Route Choice

• Final step in sequential approach
  – Trip generation (number of trips)
  – Trip distribution (origins and destinations)
  – Mode choice (bus, train, etc.)
  – Route choice (specific roadways used for each origin and destination)

• Desired output from the traffic forecasting process: how many vehicles at any time on a roadway
Route choice decisions are primarily a function of travel times, which are determined by traffic flow.

Relationship can be captured in a variety of ways, including by highway performance function.
Outline

1. General
2. HPF Functional Forms
3. Basic Assumptions
4. Route Choice Theories
   a. User Equilibrium
   b. System Optimization
   c. Comparison
Basic Assumptions

1. Travelers select routes on the basis of route travel times only
   - People select the path with the shortest TT
   - Premise: TT is the major criterion, quality factors such as “scenery” do not count
   - Generally, this is reasonable

2. Travelers know travel times on all available routes between their origin and destination
   - Strong assumption: Travelers may not use all available routes, and may base TTs on perception

3. Travelers all make this choice at the same time
HPF Functional Forms

Common Non-linear HPF

\[ T = T_0 \left( 1 + \alpha \left( \frac{v}{c} \right)^\beta \right) \]

from the Bureau of Public Roads (BPR)
Speed vs. Flow

\[ q = k_j \left( u - \frac{u^2}{u_f} \right) \]

- Free Flow Speed \( u_f \)
- Uncongested Flow
- Congested Flow
- Highest flow, capacity, \( q_m \)
- \( q_m \) is bottleneck discharge rate
Theory of User Equilibrium

Travelers will select a route so as to minimize their personal travel time between their origin and destination. User equilibrium (UE) is said to exist when travelers at the individual level cannot unilaterally improve their travel times by changing routes.

Frank Knight, 1924
Wardrop’s 1st principle
“The journey times in all routes actually used are equal and less than those which would be experienced by a single vehicle on any unused route”

Wardrop’s 2nd principle
“At equilibrium the average journey time is minimum”
Preferred routes are those, which minimize total system travel time. With System-Optimal (SO) route choices, no traveler can switch to a different route without increasing total system travel time. Realistically, travelers will likely switch to non-System-Optimal routes to improve their own TTs.
Formulating the UE Problem

Finding the set of flows that equates TTs on all used routes can be cumbersome.

Alternatively, one can minimize the following function:

\[ \min \sum_{n}^{x_n} \int_{0}^{t_n(w)} dw \]

- \( n \) = Route between given O-D pair
- \( t_n(w)dw \) = HPF for a specific route as a function of flow
- \( w \) = Flow
- \( x_n \geq 0 \) for all routes

Minimize travel times
Formulating the UE Problem

\[
\min \sum_{n} x_n \int_{0}^{t_n} v \, dw = \sum_{n} \min \int_{0}^{t_n} v \, dw
\]

\[
= \sum_{n} \int_{0}^{x_n} \min t_n \, dw
\]

n = Route between given O-D pair

t_n(w)dw = HPF for a specific route as a function of flow

w = Flow

x_n \geq 0 for all routes
Example (UE)

Two routes connect a city and a suburb. During the peak-hour morning commute, a total of 4,500 vehicles travel from the suburb to the city. Route 1 has a 60-mph speed limit and is 6 miles long. Route 2 is half as long with a 45-mph speed limit. The HPFs for the route 1 & 2 are as follows:

- **Route 1 HPF** increases at the rate of 4 minutes for every additional 1,000 vehicles per hour.

- **Route 2 HPF** increases as the square of volume of vehicles in thousands per hour.
Example: Compute UE travel times on the two routes
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Theory of System-Optimal Route Choice

Preferred routes are those, which minimize total system travel time. With System-Optimal (SO) route choices, no traveler can switch to a different route without increasing total system travel time. Travelers can switch to routes decreasing their TTs but only if System-Optimal flows are maintained. Realistically, travelers will likely switch to non-System-Optimal routes to improve their own TTs.

Not stable because individuals will be tempted to choose different route.
Formulating the SO Problem

Finding the set of flows that minimizes the following function:

\[
\min \sum_{n} x_n t_n \leq c_n = \sum_{n} \min x_n t_n \leq c_n
\]

\( n \) = Route between given O-D pair
\( t_n(x_n) \) = travel time for a specific route
\( x_n \) = Flow on a specific route

Minimize travel time times flow
Example (SO)

Two routes connect a city and a suburb. During the peak-hour morning commute, a total of 4,500 vehicles travel from the suburb to the city. Route 1 has a 60-mph speed limit and is 6 miles long. Route 2 is half as long with a 45-mph speed limit. The HPFs for the route 1 & 2 are as follows:

- **Route 1 HPF** increases at the rate of 4 minutes for every additional 1,000 vehicles per hour.
- **Route 2 HPF** increases as the square of volume of vehicles in thousands per hour. Compute UE travel times on the two routes.
Example: Solution
Example: Solution
Compare UE and SO Solutions

- User equilibrium
- System optimization
Why are the solutions different?

- Why is total travel time shorter?
- Notice in SO we expect some drivers to take a longer route.
- How can we force the SO?
- Why would we want to force the SO?
Total Travel time is Minimum at SO
• By asking one driver to take 3 minutes longer, I save more than 3 minutes in the reduced travel time of all drivers (non-linear)

• Total travel time if $X_1=1600$ is 55829
• Total travel time if $X_1=1601$ is 55819