# ABM VISUALIZATION DASHBOARD

This project develops an interactive visualization dashboard for exploring outputs from the Atlanta Regional Commission's (ARC) Activity-Based Model (ABM), which supports long-range transportation planning for the 2050 Metropolitan Transportation Plan. The ABM generates detailed travel demand forecasts across multiple scenarios, including trip origins and destinations, mode choice, and time-of-day travel patterns. However, the large volume and complexity of these outputs make them difficult to interpret directly from database tables. To address this challenge, this project implements a structured data processing and visualization workflow that transforms ABM outputs into interactive visual analytics. Using PostgreSQL for data aggregation and transformation, and web-based visualization libraries such as D3.js and Leaflet for frontend rendering, the dashboard integrates spatial and analytical views including choropleth maps, origin–destination desire lines, radar charts, and temporal travel visualizations. The resulting system enables planners and analysts to explore regional travel behavior more effectively, compare model scenarios, and communicate transportation planning insights through intuitive visual representations.

**APRIL 2026**

## Table of Contents

# 1. Introduction

## Atlanta Regional Commission (ARC)

The **Atlanta Regional Commission (ARC)** is the regional planning and coordination agency for the Atlanta metropolitan area. ARC serves as the **Metropolitan Planning Organization (MPO)** designated by the federal government for the region. Under U.S. federal transportation law, every metropolitan area with a population exceeding 50,000 must have an MPO responsible for coordinating regional transportation planning and ensuring that federal transportation funds are allocated through a structured, data-driven planning process(Atlanta Regional Commission, n.d.).

As the MPO for the Atlanta region, ARC is responsible for coordinating planning activities across a **21-county metropolitan area**, working with local governments, state agencies, and transportation providers like the Georgia Department of Transportation (GDOT) and MARTA, and local transit authorities. The organization facilitates collaboration among counties, municipalities, and public agencies to ensure that transportation investments and regional development policies are aligned with long-term regional goals(Atlanta Regional Commission, n.d.).

One of ARC's main responsibilities is developing and maintaining the region's long-term transportation plan, officially called the Metropolitan Transportation Plan (MTP), also known as the Regional Transportation Plan (RTP). This plan details transportation investments and policy priorities over a planning horizon that usually spans 20 to 30 years. It assesses major infrastructure projects, transit expansions, roadway improvements, and multimodal initiatives to ensure transportation systems can support the expected population growth and economic development(Atlanta Regional Commission, n.d.).

ARC utilizes ABM to support these planning efforts. These models simulate travel behavior across the region and forecast travel patterns by residents and workers under different scenarios. The modeling framework allows planners to evaluate the potential impacts of new infrastructure investments, land-use changes, and policy interventions before they are implemented(Atlanta Regional Commission, n.d.).

ARC deploys these analytical tools to assess congestion patterns, forecast travel demand, analyze equity impacts, and prioritize transportation investments. The outputs from these models help guide regional decision-making by providing evidence-based insights into how transportation systems will perform under future growth conditions (Marinelli, Rousseau, & Kim, 2017).

Through its planning, modeling, and coordination activities, ARC plays a crucial role in forming the long-term transportation and development strategy of the Atlanta metropolitan region.

# ARC’s Activity-Based Model (ABM)

The Atlanta Regional Commission’s (ARC) Activity-Based Model (ABM) serves as the certified regional travel demand model supporting the development and evaluation of the 2050 Metropolitan Transportation Plan (MTP) for the Atlanta metropolitan region. As the federally designated Metropolitan Planning Organization (MPO), ARC relies on advanced modeling tools such as the ABM to forecast travel behavior, evaluate transportation investments, and analyze long-term transportation scenarios across the region (Atlanta Regional Commission, n.d.; Atlanta Regional Commission, 2017). These forecasts inform planning decisions regarding roadway improvements, transit investments, and multimodal infrastructure development.

ARC’s ABM is implemented using the Coordinated Travel Regional Activity-Based Modeling Platform (CT-RAMP), a modeling framework designed to simulate travel behavior at the level of individual persons and households. CT-RAMP captures the complex decision-making processes associated with daily activity patterns, including trip generation, destination choice, mode choice, and time-of-day decisions. Unlike traditional aggregate travel demand models, CT-RAMP explicitly accounts for intra-household interactions, allowing the model to simulate coordinated travel behavior among members of the same household, such as shared vehicle use, escort trips, and joint activity participation (Vovsha et al., 2013; Atlanta Regional Commission, n.d.). This behavioral representation provides a more realistic depiction of travel decision-making compared with conventional modeling approaches.

Traditional four-step trip-based travel demand models represent travel as independent trips aggregated at the zonal level and do not explicitly represent the behavioral structure of daily activity schedules. In contrast, activity-based models represent travel as a consequence of individuals’ daily activities, making them better suited to analyze policies related to travel behavior, congestion management, land-use change, and emerging transportation technologies (Bhat & Koppelman, 1999; Bowman & Ben-Akiva, 2001). ARC’s ABM incorporates detailed demographic and socioeconomic characteristics—including household composition, age structure, employment status, and income levels—to simulate how these factors influence travel behavior. By representing these characteristics explicitly, the model can better capture how shifts in population demographics and economic conditions influence regional travel demand (Atlanta Regional Commission, 2017).

Another distinguishing feature of ARC’s modeling framework is its integration with a regional land-use and economic forecasting system. The ABM operates within a fully integrated land-use–transportation modeling environment in which socioeconomic forecasts are produced through the Production, Exchange, Consumption, and Allocation System (PECAS). PECAS allocates employment, population, and economic activity across small geographic areas within the region. These spatial forecasts are derived from regional economic projections generated by the Regional Economic Models, Inc. (REMI) forecasting model. By linking land-use forecasts with transportation modeling, ARC ensures that projected economic growth, land development patterns, and travel demand remain internally consistent across planning scenarios (Atlanta Regional Commission, n.d.; Hunt & Abraham, 2005).

The integration of economic forecasting, land-use modeling, and activity-based travel demand modeling enables ARC to evaluate how transportation investments influence both mobility and regional development outcomes. This integrated modeling framework supports scenario analysis, policy evaluation, and long-range planning efforts for the rapidly growing Atlanta metropolitan region. Through this approach, ARC's ABM provides a comprehensive analytical foundation for assessing future transportation needs and supporting evidence-based regional planning decisions.

# 2. ABMVIZ: Activity-Based Model Visualization Framework

## 2.1 Overview

ABMVIZ is the interactive visualization dashboard of Atlanta Regional Commission (ARC) deployed to transform raw Activity-Based Model (ABM) outputs into interpretable, decision-support graphics. Rather than relying on static database tables or spreadsheet summaries, ABMVIZ provides an integrated web-based analytical interface that enables spatial, temporal, and behavioral exploration of regional travel forecasts(Atlanta Regional Commission, n.d.).

ARC's ABM documentation includes an "Activity-Based Model Visualization Tool" component within its model ecosystem, and ABMVIZ is listed among ARC's interactive data and mapping platforms. The system functions as the visualization layer of the ABM, directly connected to structured SQL outputs generated from multiple forecast scenarios(Atlanta Regional Commission, n.d.).

The ABMVIZ interface includes advanced interactive modules such as:

- 3D spatial-temporal trip animations
- Time-use exploration tools
- Origin–destination (OD) desire line maps
- Mode share tree-maps
- Radar charts for behavioral comparison
- Tabular and bar-chart analytical summaries

Transportation Research Board (TRB) documentation describes ABMVIZ as an interactive analysis and visualization dashboard linked to the model database, capable of producing dynamic charts, time-use diagrams, tour tracing visualizations, and multidimensional comparative graphics. The visualization modules implemented in this practicum align with that framework(Atlanta Regional Commission, n.d.).

The interactive ABMVIZ dashboard developed in this study is publicly accessible and can be used to explore all visualization modules described in this report.

Live Dashboard: https://atlregional.github.io/ABMVIZ_MTP24TIP5

## 2.2 Purpose and Rationale

The Activity-Based Model produces highly detailed outputs across household, person, trip, tour, and time-of-day dimensions. While analytically rich, these outputs present significant usability challenges:

- Large-volume datasets (millions of records)
- Separation across forecast-year schemas (2020, 2030, 2040, 2050, etc.)
- Technical database structures inaccessible to non-technical users
- Limited visual comparability across scenarios
- Reduced transparency for stakeholders

Without an interactive visualization framework, ABM outputs remain difficult to interpret and validate. Analytical credibility weakens when model results are confined to static tables or spreadsheet summaries.

ABMVIZ addresses this gap by operationalizing the ABM as a decision-support system rather than a database repository.

## 2.3 Functional Objectives of ABMVIZ

The primary objectives of the ABMVIZ framework are:

### 1. Model QA/QC

- Rapid identification of spatial anomalies
- Detection of unexpected trip concentrations
- Validation of mode share distributions
- Cross-year consistency checks

### 2. Scenario Comparison

- Direct comparison of forecast years (2020–2050)
- Build vs. No-Build evaluation
- Behavioral shifts across land-use scenarios
- Temporal peak pattern analysis

### 3. Stakeholder Communication

- Translation of technical outputs into visual narratives
- Support for MPO briefings and public meetings
- Improved interpretability for non-technical audiences

4. Model Transparency

- Visualization of how trips evolve across time-of-day
- Spatial distribution of household and employment growth
- Mode choice variation by geography
- Exploration of time-use and activity patterns

## 2.4 System Scope (Practicum Implementation)

This practicum extends and operationalizes ABMVIZ across multiple forecast schemas (2020–2050) for the 21-county ARC region. The implemented dashboard converts structured SQL outputs into:

- Interactive choropleth spatial maps
- Origin–destination desire line visualizations
- 3D animated temporal flow representations
- Radar charts for multi-variable behavioral comparison
- Tree-maps illustrating categorical mode distribution
- Bar chart analytical summaries
- Time-use visual exploration modules

The system integrates backend PostgreSQL aggregation scripts with frontend web-based visualization libraries to create a reproducible and scalable analytical workflow.

## 2.5 Strategic Value to ARC

The ABMVIZ framework strengthens ARC’s planning capabilities by:

- Reducing analytical bottlenecks
- Enhancing transparency of regional forecasts
- Supporting defensible MPO decision-making
- Improving internal model validation workflows
- Increasing stakeholder confidence in long-range projections

By transforming the ABM from a computational engine into an interactive analytical platform, ABMVIZ elevates the practical usability of travel demand modeling within the regional planning process.

# 3. Methodology

## 3.1 Data Architecture

### 3.1.1 Source Schemas

The ABMVIZ framework was designed to operate across multiple forecast-year schemas corresponding to the ARC Activity-Based Model outputs. The primary source schemas include:

- 2020 MTP24 TIP5
- 2030 MTP24 TIP5
- 2033 MTP24 TIP5
- 2040 MTP24 TIP5
- 2050 MTP24 TIP5
- 2050NB MTP24 TIP5 (No-Build scenario)

Each schema contains disaggregated household-, person-, trip-, and network-level outputs generated from ARC's CT-RAMP–based ABM and subsequent traffic assignment procedures. Maintaining schema separation ensures version control and scenario traceability while enabling cross-year comparison within the dashboard.

### 3.1.2 Core Data Types Utilized

The dashboard integrates multiple ABM output categories, including:

- Trip-level tables (origin, destination, purpose, mode, time-of-day)
- Origin–Destination (OD) matrices
- Time-of-day segmented trip records
- Mode share distributions
- Zone-level employment data
- Zone-level population and household data
- Time-use and activity duration distributions
- Link-level traffic assignment outputs

These datasets collectively support both behavioral analysis (activity patterns, mode choice) and network-level evaluation (flow intensities, spatial distribution of demand).

## 3.2 SQL Data Engineering Pipeline

The SQL workflow developed for this practicum functions as the data transformation and preparation engine for ABMVIZ. The pipeline consists of four primary stages:

### 3.2.1 Aggregation Layer

The aggregation layer restructures disaggregate ABM outputs into analytical summaries suitable for visualization. Key operations include:

- Grouping trip records by ORIG–DEST pairs
- Categorizing trips by time-of-day intervals
- Summarizing mode share proportions
- Aggregating trips by purpose category
- Computing zone-level totals and comparative metrics

Pre-aggregation at the database level reduces frontend computational load and improves dashboard performance.

### 3.2.2 Transformation Layer

The transformation stage standardizes and formats outputs for compatibility with web-based visualization libraries. Operations include:

- Converting numeric zone identifiers to text format to ensure GeoJSON key compatibility
- Creating structured summary tables for visualization modules
- Reshaping long-format outputs into wide-format datasets for radar chart implementation
- Preparing consistent field naming conventions across schemas

This step ensures uniformity across forecast years and prevents frontend join errors.

### 3.2.3 Spatial Join Preparation

To ensure seamless integration between model outputs and geographic boundaries, spatial identifiers were standardized across datasets.

Key tasks include:

- Aligning `ZONE` fields with GeoJSON keys
- Standardizing ID naming conventions
- Detecting and resolving NULL or missing zone references
- Validating one-to-one mapping between zone IDs and spatial geometries

This step is critical for accurate choropleth mapping and OD desire line rendering.

### 3.2.4 Export Layer

The final stage of the pipeline prepares data for web deployment.

Outputs include:

- Structured CSV exports generated directly from PostgreSQL
- JSON-ready formatted datasets
- Header alignment optimized for D3.js and Leaflet ingestion
- Reduced dataset sizes through selective filtering and thresholding

This export layer bridges backend model outputs and frontend visualization modules.

# 3.3 Data Processing and Visualization Pipelines

### 3.3.1 Overview of Data Processing Pipeline

The ABMVIZ framework follows a structured, multi-stage data processing pipeline that transforms raw Activity-Based Model (ABM) outputs into interactive visual analytics. The overall architecture integrates database-driven processing with spatial workflows and frontend visualization components, ensuring both analytical rigor and computational efficiency.

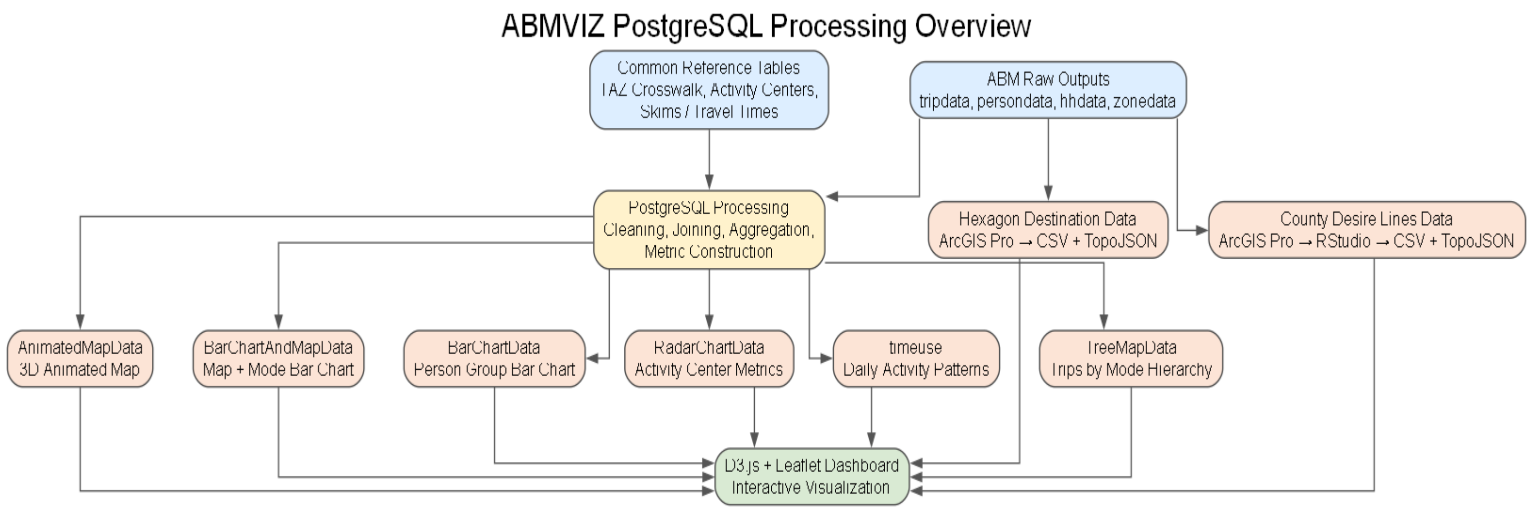
At the highest level, the pipeline begins with raw ABM outputs, including trip-level, person-level, household-level, and zone-level datasets. These data are supplemented by common reference tables, such as TAZ-to-county crosswalks, activity center mappings, and travel time skims, which provide the necessary spatial and contextual relationships for aggregation and analysis.

The core of the pipeline is implemented in PostgreSQL, where large-scale ABM datasets are cleaned, standardized, and transformed into structured analytical tables. This stage includes data type harmonization, aggregation of trip records, computation of behavioral and spatial metrics, and preparation of scenario-specific outputs. The resulting tables support multiple visualization modules, including spatial-temporal animations, bar charts, radar charts, time-use distributions, and hierarchical mode summaries.

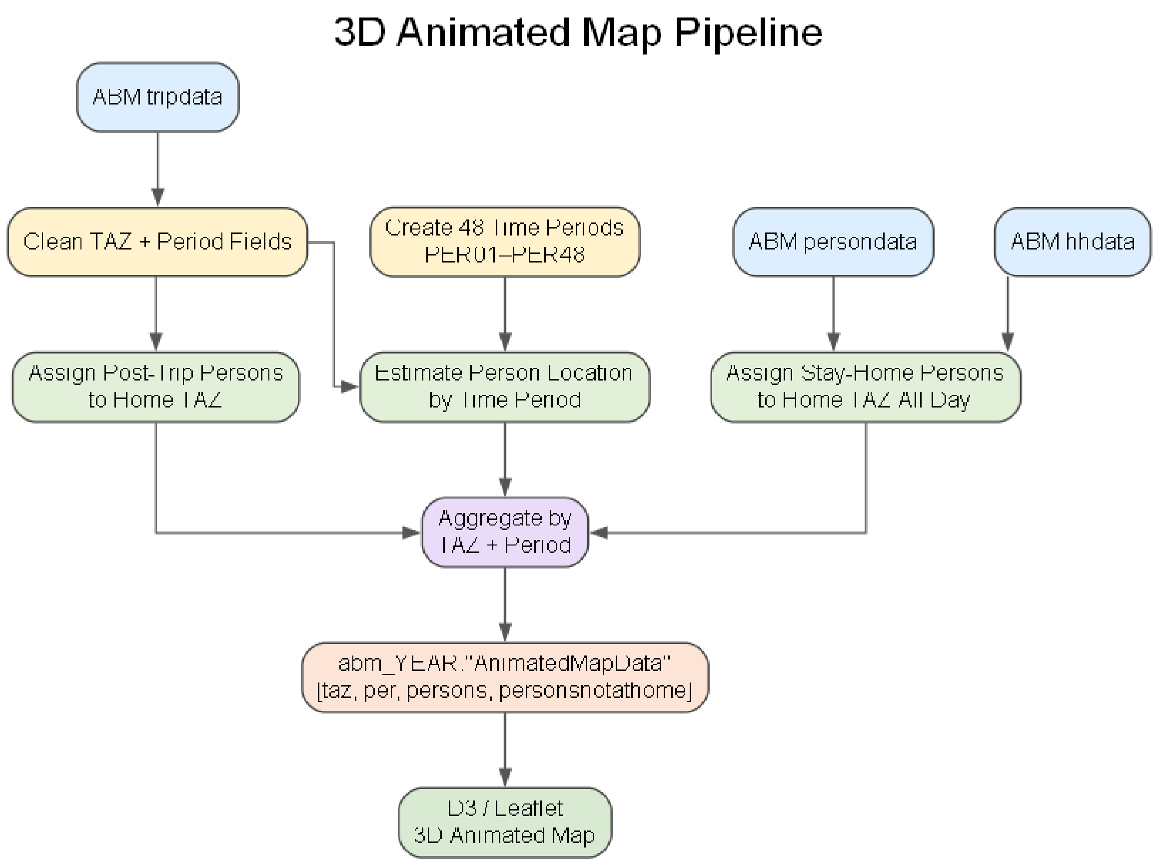
In parallel to the database workflow, spatial processing pipelines are implemented using ArcGIS Pro and RStudio to address tasks that require geographic transformation beyond standard SQL operations. These include the generation of hexagon-based spatial normalization datasets and the construction of county-to-county origin–destination desire lines. These workflows produce lightweight CSV and TopoJSON outputs optimized for web-based rendering.

All processed datasets converge in the frontend visualization layer, where D3.js and Leaflet are used to render interactive maps, charts, and analytical views. The separation of backend processing and frontend rendering ensures scalability, reduces browser-side computational load, and enables real-time user interaction across multiple scenarios and filters.

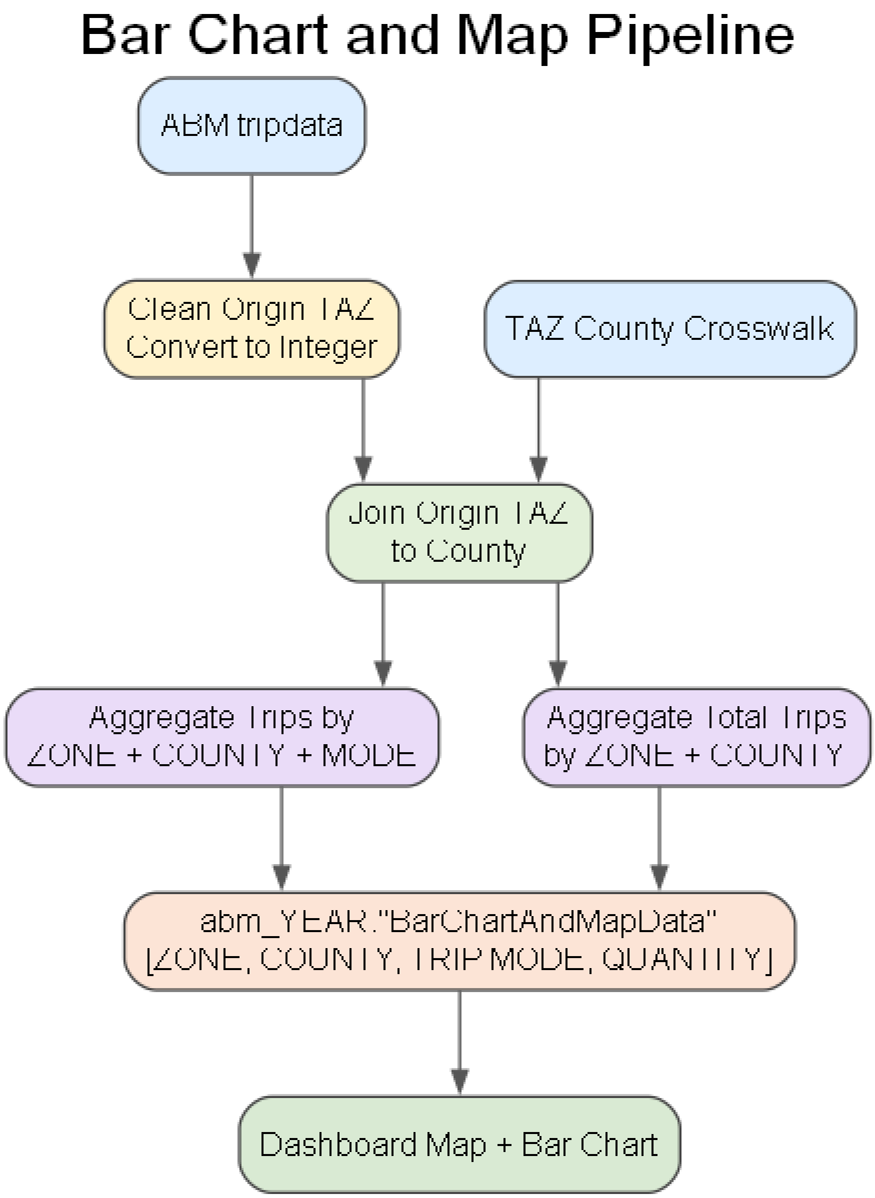
This integrated pipeline design allows the ABMVIZ system to function as a cohesive analytical platform, bridging raw model outputs, spatial data processing, and interactive visualization in a reproducible and extensible framework.



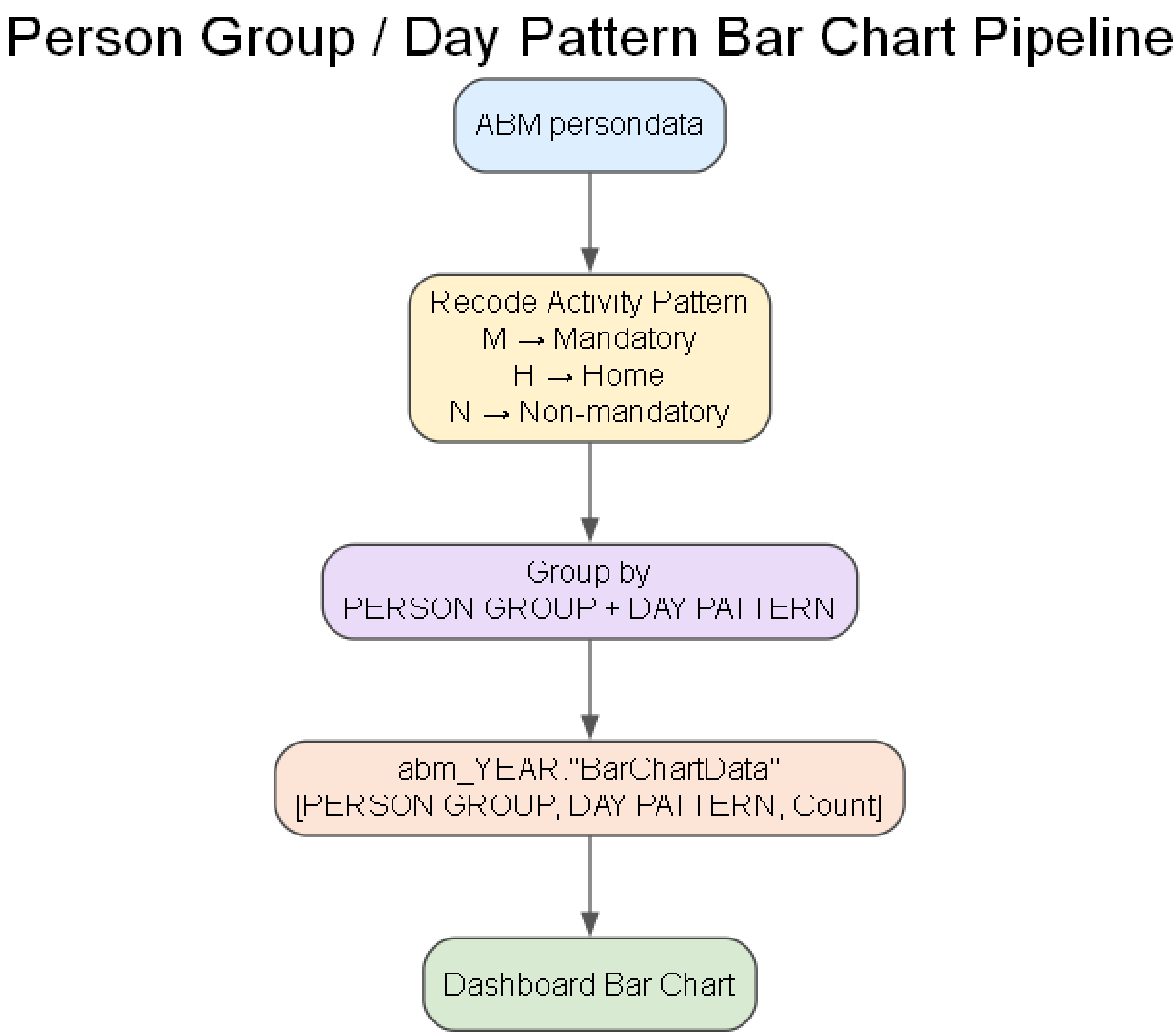
- 3d Animated Map



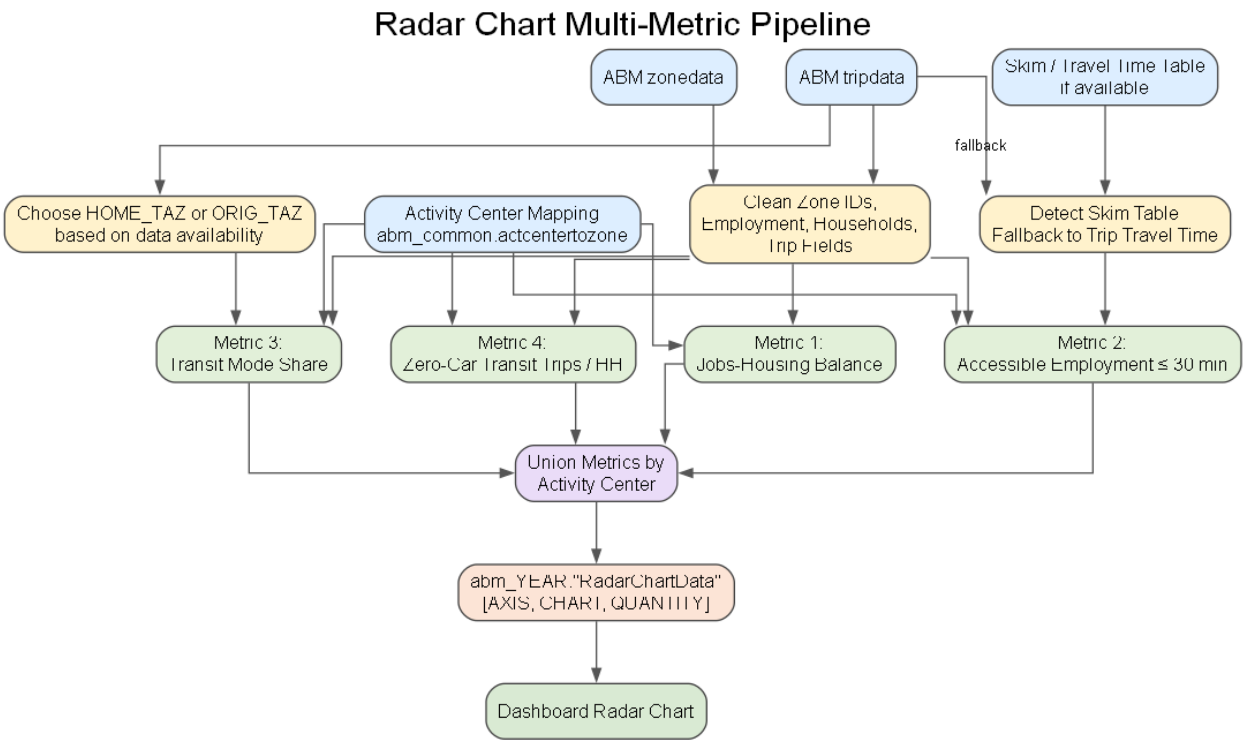
- Bar Chart and Map



- Person Bar Chart

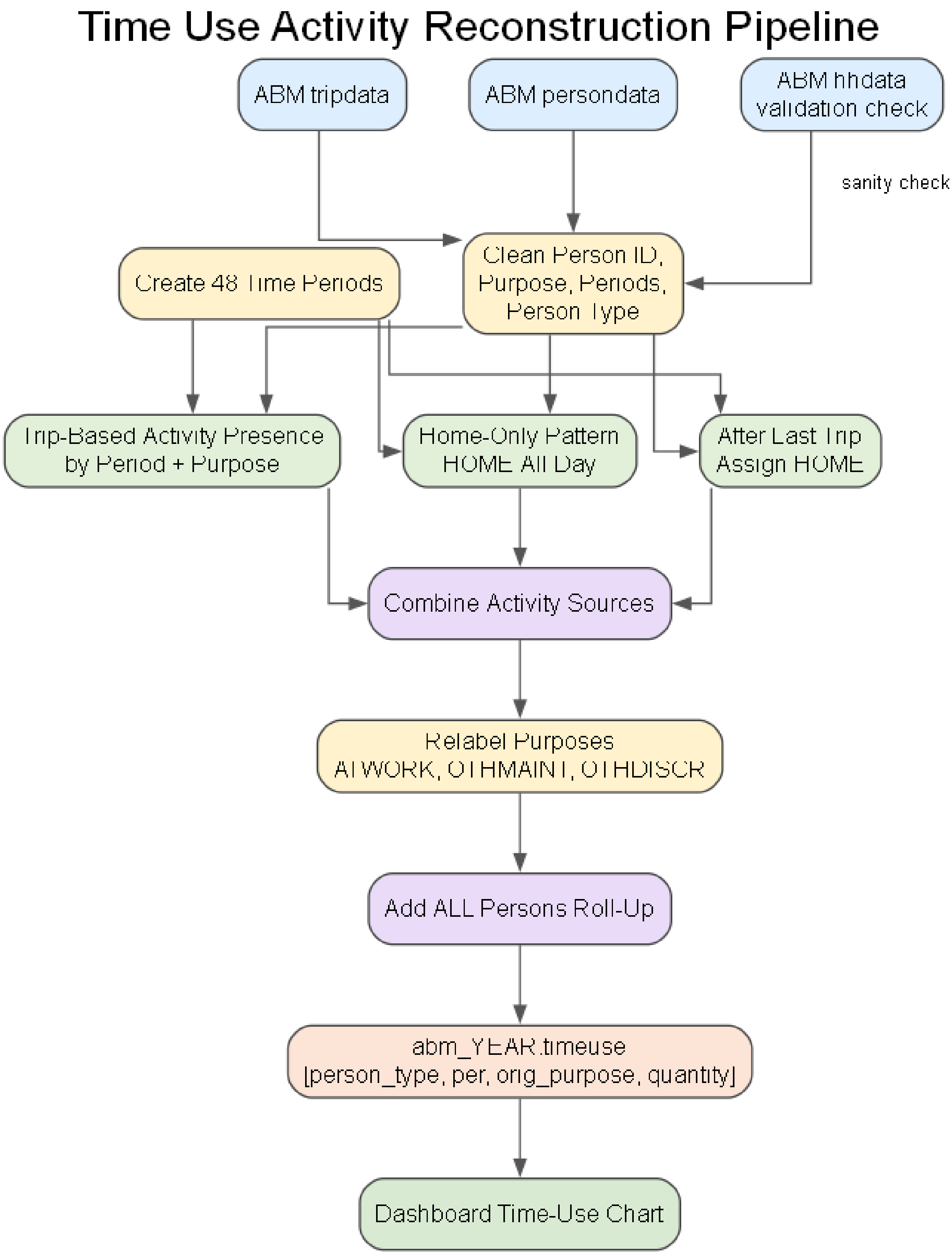


- Radar

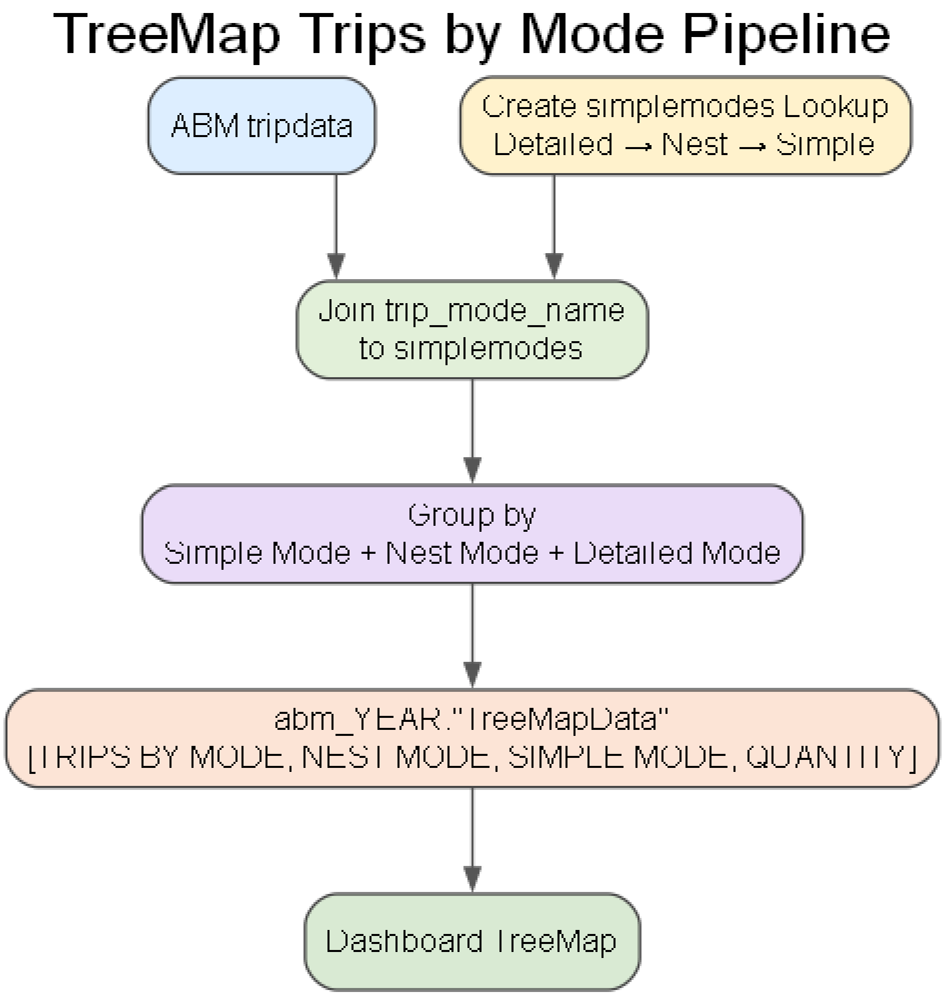


Radar Chart Multi-Metric Pipeline
ABM zonedata
ABM tripdata
Skim / Travel Time Table if available
fallback
Choose HOME_TAZ or ORIG_TAZ based on data availability
Activity Center Mapping abm_common.actcentertozone
Clean Zone IDs, Employment, Households, Trip Fields
Detect Skim Table Fallback to Trip Travel Time
Metric 3: Transit Mode Share
Metric 4: Zero-Car Transit Trips / HH
Metric 1: Jobs-Housing Balance
Metric 2: Accessible Employment ≤ 30 min
Union Metrics by Activity Center
abm_YEAR."RadarChartData" [AXIS, CHART, QUANTITY]
Dashboard Radar Chart

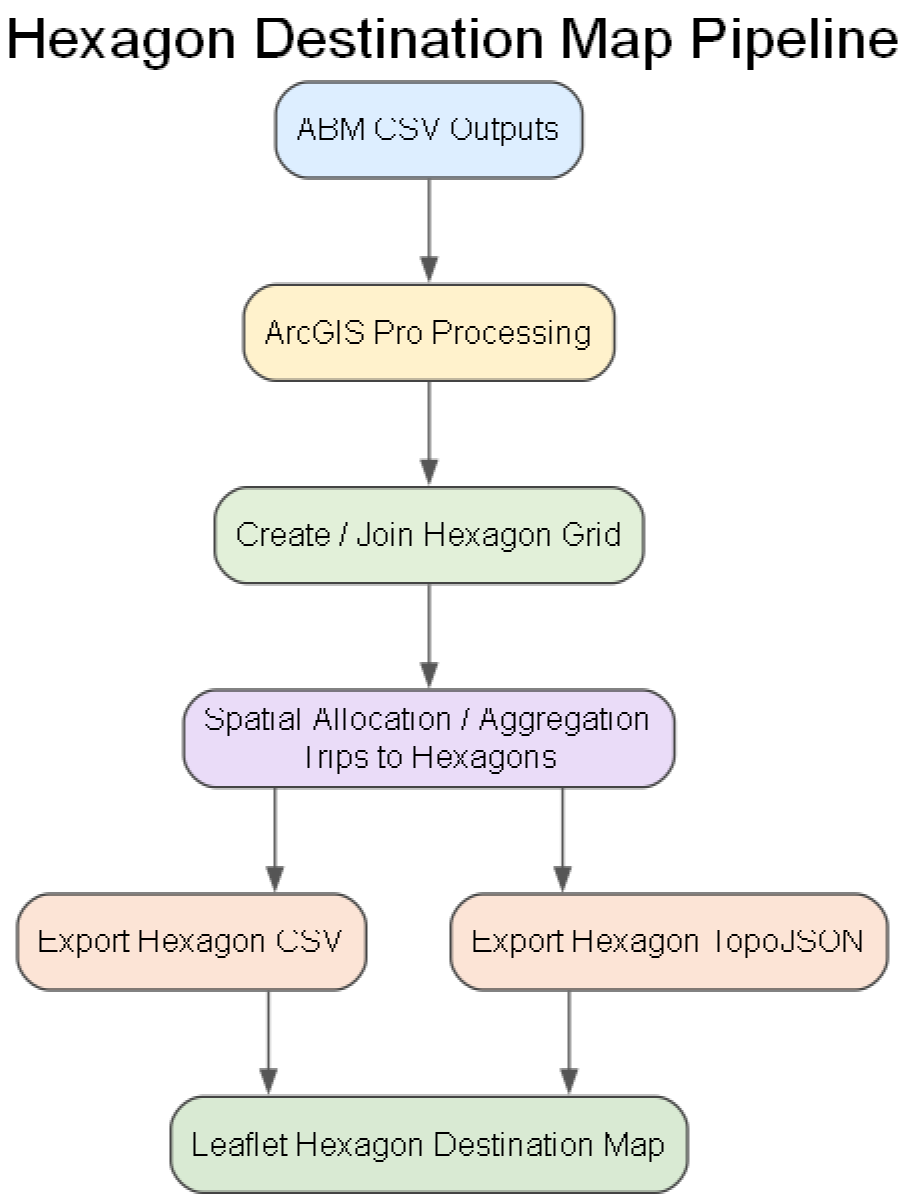
- Time Use


Time Use Activity Reconstruction Pipeline
ABM tripdata
ABM persondata
ABM hhdata validation check
sanity check
Create 48 Time Periods
Clean Person ID, Purpose, Periods, Person Type
Trip-Based Activity Presence by Period + Purpose
Home-Only Pattern HOME All Day
After Last Trip Assign HOME
Combine Activity Sources
Relabel Purposes ATWORK, OTHMAINT, OTHDISCR
Add ALL Persons Roll-Up
abm_YEAR.timeuse [person_type, per, orig_purpose, quantity]
Dashboard Time-Use Chart

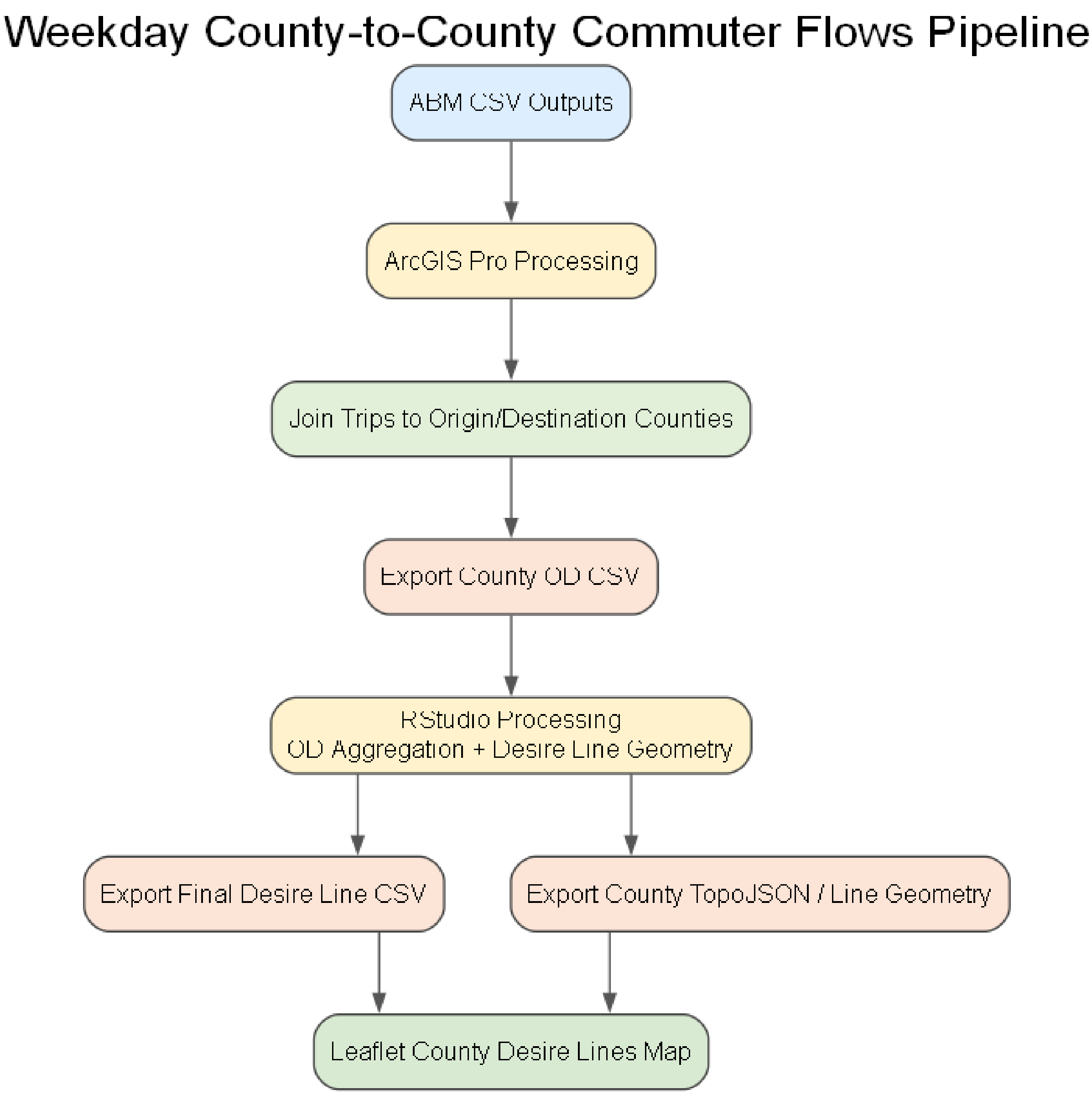
- Tree-Map


TreeMap Trips by Mode Pipeline
ABM tripdata
Create simplemodes Lookup
Detailed → Nest → Simple
Join trip_mode_name
to simplemodes
Group by
Simple Mode + Nest Mode + Detailed Mode
abm_YEAR."TreeMapData"
[TRIPS BY MODE, NEST MODE, SIMPLE MODE, QUANTITY]
Dashboard TreeMap

- Trips By Destination Hexagon Map



- Weekday County to County Commuting Flow



# 4. Applications and Technology Stack

## 4.1 Database Environment

The backend system is built on the PostgreSQL relational database management system, designed to efficiently store, manage, and query large-scale Activity-Based Model (ABM) outputs.

- **Schema-Based Architecture**
  Each forecast year and scenario (e.g., 2020, 2030, 2050, 2050 No-Build) is stored in a dedicated schema.
  This structure:
  - Prevents data overwriting
  - Enables direct cross-scenario comparisons
  - Supports reproducible analytical workflows
- **Core Tables and Data Structure**
  The database includes:
  - tripdata: detailed trip-level records (origin, destination, mode, purpose)
  - persondata: demographic and household attributes
  - zonedata: TAZ-level attributes
- **Data Type Standardization and Joins**
  Special attention was required to ensure consistency across datasets:
  - Conversion of geographic identifiers (e.g., TAZ, FIPS) to consistent string formats
  - Handling mismatches between numeric and text fields during joins
  - Use of lookup tables (e.g., TAZ-to-county mappings) for aggregation
- **Query Optimization**
  Aggregation-heavy queries (e.g., OD flows) were optimized using:
  - Indexed join keys
  - Pre-aggregated tables for visualization
  - Scenario-specific materialized outputs exported as CSV

## 4.2 Spatial Processing and Data Transformation Pipeline

Spatial preprocessing and transformation were conducted using a combination of ArcGIS Pro, RStudio, and GeoJSON-based workflows to ensure accurate and scalable geographic representations.

### a. Boundary Preparation and Validation

- Geographic boundaries (TAZ, county, hexagon grids) were processed and validated in ArcGIS Pro
- Ensured alignment between ABM zone definitions and visualization layers

- Converted shapefiles into GeoJSON/TopoJSON formats for web-based rendering

### b. Trip Aggregation (R-Based Processing)

Trip-level ABM outputs were processed in R to generate aggregated Origin–Destination (OD) datasets.

- Aggregation steps included:
    - Grouping trips by origin and destination zones
    - Summarizing trip counts by mode (SOV, HOV, transit) and purpose
    - Filtering and thresholding to reduce noise in low-volume flows
- County-to-county OD matrices were generated by:
    - Mapping TAZs to counties using lookup tables
    - Aggregating trips at the county level
    - Exporting results as lightweight CSV files for frontend rendering

### c. Spatial Normalization via Hexagonal Grids

A key limitation of Traffic Analysis Zones (TAZs) is their **uneven spatial size**, which introduces bias in visualization and spatial analysis. To address this, a hexagon-based spatial normalization approach was implemented.

- TAZ polygons were converted into a uniform grid of **1-square-mile hexagons**
- Trips were proportionally allocated using an area-weighted method based on spatial overlap

This allocation follows:

Allocated Trips = TAZ Trips x (fragment Area/TAZ Area)

- This method:
    - Reduces distortion caused by large rural TAZs vs. small urban TAZs
    - Produces smoother and more consistent spatial patterns
    - Improves visual interpretability in choropleth and density maps

### d. Data Export and Frontend Integration

Processed datasets were exported as structured CSV files and integrated into the visualization platform:

- Scenario-specific folders (e.g., MTP24_2020, MTP24_2050) contain:
  - OD flow tables
  - Aggregated metrics
  - Mode-specific summaries
- GeoJSON/TopoJSON boundary files are stored separately and linked dynamically
- The frontend (D3.js + Leaflet) consumes:
  - CSV data for attributes and flows
  - GeoJSON for spatial rendering

While PostgreSQL was used for large-scale aggregation and transformation, ArcGIS Pro was utilized for spatial preprocessing tasks such as boundary alignment and hexagon generation. R was selectively applied for flexible aggregation and transformation of county-level OD flows, where scripting provided greater control over data restructuring.

# 4.3 Frontend Architecture and Dashboard Operation

## 4.3.1 Overview

The ABMVIZ frontend serves as the interactive presentation layer of the Activity-Based Model (ABM) analytical pipeline. Its primary function is to ingest pre-aggregated model outputs and render them as interactive spatial and analytical visualizations within a web-based environment(ChatGPT, 2026).

The frontend is designed to:

- Load structured datasets generated from PostgreSQL
- Integrate tabular data with geographic boundary files
- Render interactive visualizations using JavaScript libraries
- Enable user-driven filtering and scenario comparison

This section describes the technical architecture, rendering logic, and interaction workflow of the dashboard.

## 4.3.2 Frontend Architecture

The frontend follows a modular client-side architecture consisting of four primary components:

### *4.3.2.1 Data Loading Layer*

This layer is responsible for:

- Loading structured CSV datasets generated from SQL scripts
- Loading GeoJSON boundary files (TAZ or Superdistrict)

- Parsing datasets into memory
- Validating required attributes before rendering

Data are hosted in a static environment (e.g., GitHub Pages) and fetched asynchronously using JavaScript.

#### *4.3.2.2 Data Binding and Join Logic*

Once datasets are loaded:

- Zone-level attributes are joined to GeoJSON features using a shared key (e.g., ZONE)
- OD datasets are indexed by origin and destination identifiers
- Aggregated summary tables are structured for chart rendering

A critical requirement is strict field consistency between:

- CSV zone identifiers
- GeoJSON property keys

Failure to maintain consistent data types (e.g., numeric vs text identifiers) prevents successful binding and halts map rendering.

### 4.3.2.3 Visualization Modules

The frontend consists of multiple interactive visualization modules, each designed to support a specific aspect of travel behavior analysis. While each module operates independently, all are synchronized through shared filters (scenario, geography, mode, and time).

**a. Choropleth Mapping (Leaflet)**

- Renders zone-based thematic maps (TAZ, county, or hexagon level)
- Applies dynamic color scales based on selected attributes
- Supports hover tooltips and click-based inspection
- Updates in real time with scenario and filter changes

**b. OD Desire Line Visualization**

- Displays directional flows between origin and destination zones
- Line thickness is proportional to trip volume
- Supports filtering by trip purpose, mode, and thresholds
- Uses pre-aggregated data to reduce rendering overhead

**c. Trips by County (Aggregated OD Visualization)**

- Visualizes inter-county travel flows
- Aggregates OD data to a higher spatial level for clarity

- Supports mode-based filtering (SOV, HOV, transit)
- Reduces visual clutter compared to TAZ-level desire lines

**d. Trip Destinations Analysis**

- Highlights major destination zones for selected origins or regions
- Supports ranking and filtering of high-attraction areas
- Useful for identifying employment and activity centers

**e. Radar Charts (D3.js)**

- Compares multidimensional attributes such as mode share or trip purpose
- Requires wide-format structured data
- Scales dynamically across scenarios and forecast years

**f. Tree-map and Bar Charts (D3.js)**

- Displays hierarchical and categorical breakdowns (mode, purpose)
- Enables quick comparison of relative proportions
- Fully interactive and synchronized with global filters

**g. Sunburst Diagram**

- Visualizes hierarchical relationships in trip data (e.g., purpose → mode)
- Provides an intuitive drill-down exploration of travel behavior
- Complements tree-map visualizations for deeper hierarchy insight

**h. Time Use Visualization**

- Represents distribution of activities across time-of-day
- Helps identify peak travel and activity periods
- Supports temporal filtering and scenario comparison

**i. Trip Mode Analysis**

- Focuses specifically on mode share distributions
- Enables comparison across scenarios and geographic areas
- Supports policy analysis related to mode shifts

**j. Persons Not at Home Analysis**

- Displays population activity patterns over time
- Indicates when and where people are active outside their homes
- Useful for validating ABM temporal outputs

**k. Grouped Data Visualization**

- Aggregates data by user-defined categories (e.g., income, purpose, geography)
- Supports flexible segmentation for exploratory analysis
- Provides summarized insights across multiple dimensions

**l. Transit Visualization**

- Highlights transit-specific trips and flows
- Allows isolation of transit demand patterns
- Supports evaluation of transit system performance

**m. 3D Temporal Animation**

- Animates trip intensity across time-of-day
- Shows evolution of travel demand dynamically
- Supports peak-period and congestion pattern analysis

### 4.3.3 Interaction Workflow

The dashboard interaction process follows a consistent logic sequence:

1. User selects forecast year or scenario
2. Filter state is updated
3. Relevant dataset is retrieved or filtered in memory
4. Visual components re-render dynamically
5. Tooltips and legends update accordingly

All updates occur client-side without server refresh, enabling smooth interactivity.

### 4.3.4 Performance Optimization

To maintain frontend responsiveness:

- Data are pre-aggregated in SQL prior to export
- Large OD matrices are threshold-filtered
- Rendering is limited to selected geographic extents
- Unnecessary DOM reflows are minimized
- Data joins occur once at load time

This reduces browser load and improves rendering speed for large datasets.

### 4.3.5 Error Handling and Debugging

Common frontend failure points include:

- Key mismatches between CSV and GeoJSON
- Missing attribute fields
- Undefined dataset references
- Excessive OD line rendering causing performance degradation

Mitigation strategies implemented include:

- Explicit identifier standardization in backend
- Dataset validation before rendering
- Console-based debugging
- Incremental layer rendering

### 4.3.6 Deployment Structure

The frontend is deployed as a static web application with:

- JavaScript visualization scripts
- Hosted CSV datasets
- GeoJSON boundary files
- Modular file organization

This architecture ensures portability and ease of version control.

# 5. Raw Data and Attributes

## 5.1 Data Sources and Attribute Structure

The ABMVIZ framework integrates multiple layers of output from the Atlanta Regional Commission Activity-Based Model (ABM), stored in a structured PostgreSQL environment and processed for web-based visualization.

The primary data sources include:

- Zone-level data (socioeconomic forecasts and land use)
- Trip-level data (disaggregate ABM outputs)
- Origin–Destination (OD) flow tables (aggregated movements)
- Time-use/activity data (daily behavioral patterns)

These datasets are distributed across scenario-specific schemas (e.g., abm_2020, abm_2050) and transformed into lightweight CSV files for frontend consumption.

To support consistent analysis and visualization, attributes were organized into four major categories:

(1) Zone-level, (2) Trip-level, (3) OD flow, and (4) Time-use attributes.

# 5.2 Zone-Level Attributes

Zone-level attributes represent aggregated socioeconomic and demographic characteristics associated with each Traffic Analysis Zone (TAZ) or modeling geography.

Key attributes include:

- Zone (unique spatial identifier)
- Population
- Employment
- Number of Households
- Income Class

Usage in ABMVIZ:

Choropleth mapping at the TAZ level

Input layer for higher-level aggregation

Scenario comparison of spatial growth patterns

Important note:

While TAZs serve as the base spatial unit, most flow-based analyses are aggregated to the county level to improve interpretability and reduce visual clutter.

# 5.3 Trip-Level Attributes

Trip-level records represent individual simulated trips generated by the ABM and serve as the foundation for all behavioral and flow-based analyses.

**Core attributes include:**

- orig_taz (origin zone)
- dest_taz (destination zone)
- mode (travel mode classification)
- purpose (trip purpose: work, school, discretionary, etc.)
- tod (time-of-day period)
- participants or trips (expansion factor representing trip volume)

**Derived mode groupings used in the system:**

- SOV (single-occupancy vehicle)
- HOV (high-occupancy vehicle)
- TRN (transit)
- ALL (total trips)

**Processing approach:**

- Raw trip-level data are **not directly visualized** due to size and performance constraints
- Aggregations are performed in R and SQL to generate:
  - OD flow tables
  - Mode summaries
  - Time-of-day distributions

This reduces computational load while preserving key behavioral patterns.

# 5.4 Origin–Destination Flow Attributes

OD flow datasets summarize directional movement between origins and destinations and are central to multiple visualization modules.

**Key attributes include:**

- ORIG, DEST (TAZ or county identifiers)
- ALLALL (total trips)
- ALLSOV, ALLHOV, ALLTRN (mode-specific totals)
- WRKALL, NWKALL (work vs. non-work trips)

## County-Level Aggregation Strategy

To improve visualization clarity and align with planning practice, OD flows are **aggregated from TAZ-to-TAZ to county-to-county level**.

**Process:**

- TAZs are mapped to counties using FIPS or lookup tables
- Trips are summed across all TAZ pairs within each origin–destination county pair
- Mode-specific and purpose-specific totals are preserved

**Why this matters (don't skip this):**

- Eliminates excessive overlap in desire line visualization
- Produces cleaner, interpretable flow maps
- Aligns with ARC's regional planning and reporting scale
- Enables faster rendering in browser-based visualization

### Usage in ABMVIZ:

- County-to-county desire line maps
- Mode-filtered flow exploration (SOV, HOV, transit)
- Scenario comparison at a policy-relevant scale

## 5.5 Time-Use Attributes

Time-use datasets represent simulated daily activity patterns for individuals and households, capturing how time is allocated across activities.

**Key attributes include:**

- activity_type (e.g., home, work, school, discretionary)
- duration (time spent in activity)
- time_block (hourly or grouped time periods)
- location_type (activity location classification)

**Usage in ABMVIZ:**

- Time-of-day visualizations
- Activity distribution charts
- Temporal demand analysis (peak vs. off-peak behavior)

This module provides insight into **when** travel demand occurs, complementing OD-based spatial analysis.

# 6. Quality Assurance and Quality Control (QA/QC) Procedures

Robust Quality Assurance and Quality Control (QA/QC) procedures were implemented to ensure the reliability, reproducibility, and analytical validity of the visualization outputs generated from the Activity-Based Model (ABM). Because ABM datasets contain large volumes of trip-level and zone-level records across multiple forecast scenarios, systematic validation is necessary to prevent errors from propagating through the data processing pipeline and into downstream analytical tools and visualization environments (Federal Highway Administration, 2010; Atlanta Regional Commission, 2017).

The QA/QC process was integrated throughout the analytical workflow, from database extraction to frontend visualization rendering. Data validation steps included verifying the integrity of source tables in PostgreSQL, confirming consistency of aggregated outputs across model years, and ensuring that spatial identifiers correctly matched geographic boundary files used in the visualization environment. Similar validation procedures are recommended in travel demand modeling practice to ensure that model outputs remain internally consistent and interpretable across multiple scenarios and datasets (Federal Highway Administration, 2010).

Additional checks were conducted during the data transformation stage to verify that key variables—including origin and destination zones, trip counts, and time-of-day classifications—were correctly aggregated and formatted for visualization. Particular attention was given to ensuring compatibility between tabular model outputs and spatial boundary files used in the dashboard. Because geographic features were stored in GeoJSON format while zone identifiers in the model database were numeric, explicit type conversion and identifier standardization were applied during data preparation to ensure accurate spatial joins and prevent visualization errors (ChatGPT, 2026).

These validation procedures help ensure that the dashboard accurately reflects the underlying model outputs and provides a reliable analytical interface for exploring regional travel behavior (ChatGPT, 2026).

# 6.1 Data Integrity Validation

The following validation checks were performed across all forecast-year schemas:

- **Row Count Verification:** Confirmed consistency of record counts across schemas to detect incomplete exports or missing data (ChatGPT, 2026).
- **Cross-Year Consistency Checks:** Compared aggregate trip totals and mode shares across forecast years to identify unexpected discontinuities (ChatGPT, 2026).
- **NULL Value Detection:** Identified and resolved missing zone identifiers or trip attributes prior to export (ChatGPT, 2026).
- **Duplicate OD Pair Detection:** Verified uniqueness of ORIG–DEST pairs after aggregation (ChatGPT, 2026).
- **Negative Trip Validation:** Ensured no negative trip volumes existed due to transformation or aggregation errors (ChatGPT, 2026).

These checks were automated within the SQL pipeline wherever possible to minimize manual error.

# 6.2 Spatial Quality Assurance

A critical issue identified during development involved data type incompatibility between model outputs and spatial boundary files(ChatGPT, 2026).

### Identified Issue

The `ZONE` field was exported as a numeric integer from PostgreSQL, while the GeoJSON boundary file stored zone identifiers as text strings. This mismatch prevented successful joins within the ABMVIZ frontend, resulting in:

- Choropleth maps failing to render
- Desire line layers crashing
- JavaScript runtime errors (e.g., undefined property references such as `ALLALL`)

### Resolution Strategy

To resolve this issue, the following corrective measures were implemented:

- Explicit casting of `ZONE` identifiers using `CAST(ZONE AS TEXT)` within SQL scripts
- Enforced quoted CSV export formatting
- Verified one-to-one joins between CSV outputs and GeoJSON keys prior to frontend deployment

This correction restored spatial integrity and ensured consistent rendering across all visualization modules.

# 7. Practical Applications for ARC

The implemented ABMVIZ dashboard provides operational value to the Atlanta Regional Commission (ARC) by transforming high-dimensional Activity-Based Model (ABM) outputs into interactive, decision-support tools. Rather than relying on static tables or pre-generated maps, planners can dynamically explore spatial, temporal, and behavioral patterns in travel demand.

## 7.1 Scenario Comparison and Policy Evaluation

The system enables direct comparison between alternative scenarios, such as **2050 Build vs. 2050 No-Build**, across multiple analytical dimensions.

- Users can evaluate:
    - Changes in trip distribution across TAZs and counties
    - Mode share shifts (SOV, HOV, transit)
    - Spatial redistribution of demand under infrastructure investments
- Unlike traditional workflows (manual SQL extraction → GIS mapping → static export), the dashboard:
    - Eliminates repetitive data processing
    - Enables real-time filtering and visual comparison
    - Supports iterative policy testing

This significantly reduces analysis time and allows planners to focus on interpretation rather than data preparation.

## 7.2 Equity and Environmental Justice Analysis

The dashboard supports equity-focused planning by enabling disaggregation of travel behavior across socioeconomic groups.

- Key capabilities include:
    - Visualization of trip generation by income class
    - Comparison of accessibility patterns across geographic areas
    - Identification of underserved or transit-dependent populations
- Spatial overlays allow planners to detect:
    - Disparities in mobility outcomes
    - Uneven distribution of infrastructure benefits
    - Potential inequities in future scenario investments

This functionality aligns with federal requirements for **environmental justice and equitable transportation planning**, strengthening ARC's compliance and reporting capabilities.

## 7.3 Congestion and Temporal Dynamics Communication

The inclusion of 3D temporal animation and time-of-day analysis introduces a dynamic understanding of congestion patterns.

- The system enables:
    - Visualization of peak-period demand buildup (AM/PM peaks)
    - Identification of temporal bottlenecks
    - Exploration of how congestion evolves throughout the day
- This is particularly valuable for:
    - Presentations to policymakers and stakeholders
    - Explaining why congestion is not static but time-dependent
    - Supporting strategies such as demand management or peak spreading

Compared to static maps, this approach provides a far more intuitive representation of system performance.

## 7.4 Investment Prioritization and Funding Justification

The dashboard supports data-driven investment decisions by identifying spatial concentrations of travel demand and growth.

- Planners can:
    - Detect high-growth corridors and emerging hotspots
    - Analyze OD flows to understand regional connectivity needs
    - Evaluate which areas benefit most from proposed projects
- This directly supports:
    - Long-range transportation plans (LRTP)
    - Transportation Improvement Program (TIP) prioritization

- Grant applications and funding justifications

By linking model outputs to clear visual evidence, the system strengthens the case for targeted infrastructure investments.

### 7.5 Public Engagement and Stakeholder Communication

The transition from static reports to interactive visualization significantly enhances public communication.

- The dashboard allows:
  - Non-technical users to explore scenarios independently
  - Interactive filtering to answer "what-if" questions in real time
  - Clear visualization of complex modeling outputs
- Benefits include:
  - Increased transparency in planning decisions
  - Improved stakeholder trust and engagement
  - Reduced reliance on technical intermediaries

This is particularly important in public meetings, where static PDFs often fail to convey the full implications of model forecasts.

### 7.6 Data Exploration and Internal Workflow Efficiency

Beyond external communication, the dashboard improves internal analytical workflows.

- Analysts can:
  - Quickly validate model outputs (QA/QC)
  - Identify anomalies or inconsistencies in spatial patterns
  - Explore relationships between variables without writing new queries
- This reduces:
  - Dependency on repeated database queries
  - Time spent generating custom maps for each request
  - Friction between modeling teams and planning staff

The result is a more agile and responsive analytical environment within ARC.

# 8. Future Enhancements

The adopted visualization is reproducible, yet there are several improvements could be applied to make it more automated and scalable:

- Direct connect to data using APIs instead of export and uploading CSV files;

- Establish a spatial database environment using PostGIS;
- Conduct a more interactive dashboard in which users are allowed to filter and change demographic characteristics dynamically.
- For large origin-destination datasets, using WebGL rendering can be a good alternative to improve visualization performance.
- Plugin external datasets such as LODES and LEHD to validate model outputs.

With these upgrades, ABMVIZ could move beyond being just a visualization tool and become a fully automated, enterprise-level analytics platform.

# 9. Strategic Value to ARC

The ABMVIZ framework provides measurable institutional value to ARC by:

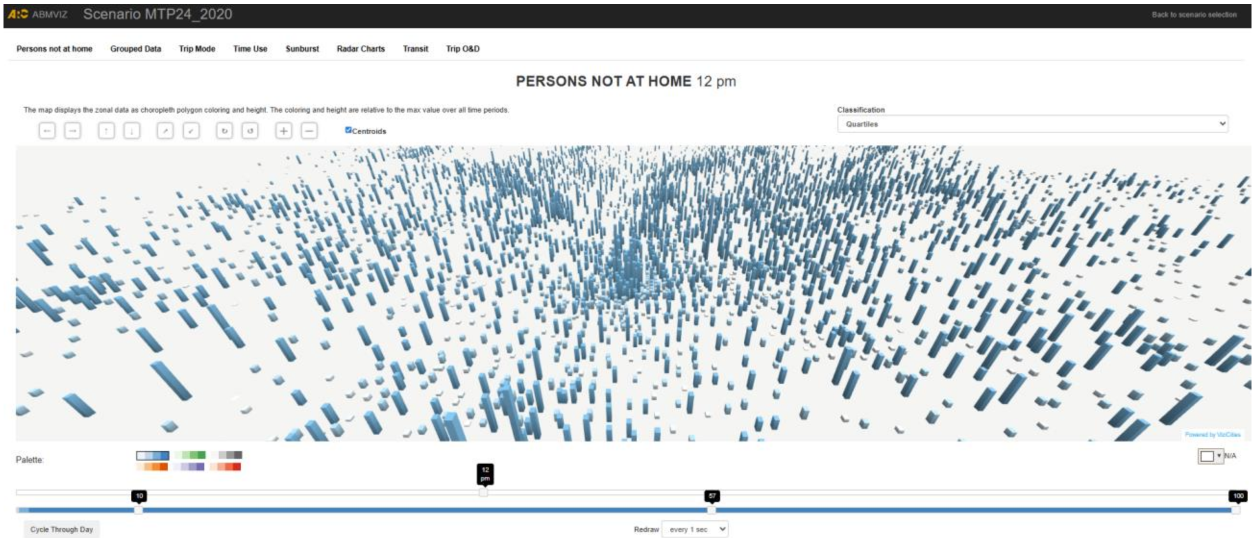
- Reducing analyst processing time through automated aggregation
- Improving transparency of regional travel forecasts
- Enhancing communication between technical staff and decision-makers
- Strengthening MPO credibility through defensible visualization tools
- Establishing a reproducible and scalable analytical workflow

Without such a framework, ABM outputs remain fragmented across schemas and database tables, limiting their accessibility and communicative effectiveness.

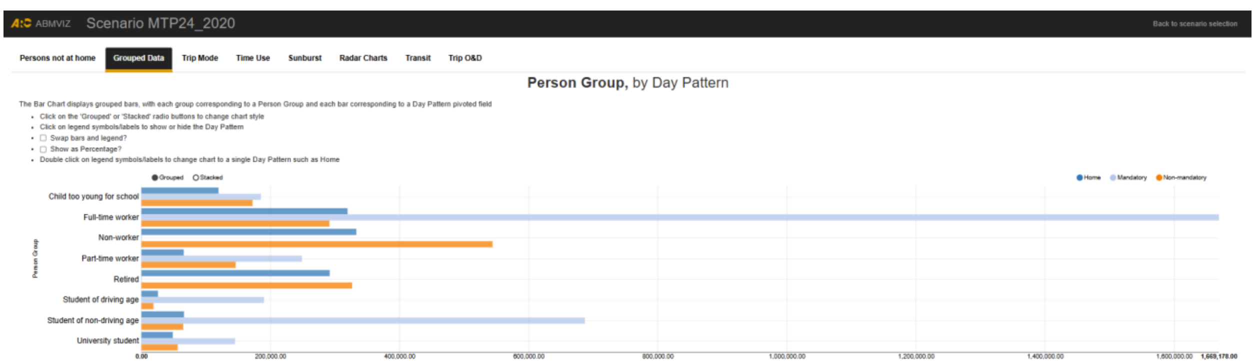
With ABMVIZ, ARC gains a structured decision-support environment that bridges modeling, policy evaluation, and stakeholder communication.

# APPENDIX

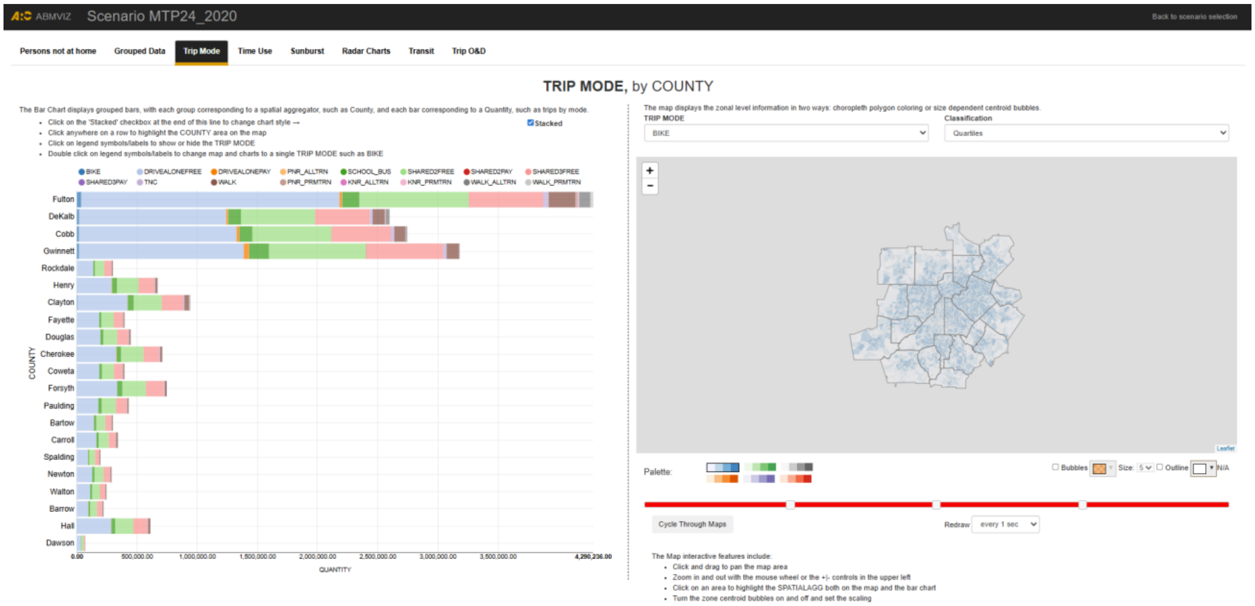
## Persons Not At Home




# Grouped Data



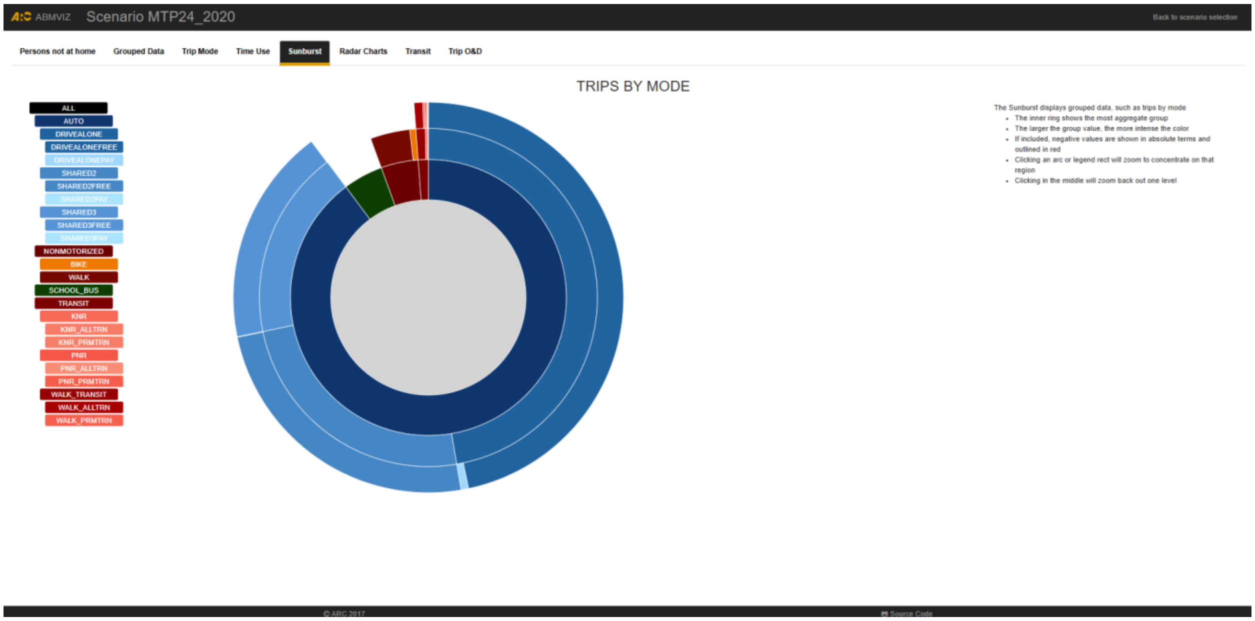

# Trip Mode


ABMVIZ Scenario MTP24_2020
Back to scenario selection
Persons not at home
Grouped Data
Trip Mode
Time Use
Sunburst
Radar Charts
Transit
Trip O&D
TRIP MODE, by COUNTY
The Bar Chart displays grouped bars, with each group corresponding to a spatial aggregator, such as County, and each bar corresponding to a Quantity, such as trips by mode.
Click on the 'Stacked' checkbox at the end of this line to change chart style →
Click anywhere on a row to highlight the COUNTY area on the map
Click on legend symbols/labels to show or hide the TRIP MODE
Double click on legend symbols/labels to change map and charts to a single TRIP MODE such as BIKE
Stacked
BIKE
DRIVEALONEFREE
DRIVEALONEPAY
PNR_ALLTRN
SCHOOL_BUS
SHARED2FREE
SHARED2PAY
SHARED3FREE
SHARED3PAY
TNC
WALK
PNR_PRMTRN
KNR_ALLTRN
KNR_PRMTRN
WALK_ALLTRN
WALK_PRMTRN
Fulton
DeKalb
Cobb
Gwinnett
Rockdale
Henry
Clayton
Fayette
Douglas
Cherokee
Coweta
Forsyth
Paulding
Bartow
Carroll
Spalding
Newton
Walton
Barrow
Hall
Dawson
COUNTY
0.00
500,000.00
1,000,000.00
1,500,000.00
2,000,000.00
2,500,000.00
3,000,000.00
3,500,000.00
4,290,236.00
QUANTITY
The map displays the zonal level information in two ways: choropleth polygon coloring or size dependent centroid bubbles.
TRIP MODE
BIKE
Classification
Quartiles
Leaflet
Palette:
Bubbles
Size:
Outline
N/A
Cycle Through Maps
Redraw
every 1 sec
The Map interactive features include:
Click and drag to pan the map area
Zoom in and out with the mouse wheel or the +/- controls in the upper left
Click on an area to highlight the SPATIALAGG both on the map and the bar chart
Turn the zone centroid bubbles on and off and set the scaling

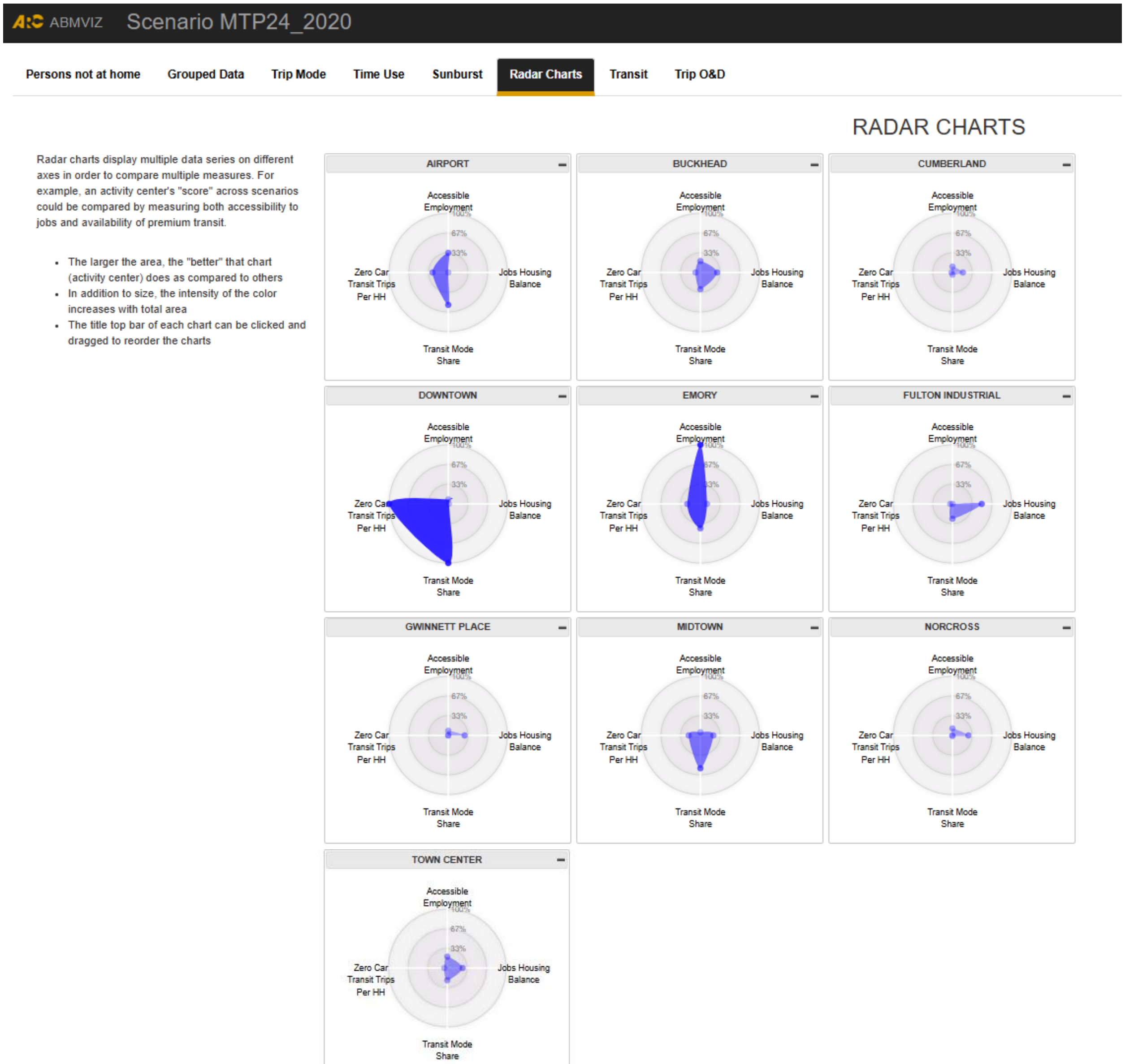
# Time Use


ABMVIZ Scenario MTP24_2020
Back to scenario selection
Persons not at home
Grouped Data
Trip Mode
Time Use
Sunburst
Radar Charts
Transit
Trip O&D
TIME USE
Time Use displays person out-of-home travel purpose by time of day. The vertical axis displays the sum or percent of activity and the horizontal axis displays the period of the day.
Select a person type below to filter the data
Click on legend symbols/labels to show or hide the purpose
Select stacked to show absolute numbers or expanded to show percents
ALL
CHILD TOO YOUNG FOR SCHOOL
FULL-TIME WORKER
NON-WORKER
PART-TIME WORKER
RETIRED
STUDENT OF DRIVING AGE
STUDENT OF NON-DRIVING AGE
UNIVERSITY STUDENT
Stacked
Expanded
HOME
EATOUT
ESCORT
OTHER DISCRETIONARY
OTHER MAINTENANCE
SHOPPING
SOCIAL
WORK SUB-TOUR
UNIVERSITY
SCHOOL
WORK
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
© ARC 2017
Source Code

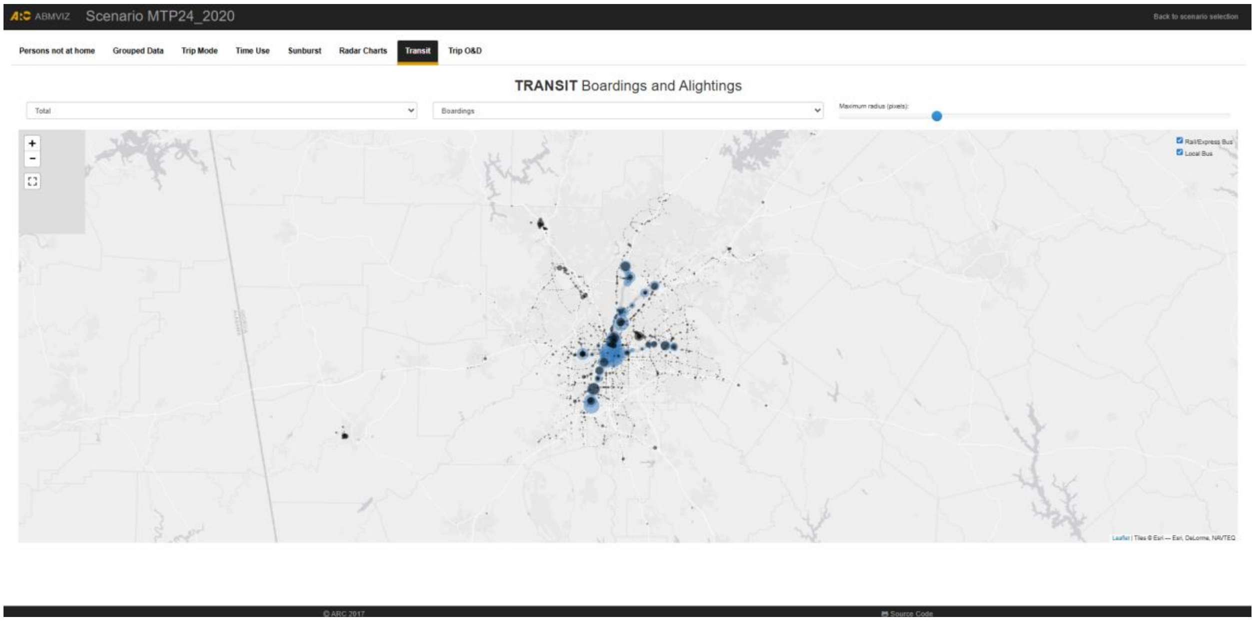
# Sunburst


ABMVIZ
Scenario MTP24_2020
Back to scenario selection
Persons not at home
Grouped Data
Trip Mode
Time Use
Sunburst
Radar Charts
Transit
Trip O&D
TRIPS BY MODE
ALL
AUTO
DRIVEALONE
DRIVEALONEFREE
DRIVEALONEPAY
SHARED2
SHARED2FREE
SHARED2PAY
SHARED3
SHARED3FREE
SHARED3PAY
NONMOTORIZED
BIKE
WALK
SCHOOL_BUS
TRANSIT
KNR
KNR_ALLTRN
KNR_PRMTRN
PNR
PNR_ALLTRN
PNR_PRMTRN
WALK_TRANSIT
WALK_ALLTRN
WALK_PRMTRN
The Sunburst displays grouped data, such as trips by mode
The inner ring shows the most aggregate group
The larger the group value, the more intense the color
If included, negative values are shown in absolute terms and outlined in red
Clicking an arc or legend rect will zoom to concentrate on that region
Clicking in the middle will zoom back out one level
© ARC 2017
Source Code

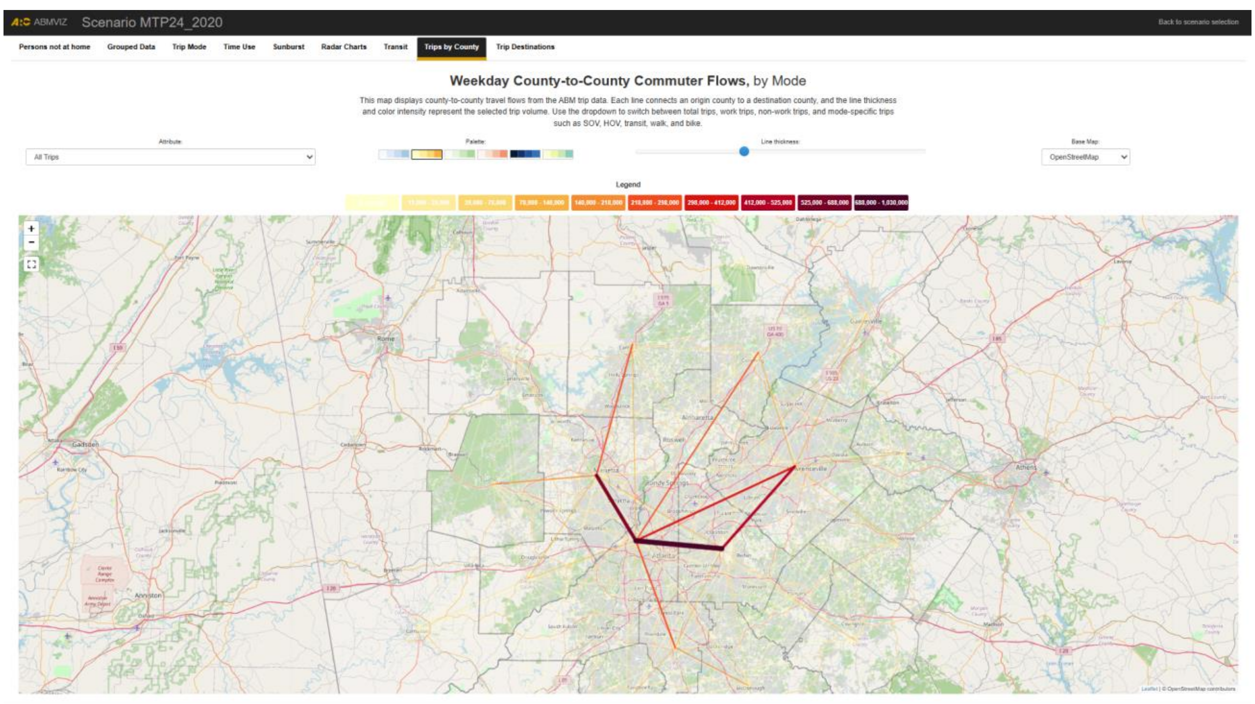
# Radar Charts



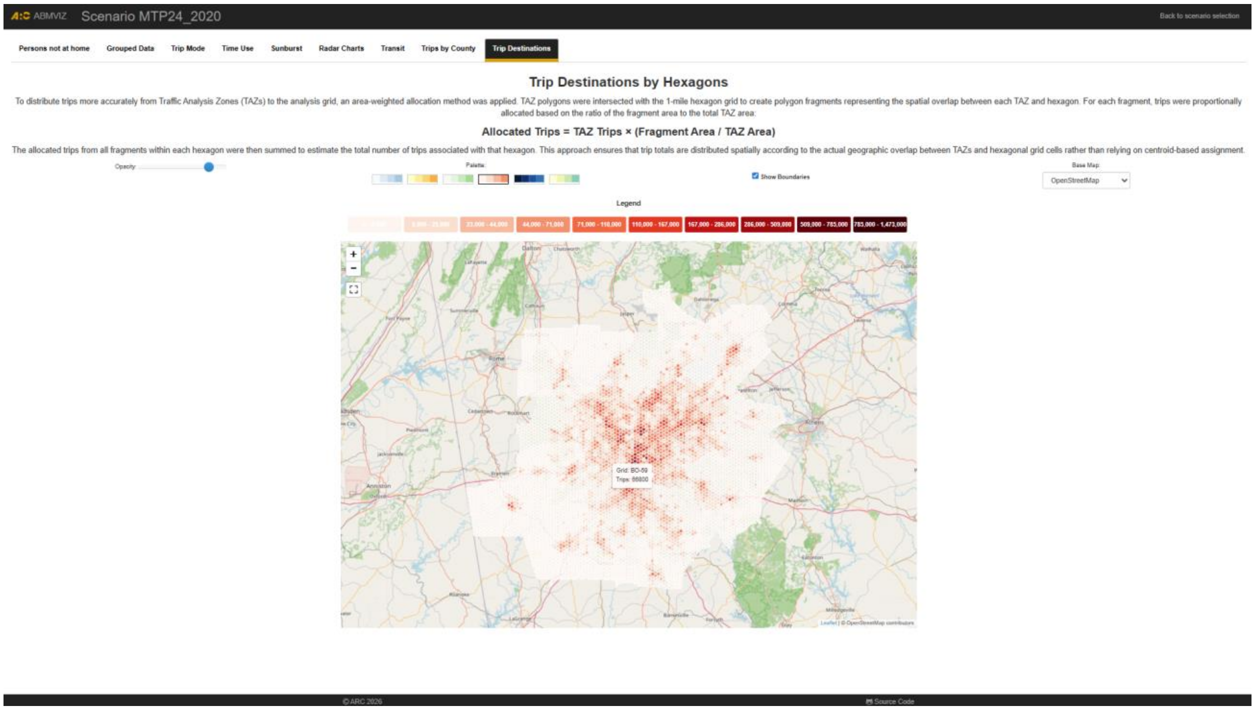
# Transit




# Trips by County



# Trips By Destinations



# References

Atlanta Regional Commission. (n.d.). Modeling.
https://atlantaregional.org/what-we-do/transportation-planning/modeling/Atlanta regional

Commission. (n.d.). ABMVIZ: Activity-Based Model visualization tool.
https://atlregional.github.io/ARC_Model/ABMVIZ.html

Marinelli, A., Rousseau, G., & Kim, K.
ARC Activity-Based Model Visualization Platform (ABMVIZ).
Transportation Research Board.

Atlanta Regional Commission. (2017).
Activity-Based Model user guide.
https://cdn.atlantaregional.org/wp-content/uploads/abm-user-guide-2017.pdf

Federal Highway Administration. (2010).
Travel demand modeling: Model validation and reasonableness checking manual.
U.S. Department of Transportation.

Bhat, C. R., & Koppelman, F. S. (1999). Activity-based modeling of travel demand. *Handbook of Transportation Science*.

Bowman, J. L., & Ben-Akiva, M. (2001). Activity-based disaggregate travel demand model system with activity schedules. *Transportation Research Part A*.

Hunt, J. D., & Abraham, J. E. (2005). Design and implementation of the PECAS land-use modeling system. *Transportation Research Record*.

Vovsha, P., Bradley, M., Bowman, J., & Ben-Akiva, M. (2013). The coordinated travel-regional activity-based modeling platform (CT-RAMP). *Transportation Research Record*.

OpenAI. (2026). ChatGPT (April 6 version) [Large language model]. https://chat.openai.com