

# Building a U.S. Census Data Explorer

## A Shiny Dashboard for ACS, Decennial Census, and LEHD Data

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# 1 Introduction

As a transportation planner, accessing and visualizing demographic and employment data is crucial for informed decision-making. The U.S. Census Bureau provides a wealth of information through various datasets, but navigating multiple APIs and data formats can be challenging. To streamline this process, I developed an interactive R Shiny dashboard that provides unified access to three major Census data sources:


- **American Community Survey (ACS)** - Detailed demographic and socioeconomic estimates
- **Decennial Census** - Complete population counts every 10 years
- **Longitudinal Employer-Household Dynamics (LEHD)** - Employment and commuting patterns

This post walks through the development process, key technical decisions, and lessons learned while building this data exploration tool.

## 2 Project Overview

The dashboard serves as a one-stop interface for Census data retrieval, featuring:

- Interactive geographic selection (state/county level)
- Variable selection through searchable tables
- Real-time data visualization on interactive maps
- Export capabilities for both tabular and geospatial data
- Responsive design optimized for different screen sizes

 **Repository:** You can find the complete source code and documentation at: <https://github.com/ar-puuk/uscensus-dashboard/>

## 3 Technical Architecture

### Core Dependencies

The application leverages several specialized R packages for Census data access and geospatial processing:

```
# Census data access
library(tidycensus) # ACS and Decennial Census API
library(lehdr)      # LEHD Origin-Destination data
library(tigris)     # Geographic boundaries

# Geospatial processing
library(sf)         # Simple features for spatial data
library(leaflet)    # Interactive mapping

# Shiny ecosystem
library(shiny)
library(shinydashboard)
```

```
library(shinyWidgets)
library(DT)           # Interactive data tables
```

## Application Structure

The app follows a modular design pattern with separate UI and server components for each data source. This approach enhances maintainability and allows for independent feature development.

```
# Modular UI components
acsUI <- fluidPage(...) # American Community Survey interface
censusUI <- fluidPage(...) # Decennial Census interface
lehdUI <- fluidPage(...) # LEHD interface

# Unified navigation
ui <- navbarPage(...)
```

## 4 Data Source Integration

### American Community Survey (ACS)

The ACS module provides access to detailed demographic estimates from 2009-2022. Key implementation features:

**Dynamic Variable Loading:** Variables are loaded based on the selected year and geographic level, ensuring users only see relevant options.

```
variables_acs <- reactive({
  if (!is.null(input$year_acs)) {
    variables <- load_variables(year = as.numeric(input$year_acs),
                               dataset = "acs5", cache = TRUE)
    # Filter variables based on geographic level
    if (input$level_acs == "tract") {
      variables <- variables |>
        filter(geography %in% c("tract", "block group"))
    }
    return(variables)
  }
})
```

**Geographic Hierarchy:** The interface maintains proper geographic relationships, with county options updating based on state selection.

### Decennial Census

The Decennial Census module focuses on the 2000, 2010, and 2020 complete counts, using the PL 94-171 dataset optimized for redistricting data.

**Streamlined Variable Selection:** Since Decennial Census has fewer variables than ACS, the interface emphasizes ease of use while maintaining the same interaction patterns.

### Longitudinal Employer-Household Dynamics (LEHD)

The LEHD module provides employment statistics and origin-destination flows, crucial for transportation planning applications.

**Version Management:** Different LODS versions cover different time periods, requiring dynamic year filtering:

```
observe({
  version <- if (!is.null(input$version_lehd)) input$version_lehd else
  "default"

  options <- if (version == "LODES5") {
    2002:2009
  } else if (version == "LODES7") {
    2002:2019
  } else {
    2002:2021
  }

  updateSelectInput(session, "year_lehd", choices = options, selected =
  max(options))
})
```

## 5 Interactive Mapping

### Base Map Configuration

The application uses Leaflet for interactive mapping, with a carefully chosen base layer that balances aesthetics and functionality:

```
default_map <- leaflet(options = leafletOptions(crs = leafletCRS())) |>
  addProviderTiles("CartoDB.Voyager") |>
  addPolygons(data = sf_states, color = "#222222", weight = 1, fillOpacity =
  0.15)
```

**CartoDB.Voyager** was selected for its clean design and good contrast with overlay data, though the code structure allows for easy switching between provider tiles.

### Dynamic Geographic Focus

Maps automatically adjust to show selected geographic areas, providing contextual awareness:

```
output$map_acs <- renderLeaflet({
  if (!is.null(input$state_acs) && input$state_acs != "") {
    selected_state_acs <- sf_states[sf_states$NAME == input$state_acs, ]
```

```

selected_bbox_acs <- sf::st_bbox(selected_state_acs)

default_map |>
  addPolygons(data = selected_state_acs, color = "#222222", weight = 4) |>
  fitBounds(selected_bbox_acs[[1]], selected_bbox_acs[[2]],
            selected_bbox_acs[[3]], selected_bbox_acs[[4]])
}
})

```

## 6 Data Export Functionality

### Flexible Format Support

Users can export data in multiple formats depending on their needs:

- **CSV files** for tabular analysis
- **Shapefiles (zipped)** for GIS applications

```

output$download_acs <- downloadHandler(
  filename = function() {
    if (input$geometry_acs) {
      paste0("acs_data_", input$state_acs, "_", input$year_acs, ".zip")
    } else {
      paste0("acs_data_", input$state_acs, "_", input$year_acs, ".csv")
    }
  },
  content = function(file) {
    if (input$geometry_acs) {
      write_sf_zip(data_acs(), file, overwrite = TRUE)
    } else {
      readr::write_csv(data_acs() |> st_drop_geometry(), file)
    }
  }
)

```

### Custom Shapefile Export

Since R's sf package doesn't directly export zipped shapefiles, I implemented a custom function to handle the complete shapefile format:

```

write_sf_zip <- function(obj, zipfile, overwrite = FALSE) {
  # Create temporary directory for shapefile components
  tmp <- tempfile()
  dir.create(tmp)
  on.exit(unlink(tmp, recursive = TRUE, force = TRUE))

  # Write shapefile and zip all components
  sf::write_sf(obj, file.path(tmp, shp_name), delete_layer = TRUE)
}

```

```
withr::with_dir(tmp, zip(tmp_zip, list.files()))

file.copy(file.path(tmp, tmp_zip), zipfile, overwrite = overwrite)
}
```

## 7 User Experience Considerations

### Variable Selection Interface

One of the biggest UX challenges was making Census variable selection intuitive. The solution uses modal dialogs with searchable data tables:

```
var_modal_acs <- modalDialog(
  title = h4("Select Variable(s) from the List"),
  DTOutput("var_table_acs"),
  size = "l",
  easyClose = TRUE,
  footer = actionButton("selectVarButton_acs", "Select Variable(s)")
)
```

This approach allows users to browse thousands of variables efficiently while maintaining a clean main interface.

### Responsive Geographic Selection

The cascading geographic selection (State → County → Geographic Level) follows familiar patterns while enforcing data availability constraints.

### Progress Feedback

API calls can take several seconds, so the interface provides clear feedback through action buttons and conditional panels that appear after data is loaded.

## 8 Performance Optimizations

### Caching Strategy

```
options(tigris_use_cache = TRUE) # Geographic boundaries
load_variables(..., cache = TRUE) # Variable metadata
```

Caching is enabled for static data like geographic boundaries and variable definitions, significantly reducing load times for repeat users.

### Data Processing Efficiency

For ACS data, margin of error columns are automatically removed to focus on estimates:

```
result_acs <- result_acs |>
  select(-matches("M$")) |> # Remove margin columns
  rename_all(~ sub("E$", "", .)) # Clean estimate column names
```

## 9 Deployment Considerations

### API Key Management

The application requires Census API keys but handles them securely through user input rather than hardcoding. This approach ensures:

- No sensitive credentials in source code
- Users maintain control over their API usage
- Easy deployment across different environments

### Error Handling

Robust error handling prevents crashes when API calls fail or users make invalid selections:

```
req(input$api_key_acs, input$year_acs, input$state_acs, input$county_acs,
    input$level_acs)
```

The `req()` function ensures all required inputs are available before processing.

## 10 Future Enhancements

Several features are planned for future releases:

- **Data Visualization:** Built-in charts and maps with Census data overlays
- **Comparison Tools:** Side-by-side analysis across years or geographies
- **Custom Geography:** Support for user-uploaded boundary files
- **Batch Processing:** Multiple state/year combinations in single requests
- **API Integration:** Direct connection to external GIS platforms

## 11 Conclusion

This Census data explorer demonstrates the power of R Shiny for creating specialized data access tools. By combining multiple Census APIs into a single interface, it significantly reduces the technical barrier for accessing demographic and employment data.

The modular architecture and attention to user experience make it a valuable tool for researchers, planners, and analysts who regularly work with Census data. The open-source approach ensures continued development and community contributions.

For transportation planners specifically, having easy access to demographic characteristics, employment patterns, and commuting flows in a single application streamlines the data gathering phase of project development, allowing more time for analysis and decision-making.

*Want to contribute or suggest improvements? Visit the project repository at: <https://github.com/arpuuk/uscensus-dashboard>*