# Chapter 9

# Modal split

## 9.1 Overview

The third stage in travel demand modeling is modal split. The trip matrix or O-D matrix obtained from the trip distribution is sliced into number of matrices representing each mode. First the significance and factors affecting mode choice problem will be discussed. Then a brief discussion on the classification of mode choice will be made. Two types of mode choice models will be discussed in detail. ie binary mode choice and multinomial mode choice. The chapter ends with some discussion on future topics in mode choice problem.

## 9.2 Mode choice

The choice of transport mode is probably one of the most important classic models in transport planning. This is because of the key role played by public transport in policy making. Public transport modes make use of road space more efficiently than private transport. Also they have more social benefits like if more people begin to use public transport , there will be less congestion on the roads and the accidents will be less. Again in public transport, we can travel with low cost. In addition, the fuel is used more efficiently. Main characteristics of public transport is that they will have some particular schedule, frequency etc.

On the other hand, private transport is highly flexible. It provides more comfortable and convenient travel. It has better accessibility also. The issue of mode choice, therefore, is probably the single most important element in transport planning and policy making. It affects the general efficiency with which we can travel in urban areas. It is important then to develop and use models which are sensitive to those travel attributes that influence individual choices of mode.

## 9.3 Factors influencing the choice of mode

The factors may be listed under three groups:

1. **Characteristics of the trip maker** : The following features are found to be important:
   (a) car availability and/or ownership;
   (b) possession of a driving license;
   (c) household structure (young couple, couple with children, retired people etc.);
   (d) income;

   (e) decisions made elsewhere, for example the need to use a car at work, take children to school, etc;
   (f) residential density.

2. **Characteristics of the journey**: Mode choice is strongly influenced by:
   (a) The trip purpose; for example, the journey to work is normally easier to undertake by public transport than other journeys because of its regularity and the adjustment possible in the long run;
   (b) Time of the day when the journey is undertaken.
   (c) Late trips are more difficult to accommodate by public transport.

3. **Characteristics of the transport facility**: There are two types of factors.One is quantitative and the other is qualitative. Quantitative factors are:
   (a) relative travel time: in-vehicle, waiting and walking times by each mode;
   (b) relative monetary costs (fares, fuel and direct costs);
   (c) availability and cost of parking

   Qualitative factors which are less easy to measure are:
   (a) comfort and convenience
   (b) reliability and regularity
   (c) protection, security

A good mode choice should include the most important of these factors.

## 9.4 Types of modal split models

### 9.4.1 Trip-end modal split models

Traditionally, the objective of transportation planning was to forecast the growth in demand for car trips so that investment could be planned to meet the demand. When personal characteristics were thought to be the most important determinants of mode choice, attempts were made to apply modal-split models immediately after trip generation. Such a model is called trip-end modal split model. In this way different characteristics of the person could be preserved and used to estimate modal split. The modal split models of this time related the choice of mode only to features like income, residential density and car ownership.

The advantage is that these models could be very accurate in the short run, if public transport is available and there is little congestion. Limitation is that they are insensitive to policy decisions example: Improving public transport, restricting parking etc. would have no effect on modal split according to these trip-end models.

### 9.4.2 Trip-interchange modal split models

This is the post-distribution model; that is modal split is applied after the distribution stage. This has the advantage that it is possible to include the characteristics of the journey and that of the alternative modes available to undertake them. It is also possible to include policy decisions. This is beneficial for long term modeling.

### 9.4.3 Aggregate and disaggregate models

Mode choice could be *aggregate* if they are based on zonal and inter-zonal information. They can be called *disaggregate* if they are based on household or individual data.

## 9.5 Binary logit model

Binary logit model is the simplest form of mode choice, where the travel choice between two modes is made. The traveler will associate some value for the utility of each mode. if the utility of one mode is higher than the other, then that mode is chosen. But in transportation, we have disutility also. The disutility here is the travel cost. This can be represented as

$$c_{ij} = a_1 t^v_{ij} + a_2 t^w_{ij} + a_3 t^t_{ij} + a_4 t_{nij} + a_5 F_{ij} + a_6 \phi_j + \delta \tag{9.1}$$

where $t^v_{ij}$ is the in-vehicle travel time between $i$ and $j$, $t^w_{ij}$ is the walking time to and from stops, $t^t_{ij}$ is the waiting time at stops, $F_{ij}$ is the fare charged to travel between $i$ and $j$, $\phi_j$ is the parking cost, and $\delta$ is a parameter representing comfort and convenience. If the travel cost is low, then that mode has more probability of being chosen. Let there be two modes (m=1,2) then the proportion of trips by mode 1 from zone $i$ to zone $j$ is($P^1_{ij}$) Let $c^1_{ij}$ be the cost of traveling from zone $i$ to zone$j$ using the mode 1, and $c^2_{ij}$ be the cost of traveling from zone$i$ to zone $j$ by mode 2,there are three cases:

1. if $c^2_{ij}$ - $c^1_{ij}$ is positive, then mode 1 is chosen.
2. if $c^2_{ij}$ - $c^1_{ij}$ is negative, then mode 2 is chosen.
3. if $c^2_{ij}$ - $c^1_{ij} = 0$ , then both modes have equal probability.

This relationship is normally expressed by a logit curve as shown in figure 9:1 Therefore the proportion of trips by mode 1 is given by

$$P^1_{ij} = T^1_{ij}/T_{ij} = \frac{e^{-\beta c^1_{ij}}}{e^{-\beta c^1_{ij}} + e^{-\beta c^2_{ij}}} \tag{9.2}$$

This functional form is called logit, where $c_{ij}$ is called the generalized cost and $\beta$ is the parameter for calibration. The graph in figure 9:1 shows the proportion of trips by mode 1 ($T^1_{ij}/T_{ij}$) against cost difference.

#### Example

Let the number of trips from zone $i$ to zone $j$ is 5000, and two modes are available which has the characteristics given in Table 9:1. Compute the trips made by mode bus, and the fare that is collected from the mode bus. If the fare of the bus is reduced to 6, then find the fare collected.

**Solution** The base case is given below.

Cost of travel by car (Equation)=$c_{car} = 0.03 \times 20 + 18 \times 0.06 + 4 \times 0.1 = 2.08$

Cost of travel by bus (Equation)=$c_{bus} = 0.03 \times 30 + 0.04 \times 5 + 0.06 \times 3 + 0.1 \times 9 = 2.18$

Probability of choosing mode car (Equation)= $p^{car}_{ij} = \frac{e^{-2.08}}{e^{-2.08}+e^{-2.18}} = 0.52$

Probability of choosing mode bus (Equation)= $p^{bus}_{ij} = \frac{e^{-2.18}}{e^{-2.08}+e^{-2.18}} = 0.475$

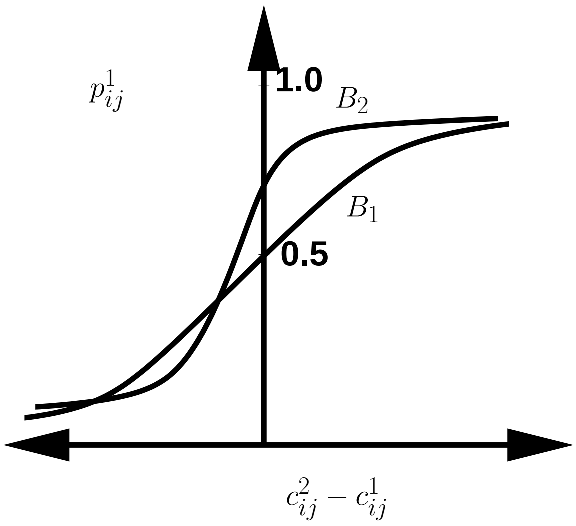


Figure 9:1: logit function

Table 9:1: Trip characterisitcs

| | $t_{ij}^u$ | $t_{ij}^w$ | $t_{ij}^t$ | $f_{ij}$ | $\phi_j$ |
|---|---|---|---|---|---|
| car | 20 | - | 18 | 4 | |
| bus | 30 | 5 | 3 | 9 | |
| $a_i$ | 0.03 | 0.04 | 0.06 | 0.1 | 0.1 |

Table 9:2: Binary logit model example: solution

| | $t_{ij}^u$ | $t_{ij}^w$ | $t_{ij}^t$ | $f_{ij}$ | $\phi_j$ | $c_{ij}$ | $p_{ij}$ | $T_{ij}$ |
|---|---|---|---|---|---|---|---|---|
| ar | 20 | - | 18 | 4 | | 2.08 | .52 | 2600 |
| bus | 30 | 5 | 3 | 9 | | 2.18 | .475 | 2400 |
| $a_i$ | .03 | .04 | .06 | .1 | .1 | | | |

Table 9:3: Trip characteristics

| | $t^v_{ij}$ | $t^{walk}_{ij}$ | $t^t_{ij}$ | $F_{ij}$ | $\phi_{ij}$ |
|---|---|---|---|---|---|
| coefficient | 0.03 | 0.04 | 0.06 | 0.1 | 0.1 |
| car | 20 | - | - | 18 | 4 |
| bus | 30 | 5 | 3 | 6 | - |
| train | 12 | 10 | 2 | 4 | - |

Proportion of trips by car = $T^{car}_{ij}$ = 5000×0.52 = 2600

Proportion of trips by bus = $T^{bus}_{ij}$ = 5000×0.475 = 2400

Fare collected from bus = $T^{bus}_{ij} \times F_{ij}$ = 2400×9 = 21600

When the fare of bus gets reduced to 6,

Cost function for bus= $c_{bus} = 0.03 \times 30 + 0.04 \times 5 + 0.06 \times 3 + 0.1 \times 6 = 1.88$

Probability of choosing mode bus (Equation)=$p^{bus}_{ij} = \frac{e^{-1.88}}{e^{-2.08}+e^{-1.88}} = 0.55$

Proportion of trips by bus = $T^{bus}_{ij}$ = 5000×0.55 = 2750

Fare collected from the bus $T^{bus}_{ij} \times F_{ij}$= 2750×6 = 16500

The results are tabulated in table

## 9.6 Multinomial logit model

The binary model can easily be extended to multiple modes. The equation for such a model can be written as:

$$P^1_{ij} = \frac{e^{-\beta c^1_{ij}}}{\Sigma e^{-\beta c^m_{ij}}} \tag{9.3}$$

### 9.6.1 Example

Let the number of trips from $i$ to $j$ is 5000, and three modes are available which has the characteristics given in Table 9:3: Compute the trips made by the three modes and the fare required to travel by each mode.

**Solution**

Cost of travel by car (Equation)=$c_{car} = 0.03 \times 20 + 18 \times 0.1 + 4 \times 0.1 = 2.8$

Cost of travel by bus (Equation)=$c_{bus} = 0.03 \times 30 + 0.04 \times 5 + 0.06 \times 3 + 0.1 \times 6 = 1.88$

Cost of travel by train (Equation)=$c_{train} = 0.03 \times 12 + 0.04 \times 10 + 0.06 \times 2 + 0.1 \times 4 = 1.28$

Probability of choosing mode car (Equation)$p^{car}_{ij} = \frac{e^{-2.8}}{e^{-2.8}+e^{-1.88}+e^{-1.28}} = 0.1237$

Probability of choosing mode bus (Equation$p^{bus}_{ij} = \frac{e^{-1.88}}{e^{-2.8}+e^{-1.88}+e^{-1.28}} = 0.3105$

Table 9:4: Multinomial logit model problem: solution

| | $t_{ij}^{v}$ | $t_{ij}^{walk}$ | $t_{ij}^{t}$ | $F_{ij}$ | $\phi_{ij}$ | $C$ | $e^{C}$ | $p_{ij}$ | $T_{ij}$ |
|---|---|---|---|---|---|---|---|---|---|
| coeff | 0.03 | 0.04 | 0.06 | 0.1 | 0.1 | - | - | - | - |
| car | 20 | - | - | 18 | 4 | 2.8 | 0.06 | 0.1237 | 618.5 |
| bus | 30 | 5 | 3 | 6 | - | 1.88 | 0.15 | 0.3105 | 1552.5 |
| train | 12 | 10 | 2 | 4 | - | 1.28 | 0.28 | 0.5657 | 2828.5 |

Table 9:5: Trip characteristics

| | $t_{ij}^{v}$ | $t_{ij}^{walk}$ | $t_{ij}^{t}$ | $F_{ij}$ | $\phi_{ij}$ |
|---|---|---|---|---|---|
| coefficient | 0.05 | 0.04 | 0.07 | 0.2 | 0.2 |
| car | 25 | - | - | 22 | 6 |
| bus | 35 | 8 | 6 | 8 | - |
| train | 17 | 14 | 5 | 6 | - |

Probability of choosing mode train (Equation)= $p_{ij}^{train} = \frac{e^{-1.28}}{e^{-2.8}+e^{-1.88}+e^{-1.28}} = 0.5657$

Proportion of trips by car,$T_{ij}^{car} = 5000{\times}0.1237 = 618.5$

Proportion of trips by bus, $T_{ij}^{bus} = 5000{\times}0.3105 = 1552.5$

Similarly, proportion of trips by train,$T_{ij}^{train} = 5000{\times}0.5657 = 2828.5$ We can put all this in the form of a table as shown below 9:4:

- Fare collected from the mode bus = $T_{ij}^{bus} \times F_{ij} = 1552.5{\times}6 = 9315$
- Fare collected from mode train = $T_{ij}^{train} \times F_{ij} = 2828.5{\times}4 = 11314$

## 9.7 Summary

Modal split is the third stage of travel demand modeling. The choice of mode is influenced by various factors. Different types of modal split models are there. Binary logit model and multinomial logit model are dealt in detail in this chapter.

## 9.8 Problems

1. The total number of trips from zone $i$ to zone $j$ is 4200. Currently all trips are made by car. Government has two alternatives- to introduce a train or a bus. The travel characteristics and respective coefficients are given in table 9:5. Decide the best alternative in terms of trips carried.

   **Solution**

First, use binary logit model to find the trips when there is only car and bus. Then, again use binary logit model to find the trips when there is only car and train. Finally compare both and see which alternative carry maximum trips.

Cost of travel by car=$c_{car} = 0.05 \times 25 + 0.2 \times 22 + 0.2 \times 6 = 6.85$

Cost of travel by bus=$c_{bus} = 0.05 \times 35 + 0.04 \times 8 + 0.07 \times 6 + 0.2 \times 8 = 4.09$

Cost of travel by trai=$c_{train} = 0.05 \times 17 + 0.04 \times 14 + 0.07 \times 5 + 0.2 \times 6 = 2.96$

Case 1: Considering introduction of bus, Probability of choosing car, $p_{ij}^{car} = \frac{e^{-6.85}}{e^{-6.85}+e^{-4.09}} = 0.059$

Probability of choosing bus, $p_{ij}^{bus} = \frac{e^{-4.09}}{e^{-6.85}+e^{-4.09}} = 0.9403$

Case 2: Considering introduction of train, Probability of choosing car $p_{ij}^{car} = \frac{e^{-6.85}}{e^{-6.85}+e^{-2.96}} = 0.02003$

Probability of choosing train $p_{ij}^{train} = \frac{e^{-2.96}}{e^{-6.85}+e^{-2.96}} = 0.979$

Trips carried by each mode

Case 1: $T_{ij}^{car} = 4200 \times 0.0596 = 250.32$ $T_{ij}^{bus} = 4200 \times 0.9403 = 3949.546$

Case 2: $T_{ij}^{car} = 4200 \times 0.02 = 84.00$ $T_{ij}^{train} = 4200 \times 0.979 = 4115.8$

Hence *train* will attract more trips, if it is introduced.