The Economic Principles in Transportation Planning

GUANGCHUAN YANG

B.Eng., M.Sc. in Transportation Engineering and Planning

October 20, 2016

Center for Advanced Transportation Education and Research (CATER)
University of Nevada, Reno
Reno, NV89557
Contents

✓ Demand–Supply Curve
✓ Commute Paradox
✓ Bus Lane Issue
Traffic Congestion
“If urban road capacity is increased, does this result in some improvement in traffic speeds, or does it make congestion worse?”
In 1995-1996, I-10 from the Phoenix airport to Queen Creek in Arizona
Reopen with Six Lanes
Six Months Later

Congestion returned with a vengeance
The Law of Demand

Transportation can be viewed as a normal consumer good

For example, the demand for car trips:

- Goes up (down) when the real price of car travel falls (increases)
- Goes up (down) when the real price of substitutes (e.g. bus travel) increases (falls)
- Goes up (down) when real income increases (falls)
The Law of Supply

- If the price of transport increases (decreases), supply of transport will increase (decrease).
- If input prices increase (decrease), the supply of transport will decrease (increase).
- Technological advances and government support may be expected to increase supply.
Demand – Supply Curves

Change of Supply

Change of Demand
Braess Paradox

Dietrich Braess (1938 - ), German Mathematician

- “Adding extra capacity to a network, when the moving entities selfishly choose their route, can in some cases reduce overall performance.”

- A rational driver would switch from a longer route to a shorter route
Numerical Example

$V = 4000$

$T_{OAD} = \frac{V_A}{100} + 45$

$T_{OBD} = 45 + \frac{V_B}{100}$

$T_{OAD} = T_{OBD}$, and $V_A + V_B = 4000$

$V_A = V_B = 2000$

$T_{OAD} = T_{OBD} = \frac{2000}{100} + 45 = 65$
Numerical Example

**Origin**
- $t = \frac{V}{100}$

**Destination**
- $t = 45$

$T_{OAD} = \frac{V_A}{100} + 45$
$T_{OABD} = \frac{V_A}{100} + \frac{V_B}{100}$
$T_{OBD} = 45 + \frac{V_B}{100}$

$MAX\left(T_{OA}\right) = \frac{4000}{100} = 40 < T_{OB}$
$MAX\left(T_{ABD}\right) = \frac{4000}{100} = 40 < T_{AD}$

Shortest Route: $T_{OABD} = \frac{4000}{100} + \frac{4000}{100} = 80$

$T_{OAD} = T_{OBD} = \frac{4000}{100} + 45 = 85$
“An increase in road capacities, by causing shifts from public transit to private transport, could lead to a new traffic equilibrium where total transport costs are higher.”
A decrease in road capacities, or better, an increase in mass transit capacity, could shift car users to buses and can therefore decrease total travel times.”

Fundamental of London Congestion Charging and Bus Priority projects
Installation of Bus Lane

What Will Happen After Converting A General Lane to A Bus Lane?

Bus Lane Planning Issues

- What is the optimal bus share ratio to maximize system performance?
- Traffic volume threshold for converting a general lane to a bus lane.
Description of Dynamic Equilibrium

a. Convert a general lane to a bus lane

b. Traffic flow condition after modal shift of car travelers to buses

c. Equilibrium traffic flow
Ideal Bus Share Ratio

![Diagram showing ideal bus share ratio with speed on the y-axis and bus proportion on the x-axis. The diagram includes car travel speed curve and bus travel speed curve, with ideal bus proportion indicated.]
Modeling Modal Shifts

Cost of car per trip

Cost of bus per trip

Capacity Reduction

Supply curve for car

Supply curve for bus

Cost Reduction

P₀
P₁

E₁
E₀

Q₀
Q₁

Car trips

Bus trips

Total demands Q

Modal Shifts
Utility Function

- Utility: the degree of satisfaction that an individual derive from his available mode choices.

- Generalized costs of its attributes, usually as a linear weighted sum of all the attributes, such as:

  ✓ $U_{car} = a_{11} Time_{car} + a_{12} Cost_{car}$

  ✓ $U_{bus} = a_{21} IVT_{bus} + a_{22} Cost_{bus} + a_{23} Access_{bus} + a_{24} Wait_{bus} + a_{25} Interchange_{bus}$
**Bi-Logit Mode Choice Model**

- \( P_n = \frac{\exp U_n}{\sum_{n \in M} \exp U_m} \)

- \( P_n \) is the probability of choosing mode \( n \);
- \( U_n \) is the utility function of mode \( n \);
- \( U_m \) is the utility function of any mode \( m \) in the choice set;
- \( M \) is the total number of available alternative modes.

\[
\begin{align*}
P_{\text{car}} &= \frac{\exp U_{\text{car}}}{\exp U_{\text{car}} + \exp U_{\text{bus}}} \\
P_{\text{bus}} &= 1 - P_{\text{car}}
\end{align*}
\]
Solution to Bus Lane System Equilibrium

John G. Wardrop (1920 - 1989), U.K. Transportation Analyst

- **User Equilibrium 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.”

- **System Optimal Principle:** “At equilibrium the average journey time is minimum.” This implies that each user behaves cooperatively in choosing his own route to ensure the most efficient use of the whole system.
A Bi-Level Programming Problem

- **START**
  - Initial modal split without bus priority
  - Implementation of bus priorities: how they impact travel costs
  - New modal split with bus priority

- **Is travel costs of two links reach equilibrium?**
  - **Yes**
    - Identify the modal shift extent and optimal bus share
  - **No**
    - Assume a bus share

- **Choose another feasible answer**
  - Calculate the total travel time of roadway system

- **Is this answer minimizes the total travel time?**
  - **No**
    - Choose another feasible answer
  - **Yes**
    - Identify the optimal bus share

- **END**
  - Upper level (System optimal principle)
  - Lower level (User equilibrium principle)
Results

"Thinking" In Process...
The Vicious Circle

Traffic Congestion

More Private Traffic

Road Construction

Modal Shifts

Demand Management
Your Choice?
Adding capacity to a network may stimulate unnecessary travel demands (*The laws of demand and supply*)

The occurrence of commute paradox was mainly attributed to the change of route and/or mode

Demand management strategies aim to regulate and adjust traffic market (*Nash Equilibrium*)
“An increase in traffic capacity on commuter expressways in urban areas results in a rise in travel demand that erodes much of the capacity-enhanced traffic improvement.”

In colloquial terms:

“If you build them, they will come!”

Anthony Downs (1930 -)
U.S. Economist
The presenter thanks Prof. Zhongyi Zuo of Dalian Jiaotong University for his discussions; Prof. John Preston of University of Southampton and Prof. Shunfeng Song of University of Nevada, Reno for their instructions of transportation economics.


References - Practices


Thanks for Your Time!

Guangchuan Yang

UNR CATER

Email: gyang@unr.edu