commute data are required than what are available with OnTheMap. In addition, even if that level of detail were present, the analysis would have to be repeated for each UDG.

The analyses in this article require numerous outputs, including a plot of the commute distance distribution for a significant number of UDGs. For this use, OnTheMap and the base LODES data are limited by two factors: (1) LODES data do not provide driving distances between two points and cannot be used to calculate changes in commute distances accurately, and (2) in a medium-sized region, there can be several million unique worker commute routes grouped into a number of different UDGs.

Staff at the East-West Gateway Council of Governments (EWG), the MPO for the St. Louis region, developed the ETURAS software toolkit to address these challenges. Using software tools and custom script, the authors added spatial attributes to calculate commute distance and visualize changes in commuter flow at any spatial extent, whether or not it is a U.S. Census-defined geography. In addition, because the aggregation process is automated, the size and number of the UDG are limited only by the workstation’s processing power. EWG is making ETURAS available in the hope that it will be of use to the LODES user community.

Following is a high-level description of the data and methods used to create ETURAS, including examples of ETURAS output.²

Analyses using ETURAS were conducted in the St. Louis region, which is served by EWG. Exhibit 1 shows the eight-county region, consisting of five counties in Missouri and three in Illinois. A key motivation for ETURAS is the desire to generate maps and other visualizations for UDGs. As the authors use the term, a UDG can be any area defined by a polygon, whether a single polygon of interest or a set of polygons such as ZIP Codes or census tracts that cover an entire region. For this analysis, the region was divided into 36 Analysis Areas (AA) (see exhibit 1). Using ETURAS, a

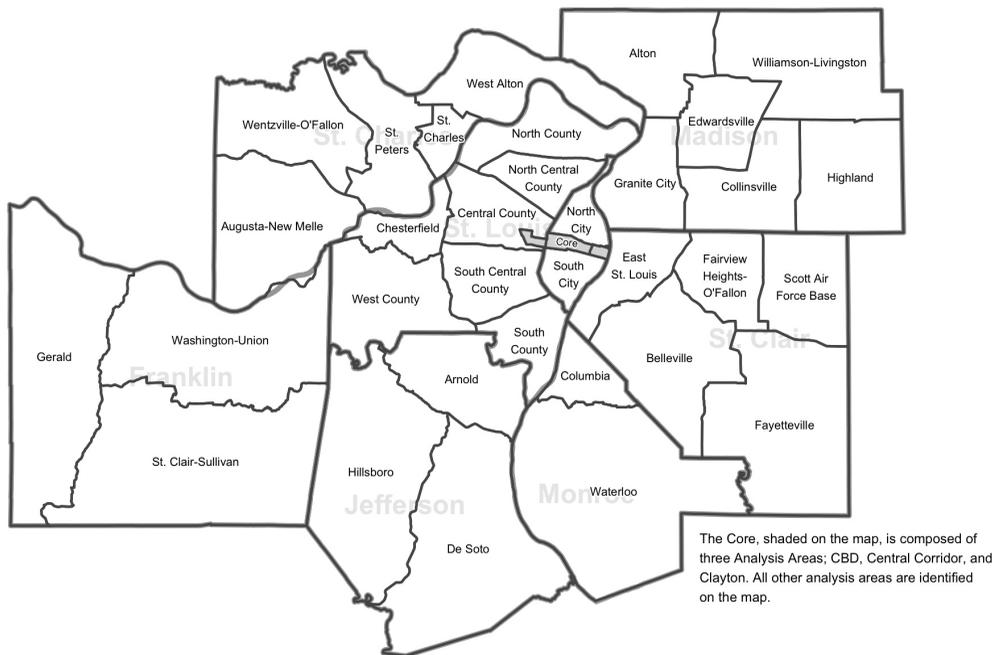
¹ *Infrastructure Investment and Jobs Act*. P.L.: 117-58 (11/15/2021). <https://www.congress.gov/bill/117th-congress/house-bill/3684>

² The complete set of scripts, data model, and technical documentation are available at <https://www.ewgateway.org/eturas>.

single script generates OD maps showing the place of work (POW) for residents and the place of residence (POR) for workers for each polygon in the UDG.

Exhibit 1

East-West Gateway Council of Governments Region in the City of St. Louis and Seven Surrounding Counties



CBD = central business district.

Sources: East-West Gateway Council of Governments; U.S. Census Bureau

Software Toolkit

LEHD / LODES

The U.S. Census Bureau created the LEHD program to develop information about employers and workers across the country. Through their partnership with the states, the U.S. Census leverages administrative data, employer data, and wage data, along with Census person data and other federal administrative datasets. The LEHD program provides five core products from this source data, but this analysis will focus on LODES.

The LODES dataset contains three core tables: (1) Origin-Destination (OD), (2) Residence Area Characteristics (RAC), and (3) Workplace Area Characteristics (WAC). The OD table contains job totals for unique worker residence-to-workplace commutes. The RAC table adds the North American Industry Classification System (NAICS) sector and worker demographics. The WAC table adds information about the employment firm. These tables are organized by year, state, and job type and are keyed at the block level.

Of these three tables, the primary focus was the OD table. Each row of the OD table contains a unique residence-to-workplace commute along with the total number of workers for that commute. In addition, each row includes limited information on worker age, earnings, and industry. The data are keyed to the year, which allows for year-to-year comparisons of commutes.

Objectives

The ETURAS software toolkit was designed with two key objectives in mind.

1. Subdivide a region by any boundary, whether that boundary was a U.S. Census-defined geography or not, and perform statistical analysis on worker commutes within that boundary. Although OnTheMap provides the ability to upload a boundary saved as a shapefile, ETURAS simplifies the process by accessing LODES locally and quickly processing a large number of boundaries through automation. Furthermore, using ETURAS, commutes can be aggregated and the aggregates then compared to illustrate a change in commuter flow over time.
2. Identify the distance of every commute, which is not possible with OnTheMap. Commute length is an important contributor to planning outcomes such as transportation costs, Vehicle Miles of Travel (VMT), and emissions. LODES only contains the origin and destination points, however, and not the commute route or distance. Although it would be simple to compute great-circle distance (as the crow flies) from origin to destination based on centroid coordinates, this distance bears only a tenuous relationship to actual driving distance. Therefore, ETURAS programmatically links the commutes to the road network and calculates the route distance.

In addition, ETURAS can be extended. Several example R scripts are included to demonstrate the range of analyses enabled by ETURAS. Example output includes a change in place of work or place of residence maps, origin-destination matrices showing commuter flow between any set of analysis areas, and commute distance distribution plots, among others.

Data Sources

The data sources used in this analysis were LEHD/LODES, Census Topologically Integrated Geographic Encoding and Referencing (TIGER) files, OpenStreetMap (OSM)/Geofabrik, and a UDG.

- **LODES:** LODES data are separated into Comma Separated Values (CSV) files, grouped principally by year, state, and job type. Data files for Illinois and Missouri were downloaded for the years 2010 and 2019 and loaded into three database entities: (1) commute, (2) residence, and (3) workplace. In addition, the LODES Crosswalk tables were downloaded and inserted into the database to link LODES to U.S. Census-defined geographies.
- **TIGER:** TIGER shapefiles (U.S. Census, 2021) are extracts from the U.S. Census Bureau's Master Address File and include polygon boundaries and line and point features for the United States. Boundary shapefiles for counties, tracts, block groups, and blocks were downloaded and loaded into the database to spatially filter and aggregate the LODES data.

- **OSM:** OSM is an initiative supported by the not-for-profit organization OpenStreetMap Foundation to provide crowdsourced road network data. Network files for Illinois and Missouri were downloaded from Geofabrik (Geofabrik, 2021), which extracts and shares OSM data for various geographies.
- **UDG:** This source can be any boundary layer of interest. At EWG, AAs were defined using economic and demographic data to analyze development trends.

Software Requirements

The tools used for this analysis are open source and freely available to planning organizations of any size. Although a degree of internal expertise with scripting languages and database management will be required, the authors hope that this article will be useful as a guide for preparing the analysis environment. Links to all the tools are listed in the appendix.

Scripting and Query Tools

A working knowledge of the following languages is required to modify the scripts and queries.

- R is a scripting language widely used for statistical computing that supports an active ecosystem of third-party extensions. Each automated step was coded in R script because of its simple syntax and bias toward working with datasets.
- Structured Query Language (SQL) is a standard database query language. Statements were written to join, filter, and aggregate the data.

Data Processing Tools

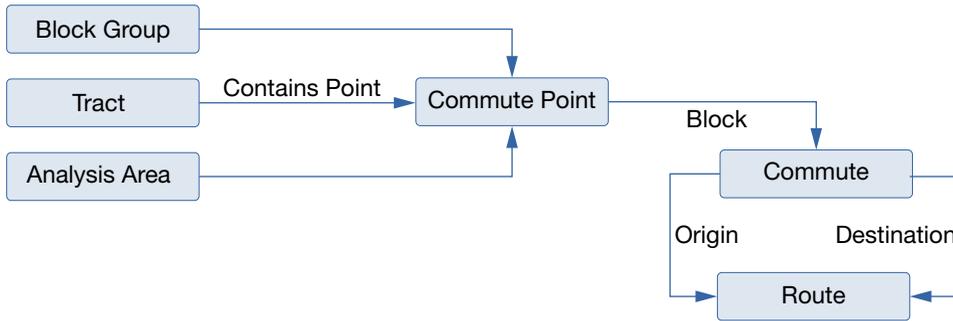
The following tools are required to create the data model and populate the database.

- PostgreSQL is an enterprise-grade database server capable of processing terabytes of data. PostGIS is an extension to PostgreSQL that adds functions to perform spatial operations on geographic data. Popular mapping tools such as ArcGIS and the open-source QGIS can directly access a PostgreSQL/PostGIS database.
- Open Source Routing Machine (OSRM) is used to calculate street routes between points. Using the OSM road network data, the distance traveled was calculated for each commute.

Loading the Data

Exhibit 2

Data Model



Source: East-West Gateway Council of Governments

Adding Spatial Attributes to Commutes

LODES data are keyed on block and include longitude and latitude values for each block. Using the internal points, each commute was processed in PostGIS and the location saved to the database; shown as “Commute Point” in exhibit 2.³

Calculating Distance

In the EWG study area, there are several million unique routes in the LODES data. To process that volume of data, OSRM was configured and populated with the OSM road network for Illinois and Missouri. Using the Multi-Level Dijkstra⁴ algorithm to compute the route, OSRM calculated the commute distance, which was subsequently stored to the database (shown as “Route” in exhibit 2).⁵ Although the OSRM server supports profiles for car, bicycle, and walk modes of transportation, only car routes were calculated for this analysis.

Using ETURAS

Geographic Extent

There are two defining boundaries for the analysis: (1) the EWG region and (2) the study area.

The EWG region is the city of St. Louis and the seven surrounding counties. The independent city of St. Louis is considered a county-level jurisdiction under Missouri law (see exhibit 1).

The study area is the St. Louis, MO-IL Metropolitan Statistical Area (MSA) and the collar counties.

³ See <https://www.ewgateway.org/eturas> for SQL statements.

⁴ Multi-Level Dijkstra is an algorithm for solving the shortest path problem.

⁵ See <https://cran.r-project.org/web/packages/osrm/index.html> for the R package used to call OSRM.

Visualizing the Data

ETURAS is a foundation that supports a variety of ways to explore commute patterns. In this section, the authors present two possible workflows, and in the Findings, they describe two analyses in the St. Louis region based on these workflows.

Change of Residence for Workers by Workplace Location

Because each endpoint of the commute route is geographically coded, commutes can be selected for any residence or workplace location. For this workflow, residence is any point in the region, and workplace is any point contained within the UDG.

All commutes with a workplace in the UDG are selected to calculate the baseline year. Next, the number of workers is summed for each of those commutes from each residential area. Then these two steps are repeated for each UDG in the region, resulting in a table of residence subtotals grouped by workplace UDG.

The process is then repeated for the comparison year.

The change of residence can then be calculated by comparing the residence subtotals for each year with each UDG.

The EWG analysis based on this workflow is detailed in the Findings section.⁶

Distance Distribution of Worker Commutes by Residence Location

Because the route for each commute has been calculated, the distance workers travel can be determined for any location. For this workflow, residence is any point contained within the UDG.

First, all commutes with a residence in the UDG are selected for a given year. Then, the histogram is computed using the distance from each of those commutes. Finally, those two steps are repeated for each UDG.

That process can be repeated for any number of years.

R was used to compute the histogram in the EWG analysis detailed in the Findings section.⁷

Additional Workflows

Because ETURAS extends commute data with geographic location and distance, several other workflows and calculations are possible, including changes in aggregate driving distance and VMT. Furthermore, any of the workflows can be run for any UDG or for the entire region.

Findings

Using the 36 AAs as the UDG, the major outputs using ETURAS are a set of maps showing the POW for the residents of the AA and the POR for the people who work in the AA.

⁶ See <https://www.ewgateway.org/eturas> for example code.

⁷ Ibid.

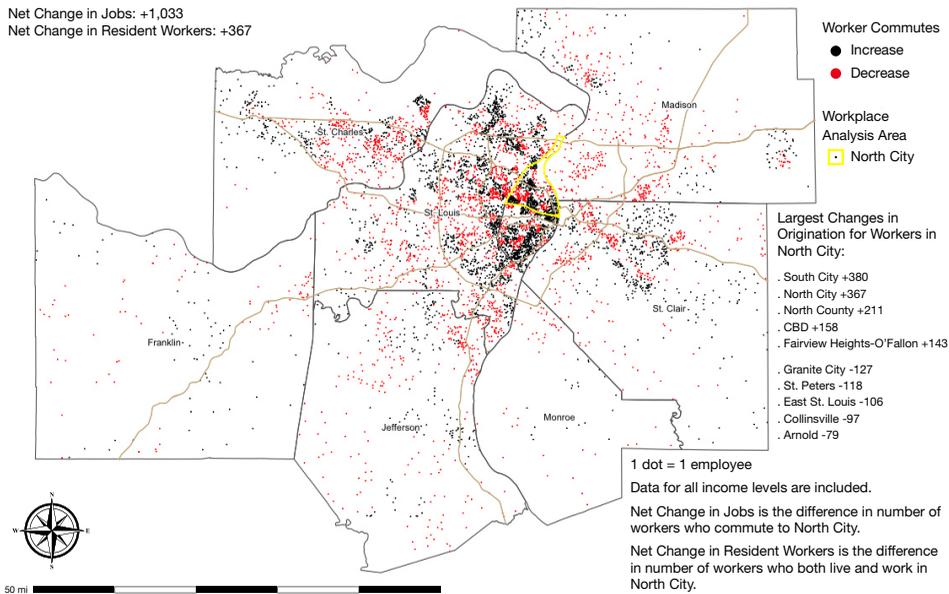
For the 36 AAs, this output represents 72 maps, all generated by a single script. ETURAS also generates change maps for both POR and POW. For example, a POW change map for a given AA uses black dots to show areas where an increasing number of AA residents work and red dots to show areas where a decreasing number are employed. Following are two examples of analyses conducted at the AA level. The first example shows a set of ETURAS outputs that show connections between housing and employment for people who either live or work in the North City AA.

With a population that is 95 percent African-American (U.S. Census, 2020) and a poverty rate nearly triple the regional average (U.S. Census, 2019b), North City is a key area for Environmental Justice (EJ) analysis.⁸ Exhibit 3 shows POR for people employed in North City. From 2010 to 2019, the number of jobs in North City increased by 1,033. The AA has drawn increasing numbers of workers from portions of North City, South City, and North County, with decreasing flows from Granite City and St. Peters.

Exhibit 4 shows areas with increases in commute trips from North City. The number of employed residents of North City increased by 367 from 2010 to 2019. The most significant increases in employment opportunities were seen in Central County, South Central County, and North Central County. These increases suggest that there may be a need for additional study of connectivity needs between North City and these areas.

Exhibit 3

Change in Place of Residence for Commuters Who Work in North City from 2010 to 2019



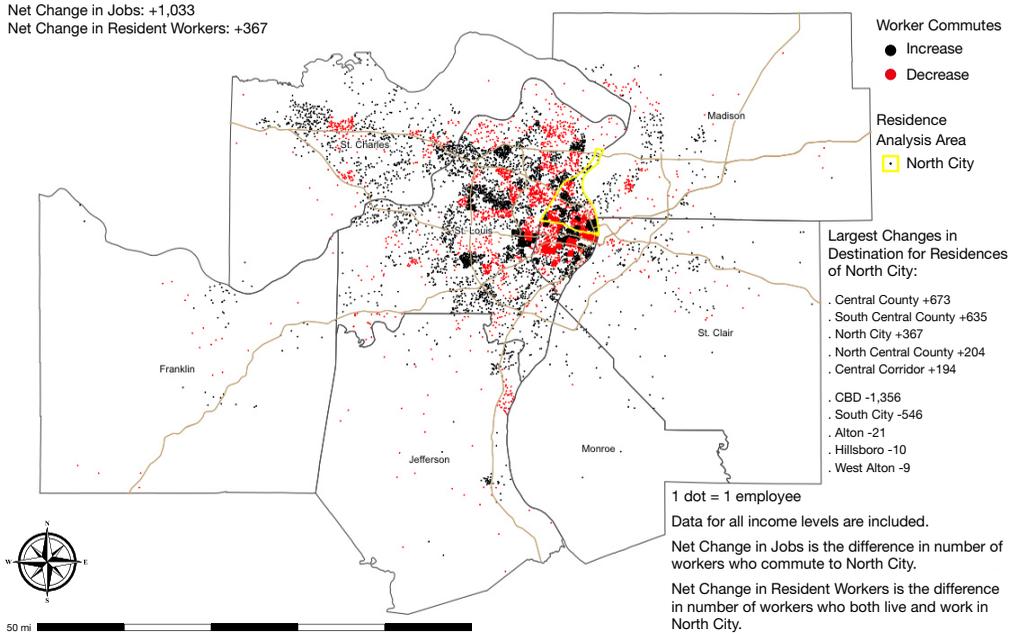
CBD = central business district.

Sources: East-West Gateway Council of Governments; Longitudinal Employer-Household Dynamics (LEHD) 2010 and 2019—U.S. Census Bureau; Topologically Integrated Geographic Encoding and Referencing (TIGER)—U.S. Census Bureau

⁸ Executive Order 12898 of February 16, 1994, Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations. Fed Reg 59, FR7629. <https://www.epa.gov/laws-regulations/summary-executive-order-12898-federal-actions-address-environmental-justice>

Exhibit 4

Change in Place of Work for Commuters Who Live in North City from 2010 to 2019



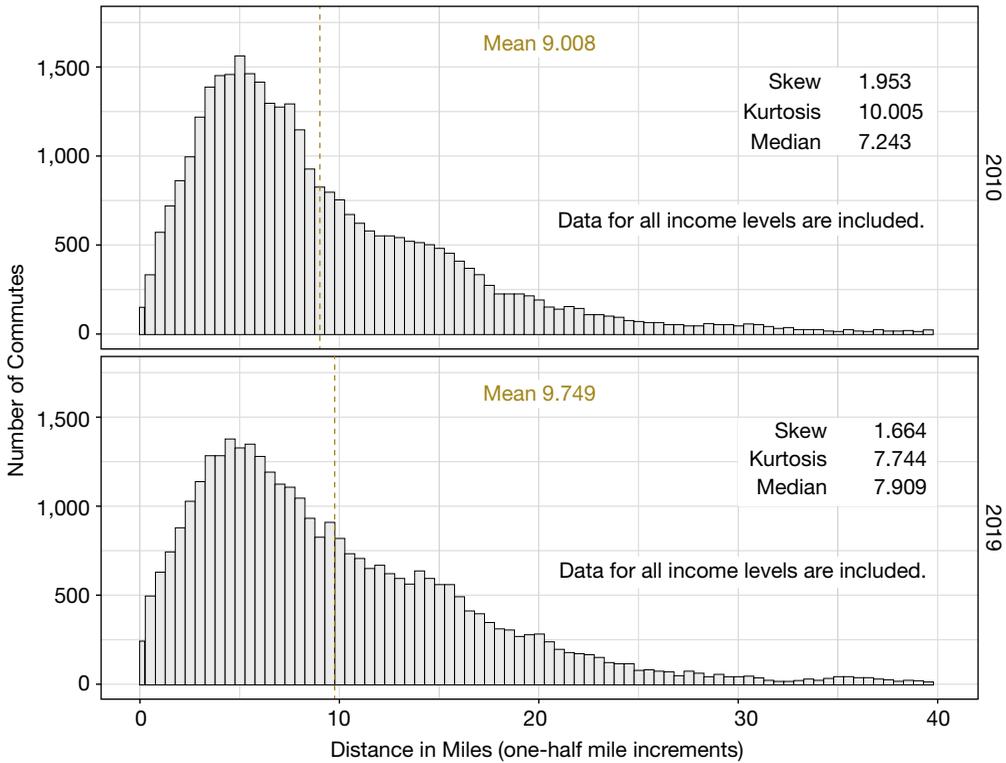
CBD = central business district.

Sources: East-West Gateway Council of Governments; Longitudinal Employer-Household Dynamics (LEHD) 2010 and 2019—U.S. Census Bureau; Topologically Integrated Geographic Encoding and Referencing (TIGER)—U.S. Census Bureau

Exhibit 5 shows the distribution of commute distances for workers who live in North City for the years 2010 and 2019. The distributions show the number of workers in each year by commute distance, in one-half mile increments. The mean travel distance for employed residents increased from 9.01 to 9.75 miles, an increase of 8.2 percent. In addition, ETURAS extensions scripted in R revealed that the percentage of commuters from North City who travel more than 10 miles to work increased from 33 percent in 2010 to 39 percent in 2019. These findings are consistent with research documenting increasing commute distances in recent decades (Barnes, 2007; Hu and Wang, 2016), with residents of EJ areas subject to longer commutes (Gottlieb and Lentnek, 2001).

Exhibit 5

Commute Distance Distribution for Commuters Who Live in North City, 2010 and 2019



Sources: Longitudinal Employer-Household Dynamics (LEHD) 2010 and 2019—U.S. Census Bureau; Open Source Routing Machine with OpenStreetMap data—<https://github.com/Project-OSRM>; East-West Gateway Council of Governments

ETURAS generated 36 x 36 OD matrices for 2010 and 2019, as well as a change matrix. Exhibit 6 shows a portion of the change matrix, with AAs from the city of St. Louis and surrounding St. Louis County. Column titles show AA names by place of residence. Names at the left show AAs by place of work. The first row shows the change in place of residence for people who work in the central business district (CBD). ETURAS reports that the number of people who both live and work in the CBD grew by 288, whereas the number commuting from North City to CBD decreased by 1,356.

Exhibit 6

Worker Change Matrix—Place of Residence by Place of Work from 2010 to 2019

		Place of Residence											
		Analysis Area	CBD	Central Corridor	Central County	Chesterfield	Clayton	North Central County	North City	North County	South Central County	South City	South County
Place of Work	CBD	288	-178	-709	-201	9	-1,129	-1,356	-881	-649	-2,468	-1,020	-800
	Central Corridor	223	621	999	267	164	707	194	1,165	1,307	1,515	964	665
	Central County	255	467	674	-229	222	351	673	1,504	364	2,218	846	-236
	Chesterfield	51	109	797	478	53	238	128	380	430	356	344	568
	Clayton	60	34	274	104	130	-99	19	-112	112	363	51	160
	North Central County	219	292	1,612	356	183	937	204	1,417	916	784	504	633
	North City	158	54	52	-11	37	51	367	211	49	380	62	-6
	North County	45	25	80	-182	-5	645	130	-174	-141	87	-140	10
	South Central County	239	226	1,513	249	195	879	635	837	1,452	1,561	1,462	1,247
	South City	123	-16	-242	-53	37	-310	-546	-91	-989	-970	-515	-374
	South County	70	32	-27	-126	19	60	173	6	-282	128	-659	-332
	West County	27	26	-45	-39	-8	78	80	94	158	44	302	186

CBD = central business district.

Sources: East-West Gateway Council of Governments; Longitudinal Employer-Household Dynamics (LEHD) 2010 and 2019—U.S. Census Bureau

The significance of the findings for the North City AA lies in implications for locational affordability. In recent years there has been a growing awareness that the total cost of living in a housing unit must include transportation costs. This finding is reflected in the Location Affordability Index (LAI) (HUD, 2019) and the Housing Plus Transportation (H+T) Index (Center for Neighborhood Technology, 2021). Commute distance is one determinant of transportation costs. The analysis enabled by ETURAS shows that in a low-income and predominantly African-American community, the average commute distance has risen in the past decade. Thus, ETURAS can be used to monitor a key component of locational affordability for households residing in EJ Areas.

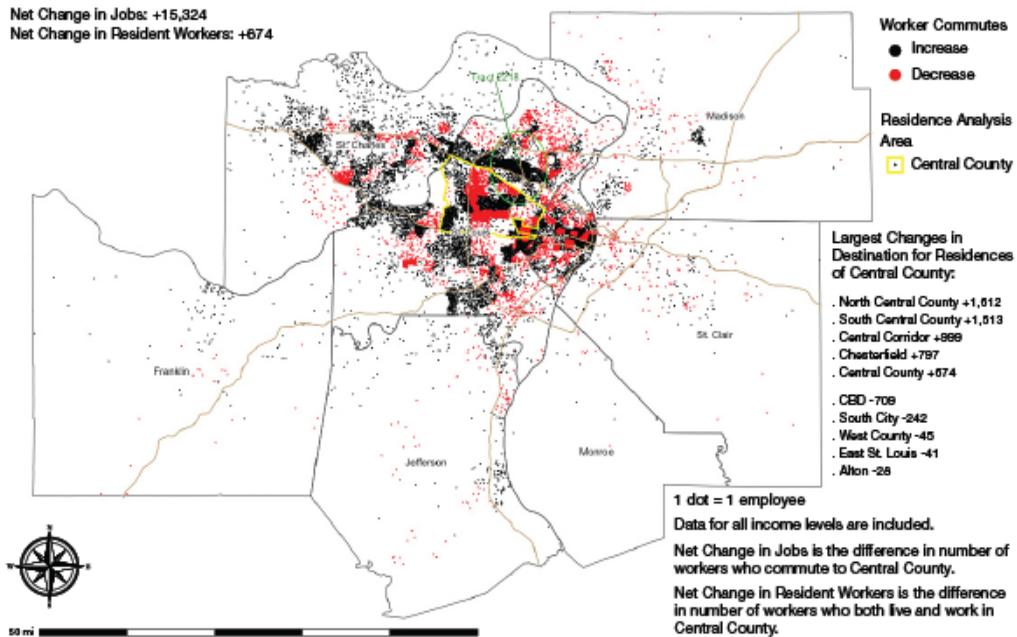
A second AA-level analysis using ETURAS is shown in exhibits 7 and 8.

Exhibit 7 shows a map that prompted additional scrutiny of a large and sudden change reported by LODS. This map shows that residents of the Central County AA had an increase of more than 1,000 commutes to a single tract, 2218. Further analysis showed that this tract was reported in LODS to have an increase in manufacturing employment of more than 11,000, from 664 to 11,104. A change this large would be significant even at the county level. Therefore, EWG staff pivoted to a county-level analysis to compare manufacturing employment as reported by LODS, the U.S. Bureau of Economic Analysis (2020), and the Quarterly Census of Employment and Wages

(U.S. Bureau of Labor Statistics, 2021). Results are shown in exhibit 8. Before 2015, LODES reported significantly lower manufacturing employment in St. Louis County than did either the Bureau of Economic Analysis (BEA) or the Bureau of Labor Statistics (BLS). LODES showed a sudden increase in manufacturing employment from 2015 to 2016, after which LEHD was reasonably consistent with the other sources. EWG staff concluded that a possible explanation for the sudden shift is that LODES was undercounting manufacturing employment prior to 2016 and corrected the issue after 2015. This variance led EWG staff to conclude that only a low level of confidence can be placed on the magnitude of increase in worker flow from Central County to Tract 2218. Thus, ETURAS can help identify changes in worker flow reported by LODES that warrant further scrutiny and validation using local knowledge.

Exhibit 7

Change in Place of Work for Commuters Who Live in Central County, 2010 to 2019

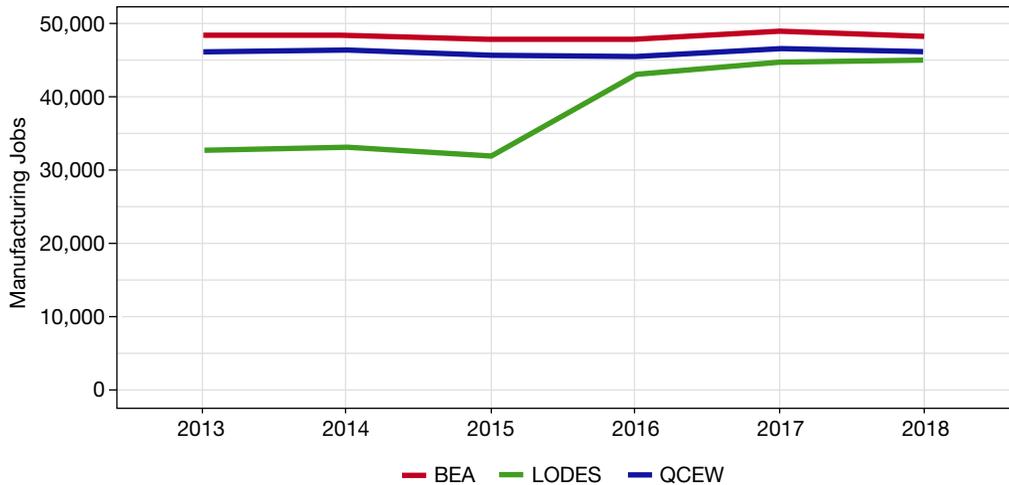


CBD = central business district.

Sources: East-West Gateway Council of Governments, Longitudinal Employer-Household Dynamics (LEHD) 2010 and 2019—U.S. Census Bureau; Topologically Integrated Geographic Encoding and Referencing (TIGER)—U.S. Census Bureau

Exhibit 8

Manufacturing Employment in St. Louis County



BEA = Bureau of Economic Analysis. LODES = Longitudinal Employer-Household Dynamics Origin-Destination Employment Statistics. QCEW = Quarterly Census of Employment and Wages.

Sources: Bureau of Economic Analysis—U.S. Department of Commerce; LEHD Origin-Destination Employment Statistics—Longitudinal Employer-Household Dynamics—U.S. Census Bureau; Quarterly Census of Employment and Wages—U.S. Bureau of Labor Statistics

Conclusions

The EWG staff have found ETURAS useful for analyzing changes in commute patterns in the St. Louis region. The authors hope that it will be useful to other LEHD/LODES users.⁹

ETURAS is a work in progress. There are two improvements planned for the future: (1) given the importance of validating trends reported in LODES, automate county-level comparisons between the LODES WAC file and both BLS and BEA datasets, as well as ZIP Code-level comparisons with ZIP Business Patterns. This comparison will help identify anomalous results that warrant further investigation. (2) Research the feasibility of creating a transit profile for the OSRM server. The OSRM server includes profiles for car, bicycle, and walking transportation modes. User-defined profiles can be added to the server, however, and a transit profile would be useful for analyzing a large urban area.

This article illustrated the use of ETURAS in analyzing changing commute patterns for North City, an AA with a large EJ population. The analysis showed increasing commute times for employed residents and highlighted several employment centers in the region that are attracting an increasing number of workers from North City.

The analysis also indicated increases in average commute distance for residents of North City. This increase suggests that the transportation component of locational affordability is trending in a direction that makes total H+T costs less affordable for many workers who reside in North City.

⁹ To access ETURAS, visit the following link: <https://www.ewgateway.org/eturas>.

ETURAS also helped EWG staff to uncover a significant discrepancy between LODES and other publicly available sources, resulting in low levels of confidence in one change reported by LODES. This variance highlights the importance of validating LODES with other public sources and local knowledge before basing decisions on this information.

This finding is especially relevant because the U.S. Census Bureau has proposed using LODES to delineate Urban Areas, which would affect eligibility for federal funding (U.S. Census, 2021). It is to be hoped that the Census Bureau allows an appeals process by which local officials can challenge LODES results that they believe may be spurious.

Finally, as noted previously, federal law now authorizes MPOs to develop strategies to link housing, employment, and economic development. The authors hope that some MPOs will find the tools described in this article helpful in fulfilling this function.

Appendix: Software Tools

Eclipse: <https://www.eclipse.org>

OSRM Backend Source and Docker Container: <https://github.com/Project-OSRM/osrm-backend>

PostgreSQL: <https://www.postgresql.org>

PostgreSQL add-on PostGIS: <https://www.postgis.net>

R: <https://www.r-project.org>

R Package OSRM: <https://cran.r-project.org/web/packages/osrm/index.html>

Authors

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