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
data(SiouxFalls)

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

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

A whole (simple) model in R (1)
A whole (simple) model in R (2)

----------------------------- Trip Distribution -----------------------------

```r
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 --------------------------

```r
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