Transportation Economics and Decision Making

Lecture-8

Travel Behavior

- Many practical transportation policy issues are concerned with choice of mode
- Example: the gain or loss of transit revenue caused by the fare increase depends on how travellers mode choice are affected by the increase.
- If few current transit riders switch to other modes, revenue will increase less than proportionally to the fare increase

Travel Behavior (2)

- The effects of changes in transit routes and schedules on ridership, revenues and traffic congestion all depend on how the changes affect individual traveller's mode choice.
- In most situations planners must choose among a variety of fare schedules and service designs.
- An understanding of separate and combine effects of these decisions on travel mode choice is essential to selection of best plan to meet specific transportation objectives.

Travel Behavior (3)

- Two well known and frequently used prediction methods are
  - Method of elasticity
  - Method of aggregate mode choice modeling
- Both of these methods have serious defects that greatly restrict their practical usefullness.

Travel Behavior (4)

- For example, the method of elasticities can not predict accurately the effects of making several changes in the transit service simultaneously.
  - (increasing both fare and schedule; and adding a new route)
- Aggregate mode split models can be exceedingly costly and cumbersome to develop.
  - Moreover, they are subject to serious biases and prediction errors owing to their reliance on aggregate data rather than records of individual trips

Travel Behavior (5)

- The range of policy questions that can be treated with aggregate models is quite limited.
  - For example, it is not quite possible to conduct multi-modal analysis with these models.
  - Several different modes such as bus transit, rail transit, carpool, and single-occupant vehicles
- In today's class our concentration will be on the third choice of models– referred as disaggregate models.

Travel Behavior (6)

- Disaggregate models achieve higher degree of policy sensitivity than either elasticity and aggregate mode choice models.
- Disaggregate models can represent a wider range of policy variables than can either elasticity or aggregate models and they can treat multimodal problems without difficulty.
- Moreover, disaggregate models avoid biases inherent in aggregate models, and they are much more efficient in terms of data and computational requirements.

Travel Behavior (7)

- A number of agencies these days use disaggregate models for modeling and policy analysis.
- This makes important for transportation professionals to understand the principles underlying the development and use of disaggregate models, since failure to understand these principles can lead to
  - erroneous models and
  - serious prediction errors

Role of Choice in Travel Demand

- Travel is a result of choices made by individuals or collective decision making units such as households
- An individual preparing to travel to work must choose
  - Whether to drive alone, carpool, or take transit
  - When to leave home
  - Which route to choose etc.
- The objective of travel demand is to model and predict the outcomes of these choices by individuals

To model outcomes of individuals…

- Identify the decisions that must be made and the options, or alternative outcomes, that are available to the individual.
- Identify variables likely to affect the choices of interest
- Develop mathematical model that describes dependence on the relevant variables

Preferences

- An individual’s choice represents an expression of his/her preference among the available options at the time and under the conditions in which the choice is made.
- It is important to understand that the preferences relevant to choices are the ones that pertain to the chooser’s existing circumstances not to an ideal set of circumstances.

Preference

- Example: a commuter boarding a bus may think t himself that he would really rather take a taxi if he could afford it
- He is taking a bus only because he does not have much money.
- Such thoughts do not imply that the commuter prefers taxi to bus under the existing circumstances
- He would prefer taxi to bus under ideal circumstances (having a lot of money), but under the existing circumstances he prefers bus.

Preference (2)

- Preference among a set of options depend on the
  - Attributes of the options
  - And of the individual involved
- Attributes of the travel mode that are relevant
  - Travel time
  - Travel cost
  - Comfort
  - Reliability
- Attributes of the individual include
  - Income
  - Auto ownership

Utility Theory

- According to utility maximization principle, there is a mathematical function U, called utility function, whose numerical value depends on the
  - Attributes of the available options and individual
- The utility function has the property that its value for one option exceeds its value for another if and only if the individual prefers the first option to the second.
- Thus ranking of available options according to individual's preference or ranking per utility function's value are the same.

Utility Function: Mathematical Representation

- Let C denote the set of options available to an individual
- E.g. drive alone, carpool, and bus
- C is called as the choice set
- Ler Xi denote the attribute for the individual in question
- Let S denote attribute of the individual that are relevant to preferences among options in C (income, car ownership etc.)

Utility Function: Mathematical Representation (2)

- U has a property that for any two options in *i* and *j* in C

$U(Xi, S) > U\,(Xj, C)$

- Implies that the individual prefers alternative *i* to alternative j and will choose *i* if given choice between *i* and *j*.

Role of Choice in Travel

- Travel is the result of choices made by individuals or collective decision making by households.
- Example: an individual preparing to travel to work must choose whether
  - Drive alone
  - Take bus, transit
  - Carpool

Role of Choice in Travel

- The utility function is defined to have following properties.
  - The function U is the same for all options. Differences among options are accounted for by differences in the numerical values of attribute X not by changing the function U
- The utility of an alternative depends only on attribute of that alternative and of the individual

A utility model for mode choice

- Suppose that an individual can travel to work by
  - Drive alone
  - Carpooling
  - Bus
- Assume the relevant attributes are
  - Travel time
  - Cost
- Assume the relevant attribute of the individual is income

Example

- Let
  - T denote door to door travel time in hours
  - C denote travel cost in dollars
  - Y denote annual income in thousands of dollars per year
- Let the utility function be $U(T, C, Y) = -T-5C/Y$
- Suppose the values of travel time and cost for the available modes are

Mode	Time (T), Hours	Cost (C), $
Drive Alone	0.5	2
Carpool	0.75	1
Bus	1	0.75

Example (2)

Mode	Y=40	Y=10
Drive Alone	-0.75*	-1.50
Carpool	-0.88	-1.25*
Bus	-1.09	-1.38

* Alternative with highest utility

Individual with income 40,000 chooses Drive alone as the alternative
Individual with income 10,000 chooses Carpool as the alternative

Example (3)

- Now, suppose, quality of transit service is improved so that travel time for bus is 0.75 hours
- The revised utilities are

Mode	Time (T), Hours	Cost ©, $	Y=40	Y=10
Drive Alone	0.5	2	-0.75*	-1.50
Carpool	0.75	1	-0.88	-1.25
Bus	0.75	0.75	-0.84	-1.13*

- The higher income individual chooses drive alone
- The lower income individual chooses bus

Observations (1)

- Although the example is very simple it illustrates some important characteristics of choice models based on the utility maximization principle.
  - First, it shows how a utility function can be used to describe the dependence of preferences and choices on attributes of the options and individuals
  - (the same utility function describes the performance of more than one individual)
  - It is not necessary to have separate utility function for each individual if differences among individuals can be accounted for by attribute variable such as income

Observations (2)

  - Second the example illustrates the use of utility theory to predict changes in preferences and choices that occur when an attribute of one of the option changes.
- Finally, the example illustrates advantages of utility models over traditional choice models
  - It can treat three or more (any) number of competitive modes (traditional models can only take two modes at a time)
  - Since the utility model operates at the individual level, it guarantees that the percentage of individuals choosing a mode are always in the range of 0-100%
  - many traditional models do not have this property

Non-uniqueness of utility functions

- In the first example problem, we considered the following utility function
- $U(T, C, Y) = -T-5C/Y$
- Let us consider three other forms
  - $V(T, C, Y) = -TY-5C$
  - $W(T, C, Y) = 10-20T-100C/Y$
  - $X(T, C, Y) = -T^2-10CT/Y-25C^2/Y^2$

Different Formulations Leading to Same Result

Mode	Time (T), Hours	Cost ©, $	Y=40	Y=10
Drive Alone	0.5	2	-30.00*	-15.00
Carpool	0.75	1	-35.00	-12.50*
Bus	1	0.75	-43.75	-13.75

Mode	Time (T), Hours	Cost ©, $	Y=40	Y=10
Drive Alone	0.5	2	-5.00*	-20.00
Carpool	0.75	1	-7.50	-15.00*
Bus	1	0.75	-11.88	-17.50

Mode	Time (T), Hours	Cost ©, $	Y=40	Y=10
Drive Alone	0.5	2	-0.56*	-2.25
Carpool	0.75	1	-0.77	-1.56*
Bus	1	0.75	-1.20	-1.89

Aggregate Travel Behavior

- Consider the utility function and income distribution of the individuals as follows

Mode	Time (T), Hours	Cost (C), $
Drive Alone	0.5	2
Carpool	0.75	1
Bus	1	0.75

Income	Percentage
17	5
19	15
27	25
33	25
37	20
40	10
Total	100

Income	Drive Alone	Carpool	Bus	Choice
17	-1.09	-1.04	-1.22	Carpool
19	-1.03	-1.01	-1.20	Carpool
27	-0.87	-0.94	-1.14	Drive Alone
33	-0.80	-0.90	-1.11	Drive Alone
37	-0.77	-0.89	-1.10	Drive Alone
40	-0.75	-0.88	-1.09	Drive Alone

Aggregate travel behavior

- Based on the income distribution 20% of population use carpool, and 80% choose drive alone, and none use bus
- Notice that aggregate travel behavior cannot be predicted correctly by averaging the utility values over individuals.
- The drive alone utility would be -0.86 (0.05(-1.09)+0.15(-1.03)+….+0.10(-0.75)
- The average utility of carpooling and bus would be -0.93 and -1.13 respectively.
- Use of average utility would result in erroneous prediction

Inadequacy of Deterministic Utility Models

- If deterministic utility models describe travel behavior correctly, then similar individuals would be expected to make same travel choices when faced with same set of alternatives.
- In practice, however, it is not unusual for apparently similar individuals make different choices when faced with similar or even identical alternatives.
- In fact the same individual makes different choices when faced with same alternatives on different occaisions.

Inadequacy of Deterministic Utility Models (2)

- Deterministic utility models can not treat such "unexplained" variation in travel behavior.
- First, analyst and the individuals making travel choices being modeled are unlikely to have the same information about the available alternatives.
- Second, the analyst is unlikely to know all the characteristics of each individual that are relevant to mode choice.

Inadequacy of Deterministic Utility Models (3)

- Deterministic utility models can be modified to "random utility models" to achieve the "unexplained effect"
- Instead of predicting that an individual will choose a particular mode with certainty, these models provide probabilities that each of the available modes will be chosen.

Limitations of Analyst's Information

- Omission of relevant variables from the model
- Measurement error
- Proxy variables
- Difference between individuals may be ignored
- Day to day variations in the choice context may be ignored

Example-1 (Missing Variable)

- Let the utility functions of three modes be
- $U_{DA} = -T_{DA} - 5C_{DA}/Y + 0.4(A-1)$
- $U_{CP} = -T_{DA} - 5C_{CP}/Y + 0.2(A-1)$
- $U_B = -T_B - 5C_B/Y$

Mode	Time (T), Hours	Cost ©, $	Zero Cars	One Car	Two Cars
Drive Alone	0.5	2	-1.57	-1.17	-0.77*
Carpool	0.75	1	-1.28	-1.08*	-0.88
Bus	1	0.75	-1.25*	-1.25	-1.25

- Households without cars use bus, with one car use carpool, and two cars use drive alone

Example-1 (Missing Variable)

- Without taking car ownership into account everyone will choose carpool.
  - But with inclusion of car ownership will lead to
    - Zero car individuals will choose bus
    - One car individuals will choose carpool
    - Two cars individuals will choose drive alone
- Thus omission of automobile ownership variable from the utility function causes variation in travel choices that are not explained in the model.

Measurement Error

- Let us assume that different individuals have different travel times for the automobile modes.
- Specifically assume that the drive alone and carpool travel times for individuals are distributed in the following relative frequencies

Percentage of individuals	20%	50%	20%	10%
DA Time	0.4	0.5	0.60	0.70
Carpool Time	0.65	0.75	0.85	0.95

Percentage Individuals	Zero Cars				No Auto Ownership
	20%	50%	20%	10%	-1.17
Drive Alone	-1.47	-1.57	-1.67	-1.77	-1.08
Carpool	-1.18	-1.28	-1.38	-1.48	-1.25
Bus	-1.25	-1.25	-1.25	-1.25	Carpool
Chosen Mode	Carpool	Bus	Bus	Bus	Carpool

Measurement Error

Percentage Individuals	One Cars				
	20%	50%	20%	10%	No Auto Ownership
Drive Alone	-1.07	-1.17	-1.27	-1.37	-1.17
Carpool	-0.98	-1.08	-1.18	-1.28	-1.08
Bus	-1.25	-1.25	-1.25	-1.25	-1.25
Chosen Mode	Carpool	Carpool	Carpool	Bus	Carpool

Percentage Individuals	Two Cars				
	20%	50%	20%	10%	No Auto Ownership
Drive Alone	-0.67	-0.77	-0.87	-0.97	-1.17
Carpool	-0.78	-0.88	-0.98	-1.08	-1.08
Bus	-1.25	-1.25	-1.25	-1.25	-1.25
Chosen Mode	Drive Alone	Drive Alone	Drive Alone	Drive Alone	Carpool

Measurement Error (2)

- Ignoring distribution of travel times of zero and one car households result in predictions that do not reflect the true variations in mode choice.
- In other words, actual choices vary in ways not explained by the model used to make predictions.