4.3.2 Mode Choice Models

Mode choice models predict the fraction (or probability) $p^i[m/oshd]$ that users of class i select mode m to travel from zone o to zone d for trip purpose s in time period h. Mode choice is an example of a travel decision that can be easily modified for different journeys, and so for which performance or level-of-service attributes have considerable influence. It was no accident that the first random utility models were formulated to analyze transportation mode choice.

Definition of Choice Alternatives

In very simple cases the alternatives of a mode choice model are the individual transportation modes. In some cases "mixed" modes, that is, combinations of different modes such as car + train and car + bus, or different services of the same transportation mode (e.g., intercity, regional and night for the railway mode), are considered as choice alternatives. In interurban contexts, because of the high regularity and low frequency of transit services, the user is generally well informed about schedules and costs and tends to associate with each mode the utility of the most convenient service. In accordance with random utility theory, the logsum of lower choice dimensions (services) should be associated with the modes that offer them. To simplify the problem, some joint models of mode and service choice have been proposed.

Definition of Choice Set

Identification of the *relevant alternatives* depends on the transportation system under study. For example, modes such as walking or bicycle are typically considered to be choice alternatives in an urban system but, for obvious reasons, not for interurban systems. The definition of the choice set of each decision-maker is particularly important for mode choice models: not all transportation modes are available for all trips, either because of an objective impossibility (e.g., the personal car is not available to a user without a driving license) or because it is not perceived as an alternative for a particular trip (e.g., motorized modes may not be considered for very short trips).

Mode availability has been handled in mode choice models using the different approaches described in Sect. 3.5, usually via a combination of several heuristic methods. Objective nonavailability is usually dealt with by excluding the alternatives from the choice set of the decision-maker or user class; whereas contingent nonavailability or nonperception is generally accounted for by including availability/perception variables in the systematic utility specification. The attributes of car, bicycle, and motorcycle availability in the specification described in Fig. 4.7 should be interpreted in this way. Recently, IAP models that implicitly represent the probability of an alternative being available/perceived (as described in Sect. 3.5) have been applied to mode choice.

Functional Form

The systematic utility functions of mode choice models usually include level-of-service and socioeconomic attributes. As discussed in Chap. 2, *level-of-service* or *performance attributes* describe the characteristics of the service offered by the specific mode. Examples are travel time (possibly broken into access/egress time, waiting time, on-board time, etc.), monetary cost, service regularity, number of transfers, and so on. These attributes have negative coefficients because they usually represent disutilities for the user. In addition to level-of-service attributes, utility functions may include Alternative Specific Constants (ASCs) or *modal preference attributes*, variables that account for each mode's qualitative characteristics (e.g., the privacy of the car) or for attributes that are not otherwise included (e.g., service regularity for metro systems). In Chap. 3 it was shown that ASCs can be included in the systematic utility of all alternatives but one. Thus, after the effects of the other attributes in the utility function are accounted for, an ASC represents the remaining preference of users for a mode compared to a reference alternative. It follows that the coefficient of the ASC might have a positive or negative sign.

The ratios of level-of-service attribute coefficients in a linear utility function, also called the *marginal rates of substitution*, often have a meaningful interpretation. Among these, the rates of substitution between level-of-service attributes and monetary cost are particularly relevant, as these express the equivalent monetary value of the level-of-service attributes. If β_t and β_c are, respectively, the coefficients of travel time and monetary cost, the perceived Value of Time (VOT) implicit in mode choice behavior will be:

$$\mathrm{VOT} = \frac{\beta_t}{\beta_c}\frac{[h^{-1}]}{[mon.unit^{-1}]} = [mon.unit/h] \tag{4.3.15}$$

Level-of-service attributes, and in particular times, monetary costs, and the like, should take into account alternatives in the "lower" choice dimension, in this case path choice. Thus, level-of-service attributes should refer to the different paths that the user can take on the network of each mode. This is done by using the EMPU of path choice which, in multinomial logit or hierarchical logit models, is the logsum variable $Y_{m/d}$. Sometimes, for the sake of simplicity, attributes are calculated only for the "minimum" cost path, although this introduces a theoretical inconsistency if path choice is not predicted with the deterministic utility (minimum cost) model described in the next section.

Socioeconomic attributes include characteristics of the decision-maker or her household. Typical examples are gender, age, family income, and car ownership and availability (number of cars owned by the household or the ratio between the cars owned and number of driving licenses).

Finally, in more sophisticated specifications some attributes may depend jointly on service and user characteristics. For example, monetary cost can be divided by user income, or differentiated by income level with different coefficients. In both cases the value of time varies by income, and is usually higher for users with higher income.

WALKING		
T_{walking}	Time (h)	−6.8237
BICYCLE		
T_{bk}	Time (h)	−8.2718
Nbcl/Nad	Number of bicycles owned in family per adult	0.6646
Bcl	Alternative specific attribute	−1.5818
MOTORCYCLE		
T_{mbk}	Time (h)	−8.2718
Age	Age variable (1 if ≤35 years, 0 otherwise)	0.6863
Nmbk/Nad	Number of scooters and motorbikes owned in family per adult	1.8572
Mbk	Alternative specific attribute	−2.3789
CAR		
T_{car}	Time (h)	−1.6142
Mc_{car}	Monetary cost (€)	−0.3338
Park	Parking (1 for priced parking destinations, 0 otherwise)	−1.1469
Hfam	Position in the family (1 if head of family, 0 otherwise)	0.4931
Ncar/Nad	Number of cars owned in family per adult	0.4014
Car	Alternative specific attribute	−1.7103
BUS		
T_{bus}	Total travel time (h)	−1.6142
Mc_{bus}	Monetary cost (€)	−0.3338
Ntrn	Number of transfers	−0.1772
Bus	Alternative specific attribute	−1.7827
$\ln L(\boldsymbol{\beta}_{\text{ML}})$		−475
$\ln L(\mathbf{0})$		−697
ρ^2		0.317
% right		0.651

Fig. 4.7 Alternatives, attributes, and coefficients of an MNL mode choice model for urban commuting trips

With respect to functional form, multinomial logit mode choice models are often used:

$$p^i[m/oshd] = \frac{\exp(V^i_{m/oshd})}{\sum_{m'} \exp(V^i_{m'/oshd})} \tag{4.3.16}$$

Figure 4.7 shows the alternatives, attributes, and coefficients of a logit mode choice model for commuting trips in a medium-sized Italian city. Other examples of MNL mode choice models are presented in Sect. 4.3.4, and in Chap. 8 on transportation demand estimation.

Hierarchical logit specifications are also being increasingly used. These models assume different levels of correlation between the perceived utilities of different mode groups, for example, private and public modes, and/or between different services of the same mode. A hierarchical logit mode choice model could also be used to predict the joint choice of mode and parking in urban areas.

In some applications to urban areas, specification of the systematic utility of the car mode includes level-of-service attributes related to parking, such as the time spent looking for a free parking space, parking cost, and walking distance to and from the parking space. In the most general case where several locations and types of parking are available, private modes such as auto are represented as groups of alternatives, each alternative corresponding to a specific parking location (d_p) and parking type (t_p) together with the given mode.

The lower-level multinomial logit model for parking choice can be specified as follows.

$$p^i[d_p t_p / oshda] = \frac{\exp(V^i_{d_p t_p})}{\sum_{d'_p t'_p} \exp(V^i_{d'_p t'_p})}$$

with

$$V^i_{d_p t_p} = \beta_{ts} Tsr_{d_p t_p} + \beta_c Mc^i_{d_p t_p} + \beta_{tw} Twl_{d_p/d}$$

where the variables are:

d_p, t_p	Parking location (zone) and type (free on street, paid on-street, paid off-street, illegal etc.)
$Tsr_{d_p t_p}$	Average search time to find a parking space of type t_p in zone d_p
$Mc^i_{d_p t_p}$	Monetary cost (price or expected fine) of the alternative depending on the user class i (e.g., related to parking duration)
$Twl_{d_p/d}$	Time on foot needed to reach final destination d from location d_p

In this case, the logsum inclusive variable Y^i_p can be expressed as

$$Y^i_p = \ln \sum_{d'_p t'_p} \exp\left(V^i_{d'_p t'_p}\right)$$

and included in the systematic utility of the car alternative in the mode choice MNL model.

An example of a hierarchical logit mode and parking choice model in an urban area is given in Fig. 4.8.

4.3.3 Path Choice Models

Path choice models predict the fraction (or probability) $p^i[k/oshdm]$ of trips by users of class i on path k of mode m from o to d for trip purpose s in time period h. The path choice models used in practice are all behavioral, and the relevant attributes are, for the most part, performance or level-of-service variables obtained from the network supply models described in Chap. 2.

Path choice behavior and the models representing it depend on the type of service offered by the different transportation modes. In particular, the case where the