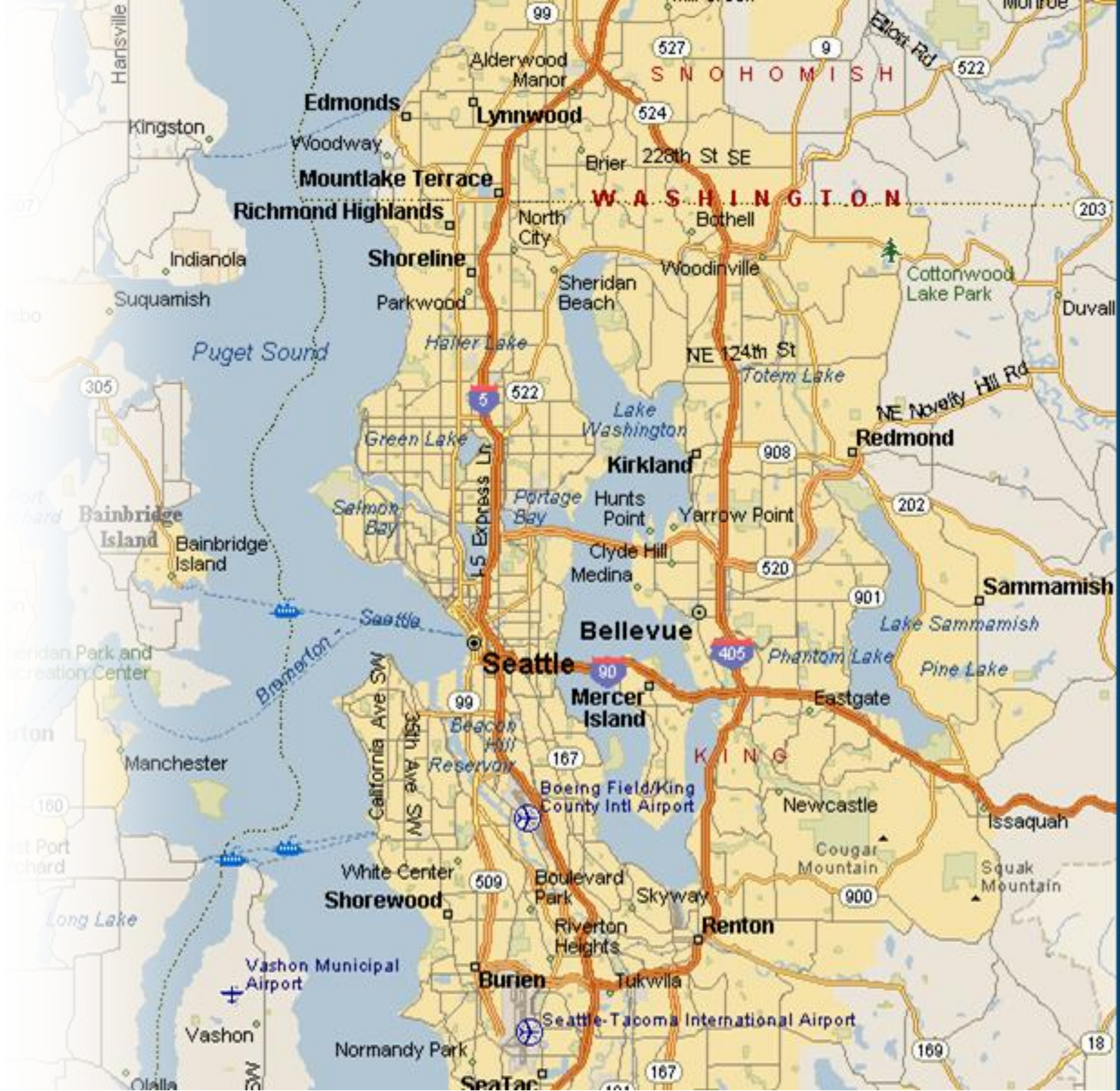
Route Choice

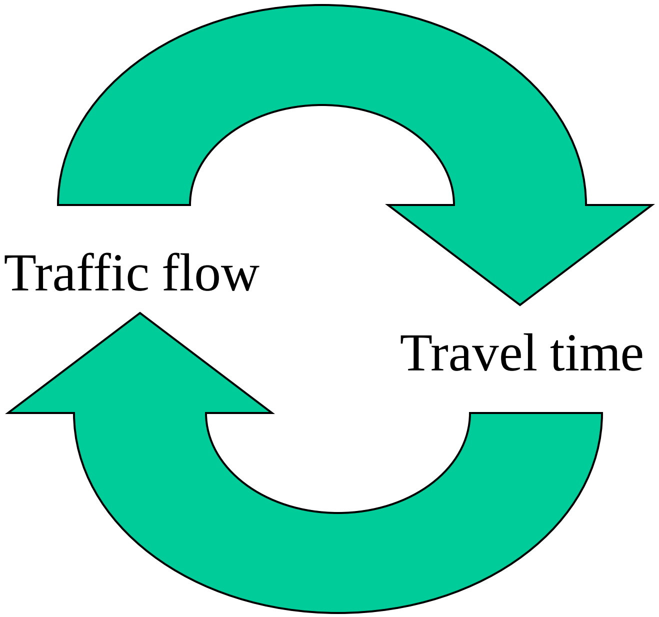


Route Choice

- 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

Complexity

- **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

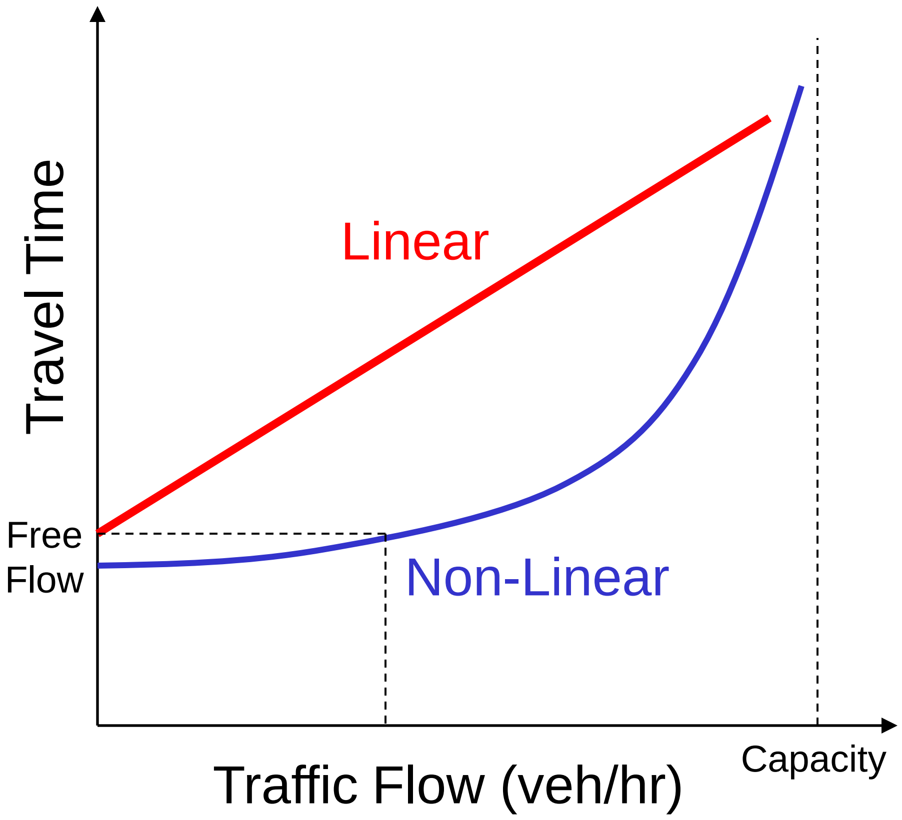
Basic Assumptions

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



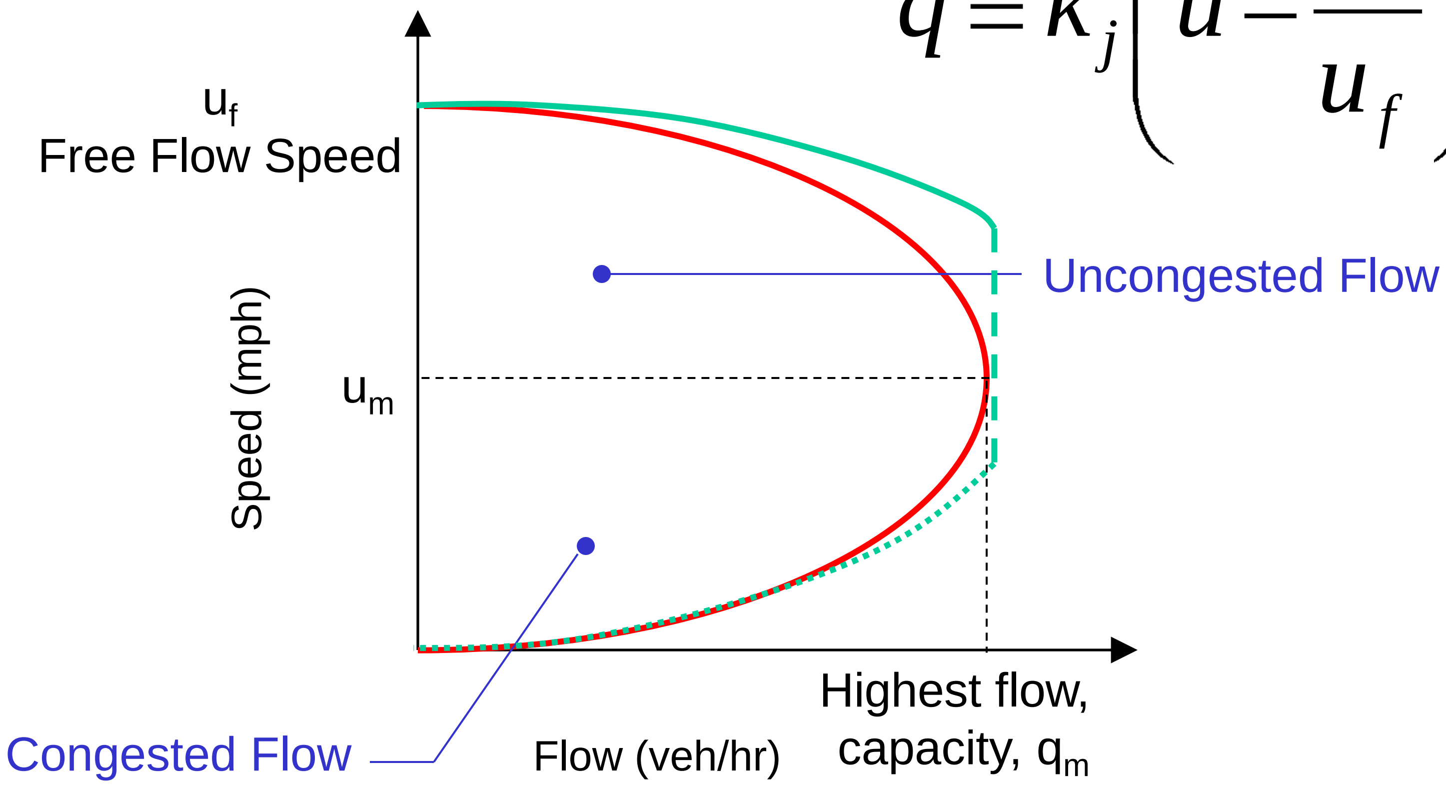
Common Non-linear HPF

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

from the Bureau of Public Roads (BPR)

Speed vs. Flow

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



q_m is bottleneck discharge rate

Theory of User Equilibrium

Travelers will select a route so as to minimize their <u>personal travel time</u> 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

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*"

Theory of System-Optimal Route Choice

Preferred routes are those, which minimize <u>total system travel time</u>. With System-Optimal (SO) route choices, no traveler can switch to a different route without increasing <u>total system travel time</u>. 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:

$$\min \sum_{n} \int_{0}^{x_n} t_n(w)\, dw$$

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	≥	0 for all routes

Minimize travel times

Formulating the UE Problem

$$\min \sum_{n} \int_{0}^{x_n} t_n(w)\,dw = \sum_{n} \min \int_{0}^{x_n} t_n(w)\,dw$$

$$= \sum_{n} \int_{0}^{x_n} \min t_n(w)\,dw$$

n = Route between given O-D pair

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

w = Flow

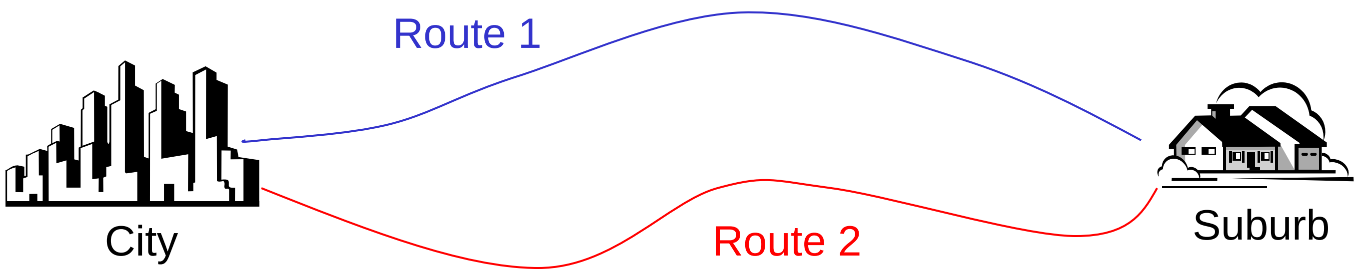
$x_n \geq 0$ for all routes

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

Example: Compute UE travel times on the two routes

Example: Compute UE travel times on the two routes

Example: Compute UE travel times on the two routes

Example: Compute UE travel times on the two routes

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:

$$\min \sum_n x_n t_n(x_n) = \sum_n \min x_n t_n(x_n)$$

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

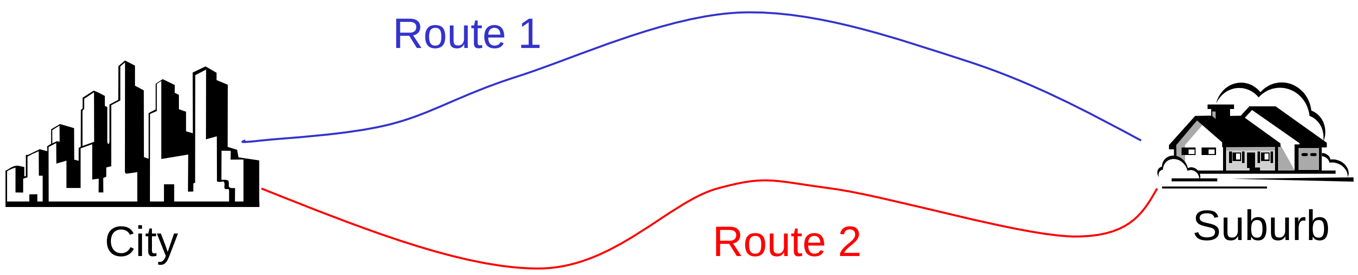
Minimize travel time times flow

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:

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

- <u>Route 2 HPF</u> increases as the square of volume of vehicles in thousands per hour. Compute UE travel times on the two routes.

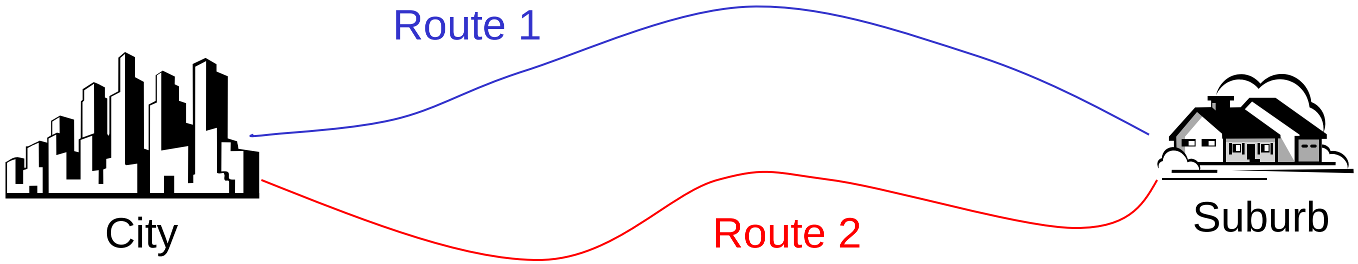


Example: Solution

Example: Solution

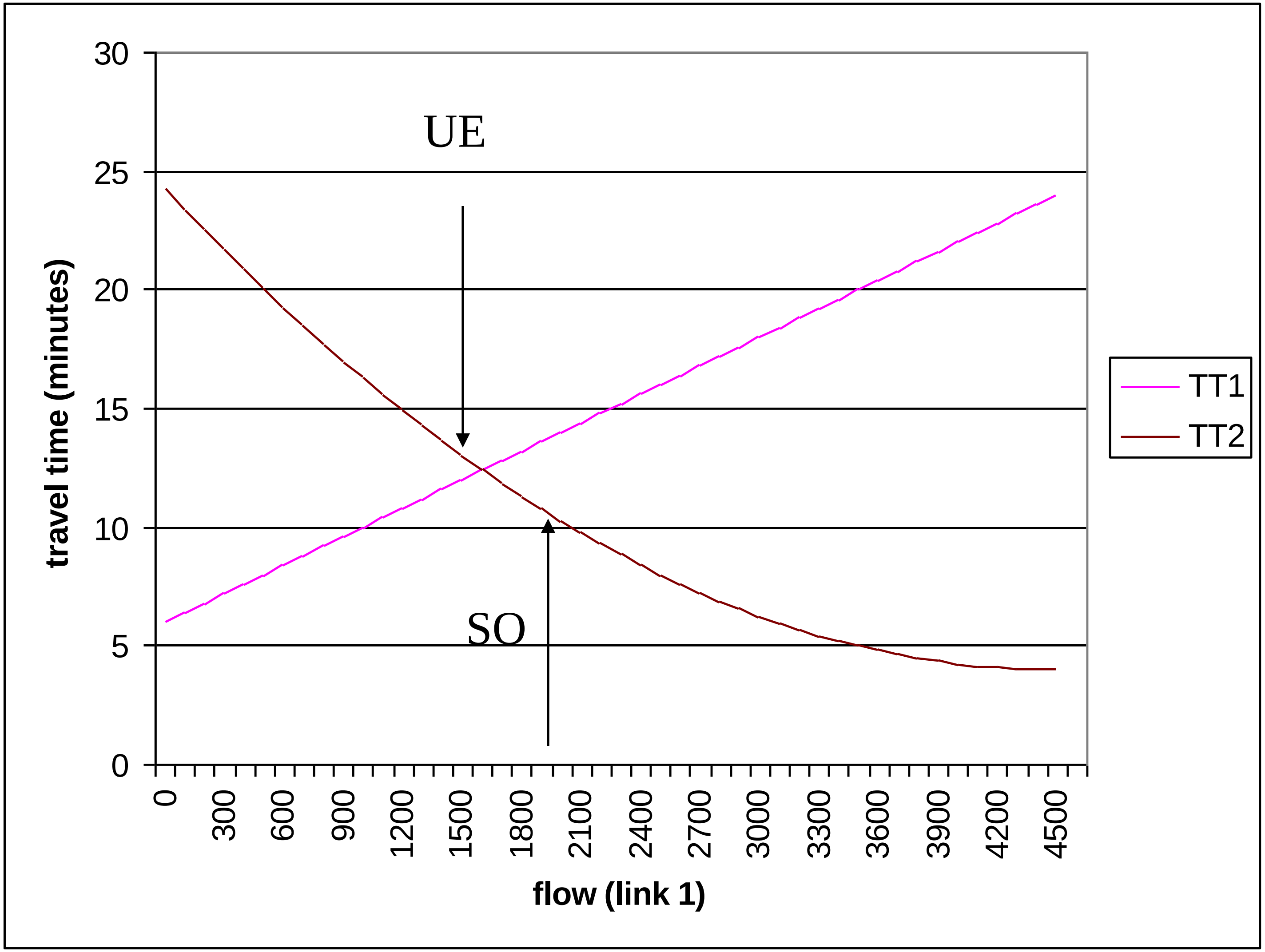
Compare UE and SO Solutions

- **User equilibrium**
- **System optimization**



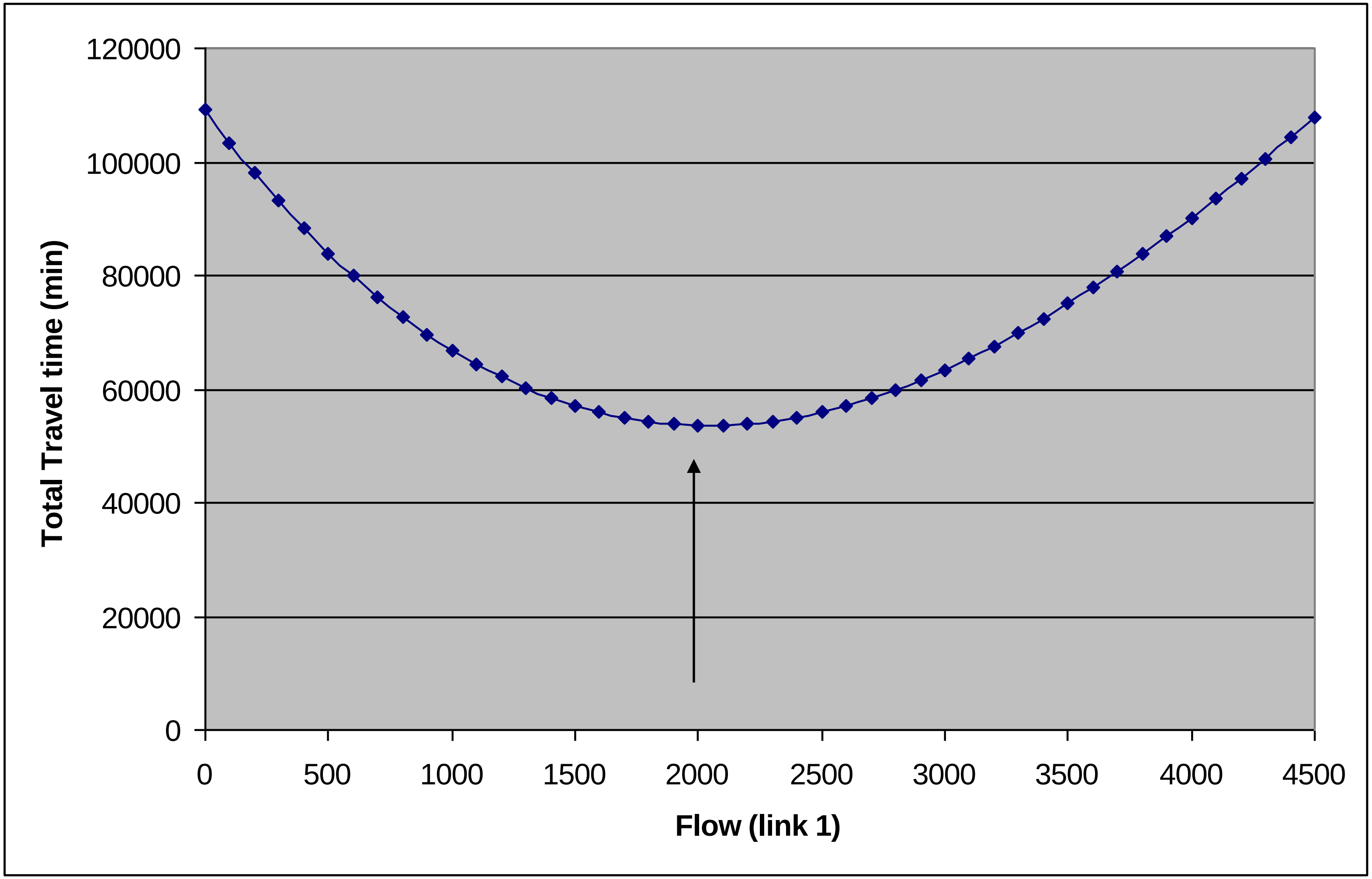
Why are the solutions different?

- 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?



30
25
20
15
10
5
0
travel time (minutes)
UE
SO
TT1
TT2
0
300
600
900
1200
1500
1800
2100
2400
2700
3000
3300
3600
3900
4200
4500
flow (link 1)

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