Travel Demand Modeling with R

Jeremy Raw, Community Planner
Federal Highway Administration, US DOT*

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* Organization for identification only:
TravelR is NOT a project of FHWA

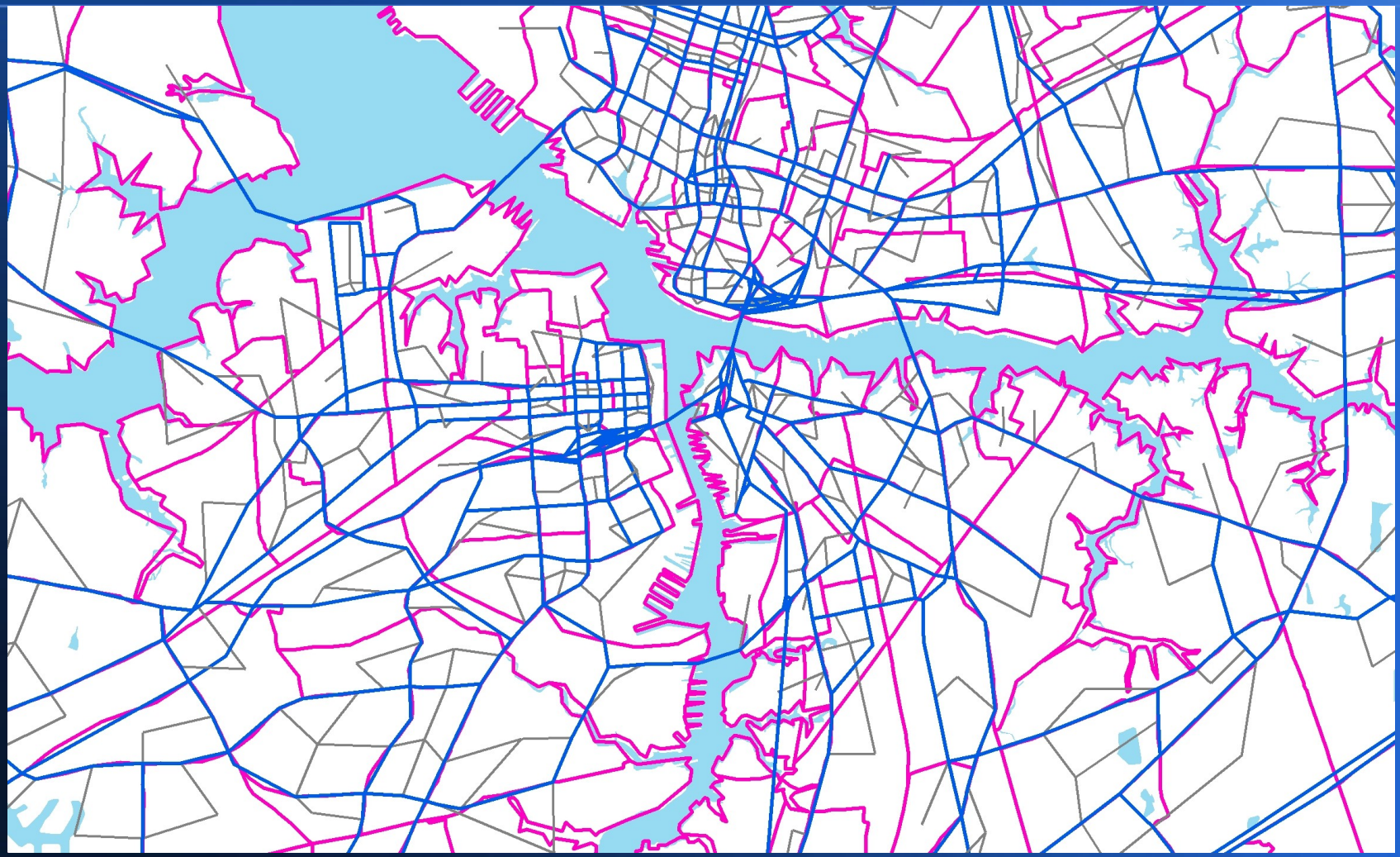
What is Travel Demand Modeling?

- Forecasting future demand and utilization of transport facilities
- Uses system structure and demographic data
  - Road and Transit Networks
  - Trip purpose
  - Population and Household structure
  - Economic activity

Scope of Travel Models

- Travel models are generalized over regions
  - Transportation Analysis Zones
  - Simplified highway and transit networks
- Often generalized over time periods
  - Estimates for the morning peak period…
  - … or perhaps an entire day

Zones and Network



Evolution of Travel Models

- Simplest models are “trip based”
  - How many trips on which routes
- More recent models may include
  - A simulation component (to capture bottlenecks)
  - Much greater detail on trip purpose and household structure
  - Extensive feedback to capture behavioral changes in response to system load

Basic Layout of a Travel Model

- Basic Modeling Operations
  - Trip or Tour Generation (e.g. Home to Work)
  - Network Skims (Zone to Zone travel costs)
  - Trip Distribution (Zone to Zone demand)
  - Mode Split (bus / auto / other)
  - Assignment (route actually chosen)
- These operations come in different flavors
  - Trip-based, Tour-based, Activity-Based
- Most models include feedback loops

Travel Modeling Computations

- Predictive Statistical models
  - For trip and activity demand
  - For mode share analysis
- Vector and Matrix computations
  - For trip distribution and tour formation
- Network analysis
  - “Best” paths, with congestion sensitivity

Why use R for Travel Modeling?

- Great presentation graphics
- Fast, efficient vector and matrix calculations
- Easy access to data stored in other formats
- Interactive and Easy to learn
  - Can replace spreadsheets
- Simple to script and to debug
- Provides tools for (almost) all computations

Who Does Travel Modeling in R?

- **R** is used frequently by individual modelers
- Oregon DOT has built their entire modeling program around **R**
  - Including GreenSTEP, a Greenhouse Gas analysis tool

What tools exist for Travel Modeling in R?

- Available **R** packages have supported most required computations
- The only noteworthy exception until recently has been *traffic assignment*
- The TravelR project aims to provide that functionality

Technical Goals of TravelR

- Provide missing functionality
  - Traffic Assignment
    - Multiple vehicle classes
    - Dynamic turn penalties
    - Select Link analysis
  - One-step Matrix Operations
    - Iterative Proportional Fitting
    - Redistricting

Community Goals of TravelR

- Encourage "open" travel models:
  - Clear assumptions
  - Documented algorithms and data
  - Easy to exchange ideas, research and models

A whole (simple) model in R (1)

```
data(SiouxFalls)

###################### Trip Generation ######################
productions<-rowSums(SiouxFalls.od)
attractions<-colSums(SiouxFalls.od)

###################### Highway Skims ########################
cost.function<-with(SiouxFalls.net$Links, function(...) FFTime)
aclass <- make.assignment.class(SiouxFalls.net, "All", SiouxFalls.od)
aset <- new.assignment.set(SiouxFalls.net,list(All=aclass),
                  cost.volume.type="vector", cost.function=cost.function)
paths <- build.paths(aset, aset$ff.cost)
travel.times <- skim.paths(paths,aset$ff.cost)[["All"]]
```

A whole (simple) model in R (2)

```
#################### Trip Distribution ############################
    base.distribution <- hwy.gamma.function(travel.times,-0.02,-0.123)
        • # HBW coefficients from NCHRP 365
    trip.table <- ipf(base.distribution,list(rows=productions,
                                cols=attractions),method="absolute")
    aset <- hwy.update.demand(aset,"All",trip.table)

#################### Trip Assignment ############################
    assignment.results <- highway.assign(aset,method="Frank.Wolfe")
    loaded.links <- assignment.results$volumes
```

TravelR: Highway Networks

- Highway network is a directed graph
- Edges (“Links”) have flow capacity attributes
- Privileged vertices (“centroid nodes”) correspond to sources and sinks for demand
  - Centroids are the center of a traffic zone
- TravelR can import networks from data tables

Basic Highway Path Operations

- Generate Shortest Paths
  - Span “centroids” only, not all vertices
- Compute (“skim”) path values
  - Apply function to a vector of attributes along a path
    - e.g. Add up total path distance or traversal time
  - Return a zone-to-zone matrix of values
- “Load” values from demand matrix onto shortest paths
  - Accumulate zone-to-zone values for each link in each path

Unique Requirements for Paths

- Turn Penalties
  - Path-based costs at junctions
    - Prohibited turns
    - Delay due to crossing traffic
- Select Link Analysis
  - Compute volume or skim values for selected paths
    - Intercepting (“Selecting”) a certain link or set of links
    - Between certain zone pairs

Highway Path Implementation

- Low Level Functions written in C++
- Features Include:
  - Optimized Shortest Path Building (zone to zone)
  - Low-level turn penalty management
  - Low-level link intercept management (select link)
  - Optimized Skim and Load operations
  - Simple R Interface

The Highway Assignment Problem

- The Highway Assignment problem:
  - Map a demand matrix onto network links
  - Link costs increase with flow volume
  - Generate minimum cost route allocation
- Common algorithms
  - Frank-Wolfe (Convex Combinations)
  - Many variations…

Unique Requirements for Assignment

- Multiple Vehicle Classes
  - Not all vehicle classes respond equally to congestion
    - Trucks versus Passenger Automobiles

Highway Assignment Implementation

- Assignment class defines
  - Network subset (e.g. HOV lanes removed)
  - Penalty subset (e.g. Rush hour no-left-turns)
  - Demand Matrix (zone to zone demand)
  - Cost Function (or “Volume/Delay Function”)
    - Controls how this class perceives cost increase due to increased link volume

Highway Assignment Implementation

- Assignment Set defines
  - A collection of Assignment Classes
    - Single-occupant vehicles
    - High-occupancy vehicles
    - Trucks
    - …
- Highway assignment finds optimum network flow for all classes in an Assignment Set

Directions for TravelR…

- Long-range goal:
  - A common platform for travel model research
- Travel modeling has been dominated by closed source, proprietary software
  - Slow rates of innovation
  - Difficulty communicating, testing and disseminating research results
- R is an ideal platform for interactive investigation of modeling strategies

Where to Find Out More?

- Travel Model Improvement Program

  http://tmip.fhwa.dot.gov

- The TravelR Package

  http://travelr.r-forge.r-project.org

  http://r-forge.r-project.org/projects/travelr

Why we Need Open Models

Find an elegant cartoon summary
of all that can go wrong with statistical models
here:

http://www.xkcd.com/605