1.201: An Introduction

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Transportation Systems Analysis: Demand & Economics

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Outline

1. Context, Objectives, and Motivation
2. Introduction to Microeconomics
3. Introduction to travel demand
4. Course Structure
Context for Transportation Systems Analysis

- Conceptual View of TSA
- Models and Prediction
- Prediction in Context: Analysis and Implementation

A Conceptual View of TSA

3 elements in transport system problems:

- Transport system, $T$
- Activity system, $A$
- Flow pattern, $F$

A Conceptual View of TSA

3 types of inter-relationships:

Type I:  \textit{Flow} determined by both \textit{Transport} and \textit{Activity} systems

- the short-run "equilibrium" or outcome
- many problems are dynamic rather than static

Type II:  \textit{Flow} pattern causes change over time in the \textit{Activity} system through services provided and resources consumed

Type III:  \textit{Flow} pattern also causes changes over time in the \textit{Transport} system

- transport operator adds service on a heavily-used route
- new highway link constructed

Models and Prediction


Figure by MIT OpenCourseWare.
Models and Prediction

Options

- Technology
- Networks
- Link characteristics
- Vehicles
- System operating policies
- Organizational policies
- Travel options
- Other activity options

Impacts

- User
- Operator
- Physical
- Functional
- Governmental

Figure by MIT OpenCourseWare.

Figure by MIT OpenCourseWare.

Objectives of this Course

- Build the economic framework to analyze the supply and demand for transportation
- Develop methodologies for predicting transportation demands and costs
- Demonstrate how principles of economics can be applied within the context of transportation systems to understand the effects of different plans and policies
Why Study Transportation Economics? (I)

- Example 1: High-Speed Rail
  - Has been successful in Japan, China, and some European countries, but no experience in the US
  - Is the demand going to be sufficient to justify the high costs?
  - Demand forecasting is complicated
Why Study Transportation Economics? (II)

- Example 2: Traffic Jams
  - Building more highways
  - Intelligent Transportation Systems
  - Encouraging transit ridership
  - Pricing
Example 3: Trucks in the Alpine Valleys

- Highways in narrow valleys trap noise and exhaust fumes from the trucks
- In 1994, Swiss voters decided to close highways to truck traffic beginning in 2004
- How should one evaluate this decision?
- What are the benefits and costs of this decision?
- How to compare costs to the trucking firms with the environmental impacts?
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What Is Microeconomics?

- Branch of economics that deals with the behavior of individual economic agents – consumers, firms, worker, and investors – as well as the markets that these units comprise.
Demand and Supply

- Market demand function
  - Represents behavior of users
- Market supply function
  - Represents congestion and behavior of service providers
- Supply/Demand Interaction: Equilibrium
Equilibrium

![Graph showing supply (S) and demand (D) curves intersecting at equilibrium price $P_0$ and quantity $Q_0$.]
Shifting Curves

Price

\[ P_0 \]

Quantity

\[ Q_0 \]

\[ S \]

\[ D \]

\[ S' \]

\[ D' \]

?
Comparative Statics

- Create a *model* of market behavior:
  - Explain consumer and firm choices as a function of exogenous variables, such as income and government policy
- Develop scenarios:
  - Changes in exogenous variables
- Derive changes in the endogenous variables
Comparative Statics Example

The market for taxi service:

- Supply model: \( Q_S = -125 + 125P \)
- Demand model: \( Q_D = 1000 - 100P \)
- Where does the market clear?

- What happens if demand shifts such that now \( Q_D = 1450 - 100P \)?
The Solution
Consumer Behavior

How do we characterize a consumer?

- Preferences across goods
- Prices of goods
- Budget available to spend on those goods
Utility Function

- A function that represents the consumer’s preferences ordering
  \[ U = f(x_1, x_2, \ldots, x_m) \]
  Consumption levels of goods 1..m

- Utility functions give only an *ordinal* ranking:
  - Utility values have no inherent meaning
  - Utility function is not unique
  - Utility function is unaffected by monotonic transformation
Consumer Behavior

- Assumed behavior by consumer: utility maximization subject to budget constraints
- When facing prices $p$ and having income $I$, consumer allocates income across goods so as to maximize utility.
- Problem: $\text{Max } U(x_1, \ldots, x_m)$ subject to

$$\sum_{i=1}^{m} p_i x_i \leq I$$
Demand Function

- Optimal consumption bundle $X^*$
- By varying price $p$ and income $I$ and solve for $X^*$, we derive the demand function $X^*(p, I)$
Consumer Welfare

[Diagram showing a demand curve with price and quantity axes. The diagram highlights a welfare gain from a decrease in price.]
Firm Behavior

How do we characterize a firm?

- The technology and inputs for creating products
- The prices of the required inputs
- The demand for the firm’s product(s)
Production

- Technology: method for turning inputs (including raw materials, labor, capital, such as vehicles, drivers, terminals) into outputs (such as trips)
- Production Possibility Set: quantities of output possible given levels of input
Possibility Set

- The firm may choose to produce any element in its production possibility set
- Example: taxi services and drivers
Production Functions

- Simplified form: \( q = f(z) \)
  - \( q \): output; \( z \): inputs
- Isoquants for two-input production:

\[
q = f(K, L)
\]
Production Functions

- Does the technology allow substitution among inputs or not?

![Diagram showing Perfect Substitutes and Fixed-Proportions]
Cost Functions

- Now consider input price vector $w$.
- Assume efficient behavior by firm: produce output $q$ for the lowest possible cost.
- Therefore, cost function is:
  \[ c(w, q) = \min_{z} \ w \cdot z \]
  subject to $q = f(z)$
- This function describes the cost of producing any feasible level of output.
Firm Objective

- Maximize profit
- Maximize revenue when cost is fixed
- Minimize cost when prices are fixed
Profit Maximization

- Firm maximizes: profit = revenue - cost
  \[ \pi(q) = p \cdot q - c(q) \]
- General result: MR(q) = MC(q)
  - MR: marginal revenue
  - MC: marginal cost
- For a competitive firm, \( p \) is fixed
  - MR = \( p \)
  - Quantity supplied is determined such that MC = \( p \)
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Transportation Demand Analysis

- Use models to understand complex processes
  - Transit ridership
  - Sprawl
  - Congestion pricing
  - Traveler information systems
  - Jobs-housing balance
- Assist decision making
Choices Impacting Transport Demand

- Decisions made by Organizations
  - Firm locates in Boston – Firm locates in Waltham
  - Firm invests in home offices, high speed connections
  - Developer builds in suburbs – Developer fills in in downtown

- Decisions made by Individual/Households
  - Live in mixed use area in Boston – Live in residential suburb
  - Don’t work – Work (and where to work)
  - Own a car but not a bike – Own a bike but not a car
  - Own an in-vehicle navigation system
  - Work Monday-Friday 9-5 – Work evenings and weekends
  - Daily activity and travel choices: what, where, when, for how long, in what order, by which mode and route, using what telecommunications
Discrete Choice Analysis

- Method for modeling choices from among discrete alternatives
- Components
  - Decision-makers and their socio-economic characteristics
  - Alternatives and their attributes
- Example: Mode Choice to Work
  - Decision maker: Worker
  - Characteristics: Income, Age
  - Alternatives: Auto and Bus
  - Attributes: Travel Cost, Travel Time
Role of Demand Models

- Forecasts, parameter estimates, elasticities, values of time, and consumer surplus measures obtained from demand models are used to improve understanding of the ramifications of alternative investment and policy decisions.
- Many uncertainties affect transport demand and the models are about to do the impossible
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Structure of This Course

● Alternating:
  – Theory:
    • Demand, Costs, Pricing, Revenue, Project Finance, Project Evaluation
  – Applications:
    • Public Transportation, Maritime, Aviation, Developing Countries, ITS