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# Consideration of Alternative Access, Egress, and Line-Haul Travel Choices Within UTPS Framework

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**In many large metropolitan areas more than one line-haul transit service is often available in some travel corridors. Examples include express bus and rail rapid transit, commuter rail and rail rapid transit, private suburban bus lines and competing service provided by regional transit operator. This is especially true as one moves away from the core area and corridors become wider. Coupled with the choice of line-haul modes are several choices of accessing these modes such as walk, feeder bus, park-and-ride, and kiss-and-ride. This paper addresses these issues and describes a systematic procedure for analyzing such mode choices. It is argued that straightforward use of urban transportation planning system (UTPS) programs prevents meaningful analysis of important policy issues due to their all-or-nothing assignment principle, when real access-egress and line-haul choices have to be considered.**

Much progress has been made in the last two decades in quantitative aspects of long-range planning of highway and mass transportation facilities. The forecasting of travel demand along highway links and transit lines that comprise the transportation network of a metropolitan area has been greatly facilitated by the availability of two software packages, PLANPAC (1) and Urban Transportation Planning System (UTPS) (2), developed by the U.S. Department of Transportation. Several publications (3,4) describe the sequence of trip generation, trip distribution, mode choice, and route-assignment models used to simulate the traffic flow by using these packages. This paper addresses the problems associated with application of computer programs UNET, UPATH, UPSUM, UMODEL, and ULOAD (2) if alternative access, egress, and line-haul choices are available between an origin-destination (O-D) pair. Briefly, UNET is used to prepare the computerized description of a transit system that serves the study area. UPATH finds the minimum impedance (travel time, travel cost, or both) path between any O-D pair in the system and zone-to-zone fare matrix. UPSUM computes the travel time along minimum impedance path and can store the time spent walking, waiting, transferring, and in-motion along various travel modes (walk, automobile, bus, or rail) used between an O-D pair. UMODEL computes the share of transit trips (mode split) given the transit level-of-service data prepared by UPATH and UPSUM, highway level-of-service data prepared by either PLANPAC programs BUILDHR (1) and BUILDVN (1), or UTPS programs HR (2) and UROAD (2). It computes total person trips between an O-D pair by using a user-specified mode split model. Finally, ULOAD loads the resulting transit trips along the minimum impedance path to produce a transit assignment.

## PROBLEM DEFINITION

The process described above is satisfactory for synthesizing transit travel patterns if only one transit path is overwhelmingly used by an O-D pair. However, in large metropolitan areas, as one moves away from the core of the region, several options for commuting exist. For example, rail rapid transit with walk, feeder bus, park-and-ride and kiss-and-ride access; express bus with walk, feeder bus, park-and-ride, and kiss-and-ride access. Even if a very fine zone system and detailed network description are used in demand analysis, the problem of all-or-nothing assignment cannot be easily overcome. Assessment of travel demand along competing line-haul and access-egress service is essential in project-level planning and design of transit facilities. The following sections describe the computerized network analysis and mode choice estimation process developed for the Northeast Ohio Areawide Coordinating Agency (NOACA) as part of its alternatives analysis work program. It is described in detail elsewhere (5). The procedure follows, in its general structure, the mode split procedures of the Chicago Area Transportation Study (CATS) (6) and the North Central Texas Council of Governments (7).

### Modeling Procedures

The procedure provides

1. Explicit estimation of use of one or more available line-haul transit modes;
2. Explicit representation and estimation of access-egress modes and their impact on use of main line-haul mode;
3. Method to represent parking fee-walking distance trade-off faced by automobile users in high-density areas, such as the central business district (CBD); and
4. Method to represent and analyze impacts of alternative transportation system management strategies (such as parking costs, toll pricing, fare changes, and fuel price changes) on transit use.

### Modeling Structure

The heart of the procedure is a disaggregate logit mode-choice model that estimates modal use for individual trips. The procedure provides a modeling structure, including sampling and aggregation procedures based on the principles of Monte Carlo simulation (5), that links the mode-choice model to available aggregate descriptors of level-of-service and socioeconomic attributes of the travelers.

The mode choice model is a modified nested binary choice logit model. The derivation of logit choice models and the justification of their use for the analysis of mode choice are thoroughly discussed in the literature [for example, see Lisco and Stopher (8,9), and McFadden and Domencich (10)]. The analysis of transit starts with an estimation of the disutility of each access and egress mode of each valid transit path. The submode that has the least disutility is assumed to represent the resultant disutility of the access and egress portions of the path. Given the access and egress resultant disutilities and the line-haul service attributes, the composite disutility of each valid transit path is determined.

The transit path that has the least disutility is assumed to represent the resultant disutility of transit for analysis of the automobile versus transit mode choice. A binary logit mode choice formulation is used in computing the probability of choosing transit [$P_r(t)$] and automobile [$P_r(a)$]. The automobile option reflects both drive alone and passenger modes. In order to develop the vehicle trip table for highway assignment, the expected automobile occupancy is estimated as a function of (a) trip purpose, (b) trip length, (c) trip orientation, and (d) zonal income of the tripmaker's place of residence. The development of the automobile-occupancy model and associated look-up curves are described elsewhere (5,11). The expected automobile occupancy is also used in computing the disutility for automobile travel. Automobile operating cost and parking fee are divided by expected automobile occupancy to reflect shared cost of automobile travel among the occupants.

After the probability of transit use has been computed, the probability of using alternative transit line-haul modes is computed by using a binary choice logit model. The results are then weighted by the probability of using transit. In its present form, the modeling process assumes that the individual tripmaker will use the best access and egress mode associated with each line-haul mode with the probability one. Therefore, absolute probability of the best access and egress mode is taken to be equal to the probability of line-haul mode computed above.

Note that simulated trips that originate from the same zone will have different access-egress modes that have the least disutility depending on the distance from the line-haul facility. Therefore, at the zonal level, distribution over various access-egress modes is achieved. This contrasts sharply with the conventional use of UNET and UPATH programs where all trips get assigned to the centroid connector by providing access to the transit network. Details of disutility calculations and estimation of mode-choice probability follow. Details of the model structure can be found elsewhere (5).

## DISUTILITY CALCULATIONS

The variables in disutility calculations are defined in Table 1.

For transit access, the disutility of walk access to line-haul facility i is computed as

$$U_{wa}(i) = VWALK \times WKTL(i,a) \quad (1)$$

$$U_{ba}(i) = VWALK \times WKTB(i,a) + VWAIT \times WTTB(i,a) + VIVT \times BIVT(I,a) + VCOST \times BAFAR(i,a) + VTFER \times 1 + VBIASA(B) \quad (2)$$

where i is the transit path and a is access.

Disutility of park-and-ride access is computed as

$$U_{pa}(i) = VWALK \times PRWK(i) + VIVT \times PRIVT(i) + VCOST \times [PROPC(i) + 0.5 \times PRPCST(i)] + VBIASA(P) \quad (3)$$

Disutility of kiss-and-ride access is computed as

$$U_{pa}(i) = VIVT \times 2 \times PRIVT(i) + 2 \times VCOST \times PROPC(i) + VBIASA(k) \quad (4)$$

Resultant access disutility is computed as

$$U_a(i) = Min[U_{wa}^{(i)}, U_{ba}^{(i)}, U_{pa}^{(i)}, U_{ka}^{(i)}] \quad (5)$$

For transit egress, the disutility of walk egress from transit line-haul is computed as

$$U_{we}(i) = VWALK \times WKTL(i,e) \quad (6)$$

where e is egress.

Disutility of feeder bus egress is computed as

$$U_{be}(i) = VWALK \times WKTB(i, e) + VWAIT \times WTTB(i, e) + VIVT \times BIVT(i, e) + VCOST \times BAFAR(i, e) + VTFER \times 1 + VBIASA(B) \quad (7)$$

Resultant egress disutility is computed as

$$U_e(i) = \mathrm{Min}[U_{we}(i), U_{be}(i)] \quad (8)$$

For transit line-haul, the disutility of transit line-haul path is calculated as follows:

$$U_{tm}(i) = VWAIT \times TOVT(i) + VIVT \times TIVT(i) + VTFER \times NTFER(i) + VBIASTM(i) + U_a(i) + U_e(i) \quad (9)$$

where i is 1 for a path that contains feeder bus and express bus only and i is 2 for a path that contains feeder bus and rail only.

Resultant transit utility is calculated as

$$U_t = \mathrm{Min}[U_{tm}(1), U_{tm}(2)] + VBIAST \quad (10)$$

For automobile, the disutility of automobile travel is calculated as

$$U_a = VIVT \times AIVT + VWALK \times AWTIME(D) + \{VCOST[0.5 \times APCOST(D) + AOPC]/OCC\} + VAA \times AA \quad (11)$$

The probability of choosing transit is computed as

$$P_r(t) = 1/[1 + \exp(U_a - U_t)] \quad (12)$$

The probability of choosing automobile is computed as

$$P_r(a) = 1 - P_r(t) \quad (13)$$

The probability of choosing specific transit path is calculated as

$$P_r[tm(1)] = \left(1/\{1 + \exp[U_{tm}(2) - U_{tm}(1)] \times P_r(t)\}\right) \quad (14)$$

$$P_r[tm(2)] = 1 - P_r[tm(1)] \quad (15)$$

The values of calibration parameters used in disutility calculations are given in Tables 2 and 3 for trips destined to the CBD and to the non-CBD, respectively. These values were obtained by researching the disaggregate mode choice literature and fine-tuning them to replicate observed ridership patterns in the Cleveland metropolitan area. The details of the model calibration and validation procedures can be found elsewhere (5).

## SYNTHESIS OF A PSEUDOOBSERVATION

As mentioned earlier, the modeling process described in this paper uses pseudosample enumeration technique to provide zonal level aggregate mode-split

**Table 1. Variables used in modal disutility calculations for trips to CBD and non-CBD destinations.**

| Notation | Description | Notation | Description |
|---|---|---|---|
| WKTL | Walk time to or from line-haul facility | AIVT | In-vehicle time spent driving automobile if automobile is line-haul mode |
| WKTB | Walk time to or from feeder bus that serves line-haul facility | AOPC | Operating cost of driving automobile if automobile is line-haul mode |
| WTTB | Wait time to board feeder bus | AA | Automobile availability estimated as AA = 0, if no. of automobiles owned by household is 0, AA = 0.8 + 0.2/(no. of persons in the household), if no. of automobiles owned by household is 1, and AA = 1, if no. of automobiles owned by household is 2 or more |
| BIVT | In-vehicle time spent riding feeder bus | | |
| BAFRA | Fare for feeder bus | | |
| PRWK | Walk time from park-and-ride lot to line-haul facility | | |
| PRIVT | In-vehicle time spent driving automobile to park-and-ride lot | $U_{wa}$ | Disutility of walk access |
| PROPC | Operating cost of driving automobile to park-and-ride lot | $U_{ba}$ | Disutility of feeder bus access |
| PRPCST | Parking fee for leaving car at park-and-ride lot | $U_{pa}$ | Disutility of park-and-ride access |
| TOVT | Total wait time to board first line-haul and subsequent line-haul facilities | $U_{ka}$ | Disutility of kiss-and-ride access |
| | | $U_a$ | Resultant access disutility |
| TIVT | Total in-vehicle time spent riding first line-haul and subsequent line-haul facilities | $U_{we}$ | Disutility of walk egress |
| | | $U_{be}$ | Disutility of feeder bus egress |
| NTFER | No. of line-haul transfers | $U_e$ | Resultant egress |
| AWTIME(D) | Walk time between parking lot and final destination if automobile is line-haul mode | $U_{tm}$ | Disutility of transit line-haul path |
| | | $U_t$ | Resultant transit disutility |
| APCOST(D) | Parking fee paid if automobile is line-haul mode | $U_a$ | Disutility of automobile line-haul travel |

**Table 2. Calibrated values of parameters used in modal disutility calculations for trips to CBD.**

| Description | Notation | Home-Based Work Trips | Home-Based Nonwork Trips | Home-Based School Trips | Non-Home-Based Trips |
|---|---|---|---|---|---|
| Value of in-vehicle time (min) | VIVT | -0.025 | -0.012 | -0.025 | -0.016 |
| Value of out-of-pocket cost (¢) | VCOST | -0.012 | -0.01 | -0.012 | -0.008 |
| Value of out-of-vehicle walk time (min) | VWALK | -0.058 | -0.04 | -0.058 | -0.024 |
| Value of out-of-vehicle wait time (min) | VWAIT | -0.09 | -0.03 | -0.09 | -0.048 |
| Value of no. of transit transfers | VTFER | 0 | 0 | 0 | 0 |
| Value of automobile availability | VAA | 0 | +4.12 | 0 | NA |
| Value of bias coefficient for feeder bus mode of access-egress | VBIASA(B) | 0.25 | 0 | +0.25 | +0.35 |
| Value of bias coefficient for park-and-ride mode of access | VBIASA(P) | -0.36 | -0.22 | -0.36 | -0.125 |
| Value of bias coefficient for kiss-and-ride mode of access | VBIASA(K) | -0.40 | -0.26 | -0.40 | -0.1 |
| Value of bias coefficient for express bus in line-haul operation | VBIASTM(E) | +0.31 | -0.52 | +0.31 | -0.67 |
| Value of bias coefficient for rail transit in line-haul operation | VBIASTM(R) | +0.31 | -0.45 | +0.31 | -0.43 |
| Value of transit bias | VBIAST | +0.14 | +2.48 | +0.14 | +0.06 |

**Table 3. Calibrated values of parameters used in modal disutility calculations for trips to non-CBD.**

| Description | Notation | Home-Based Work Trips | Home-Based Nonwork Trips | Home-Based School Trips | Non-Home-Based Trips |
|---|---|---|---|---|---|
| Value of in-vehicle time (min) | VIVT | -0.01 | -0.001 | -0.001 | -0.008 |
| Value of out-of-pocket cost (¢) | VCOST | -0.01 | -0.01 | -0.010 | -0.009 |
| Value of out-of-vehicle walk time (min) | VWALK | -0.03 | -0.03 | -0.021 | -0.05 |
| Value of out-of vehicle wait time (min) | VWAIT | -0.06 | -0.04 | -0.05 | -0.05 |
| Value of no. of transit transfers | VTFER | -0.23 | -0.1 | -0.10 | 0 |
| Value of automobile availability | VAA | +3.3 | +5.0 | +3.5 | NA |
| Value of bias coefficient for feeder bus | VBIASA(B) | +0.42 | +0.23 | +0.34 | +0.55 |
| Value of bias coefficient for park-and-ride mode of access | VBIASA(P) | -0.55 | -0.10 | -0.73 | -0.60 |
| Value of bias coefficient for kiss-and-ride mode of access | VBIASA(K) | -0.25 | -0.10 | -0.40 | -0.40 |
| Value of bias coefficient for express bus in line-haul operation | VBIASTM(E) | -0.65 | -1.75 | -0.87 | -1.50 |
| Value of bias coefficient for rail transit in line-haul operation | VBIASTM(R) | -0.70 | -1.35 | +0.13 | -1.45 |
| Value of transit bias | VBIAST | 1.67 | +1.32 | +2.65 | -1.56 |

forecasts for planning purposes. This is one of the most satisfactory procedures to develop aggregate mode-split rates by using disaggregate mode choice models when computer resources are available. Details and discussion of aggregate forecasting from disaggregate choice models can be found elsewhere (5,12). A computer program, MSPLIT (13), was written that performs the necessary Monte Carlo simulation by sampling frequency distributions of zonal socioeconomic attributes and level-of-service data. The process is described briefly here and details can be found elsewhere (5).

## Assigning of Automobile-Related Level-of-Service and Socioeconomic Attributes

The components of disutility associated with automobile travel are shown in Equation 11. Automobile in-vehicle time and operating costs on the line-haul portion of the journey are taken from input zone-to-zone highway travel time and distance skim matrices. The intrazonal variability of these components is assumed to be small and so can be ignored. For non-CBD destinations, walk time at destination and parking fee are also assumed to have minimal intrazonal variability and are estimated by using input zonal level data. For high-density areas such as the CBD, where considerable variation in parking fee choice and associated walking distance to reach the final destination exists, a simulation approach is used to assign these attributes to the sampled observation. Cumulative probabilities of walking certain distances between the parking lot and final destination in the Cleveland CBD are shown elsewhere (5). These values were derived from a special parking lot survey conducted in the downtown area. In addition, for each traffic analysis zone within the CBD area, a curve was derived to show the minimum parking fee that must be paid if one wishes to park within 0.1, 0.2, 0.3,...,1.0 mile from the zone centroid. MSPLIT generates a walking distance randomly by using the aforementioned probability distribution and computes a parking fee for the associated distance by using input parking fee-walking distance curve. Methodology for constructing these curves is also described elsewhere (5).

Automobile availability (AA) for the pseudoobservation is estimated by random sampling from the joint distribution of automobile ownership and household size available for the zone of trip production. The methodology for developing joint automobile ownership and household size distributions as a function of zonal mean automobile ownership and zonal mean household size is described elsewhere (14). These distributions have been hardcoded inside the MSPLIT computer program. Automobile availability is defined by using the sampled number of automobiles and number of persons in the household, by using the relation given in Table 1. Since households that have a greater number of automobiles make more trips than households that have no car or fewer cars, the joint probability distribution of automobile ownership and household size is weighted prior to sampling by the relative tripmaking frequencies of households of varying size and automobile ownership characteristics. These tripmaking frequencies are input to MSPLIT as control cards; their derivation is described elsewhere (15).

## Determining Choice Set of Public Transportation

The number of transit paths that are assumed to be available to a pseudoobservation and their characteristics depend on the transit network. The available access-egress submodes vary for each path, depending on the priority mode of the path and automobile ownership levels. The following paragraphs explain the process of determining the choice set and its attributes.

Four distinct types of transit service are available in the Cleveland metropolitan area. In the densely developed central city area, frequent radial and crosstown bus service is provided. These routes are designated as local bus routes and are coded as mode 4 in the UNET (2) transit network description. The service to inner and outer suburbs within Cuyahoga County and adjacent developed communities is provided by using radial bus routes that operate more frequently during rush hours. These routes are designated as express bus routes and are coded as mode 6 in the UNET transit network description. In addition to the local and express bus service, a heavy rail line service is available within Cleveland and two light rail lines operate between Shaker Heights and the Cleveland CBD. Heavy rail service is coded as mode 7 and light rail service is coded as mode 8 in the UNET network description. Local crosstown buses interface with the express bus and rail service and, therefore, provide feeder service as well. Modes 4, 6, 7, and 8 are operated by the regional transit authority. Limited intercity bus service between the Cleveland CBD and some of the outlying communities in Lorain and Lake Counties is also provided by private operators. This service is designated as mode 5 in the network description.

Nontransit modes 1, 2, and 3 are used to designate CBD sidewalk links, centroid automobile connectors, and centroid walk connectors, respectively.

The automobile connectors are used only if express bus and rail service cannot be accessed by using local bus from any given zone. As will be shown later, level-of-service provided by alternate access modes is estimated by using a zonal transit service (ZTS) description file (13) prepared exogenously.

The modeling process developed for the Cleveland area is capable of analyzing mode split between competing rail and express bus service (if available) between any O-D pair. In order to accomplish this split, it is necessary to develop three sets of transit paths by using computer program UPATH (2). These paths are developed as follows:

1. Set 1 includes paths developed by using complete transit network description.
2. Set 2 includes paths developed by using transit modes 4, 5, and 6 only; that is, rail service is excluded from the network description by using no transfer allowed (NOX) option of UPATH (2).
3. Set 3 includes paths developed by using transit modes 4, 5, 7, and 8 only; that is, express bus service is excluded from the network description by using the NOX option.

Each set is then analyzed to determine for each O-D pair:

1. Priority mode, that is, the highest numbered mode used in the path;
2. First line-haul mode used;
3. Last line-haul mode used;
4. Wait for first line-haul and subsequent line-haul modes used in the path;
5. Total line-haul in-vehicle time;
6. Number of line-haul transfers;
7. Automobile in-vehicle time, if access to the transit system is using mode 2 (automobile connector); and
8. Wait time for the feeder bus at the origin end, if feeder bus is not part of the line-haul.

A computer program TPATH (5,13) has been written to facilitate the transit path analysis mentioned above. This program is similar in concept to the UTPS program UPSUM (2). Both programs read the path description produced by UPATH and prepare zone-to-zone transit skim trees. TPATH, however, distinguishes between the line-haul and access-egress portions of the paths. It trims the access-egress portions of the path and summarizes in the skim trees only the line-haul attributes.

Legs that have mode 3 are never considered part of the line-haul. The only exception is in the high-density area, such as the CBD, where the detailed sidewalk network (mode 1) and fine zone system are used. If program (TPATH) encounters a 3-1 or 1-3 mode sequence, then those legs are also considered part of the line-haul. This preserves the user-coded travel impedance, which is considered sufficiently accurate. Intrazonal variability in such areas is assumed to be small and can be ignored.

Legs that have modes 6, 7, or 8 (express bus and rail) are always considered part of the line-haul and are never removed from the network. If the highest numbered mode used in the path is 5 or less (local or suburban bus as the priority mode), legs that have modes 4 or 5 are considered part of the line-haul.

If mode 6, 7, or 8 is the priority mode in the path, legs that have mode 4 at the beginning or end of the line-haul portion are considered either approach (access-egress) or line-haul legs, depending on the user-specified criteria for either end. The decision to remove modes 4 and 5 from the line-haul portion depends on input values of two parameters:

1. CRTIME--If the in-vehicle time on modes 4 or 5 is greater than the criterion CRITIME, then they are considered part of the line-haul or
2. CRATIO--If the ratio of the in-vehicle time on modes 4 or 5 to the total path's in-vehicle time is greater than criterion CRATIO, then they are considered part of the line-haul.

By using these two parameters it is possible to preserve transit legs of certain length at either end as part of the line-haul.

If a leg that has mode 2 (automobile connector) is the first leg in the path, then it is considered part of the line-haul. Recall that automobile connectors are coded only if access at the origin end is not possible by using walk and feeder bus modes. Automobile egress is never permitted in the path building.

Determination of Choice of Access Modes

The choice set generated for a pseudoobservation depends on the use of the first line-haul mode as determined by TPATH. If the first line-haul mode is 4 or 5, then only walk access is considered. If the first line-haul mode is 6, 7, or 8, then walk, feeder bus, kiss-and-ride, and park-and-ride options are considered for automobile-owning households and walk and feeder bus for non-automobile-owning households.

Determination of Choice of Egress Modes

The choice set for pseudoobservation for egress is based on the use of the last line-haul mode. If the last line-haul mode is 4 or 5, then only walk egress is considered. If the last line-haul mode is 6, 7, or 8, then walk and feeder bus, if available, are considered for egress.

Determination of Choice of Transit Line-Haul Paths

The determination of choice for line-haul travel depends on the priority mode along three sets of paths (full network, network excluding rail service, and network excluding express bus service) as analyzed by using TPATH. The identification of choice set is done as follows. If the priority mode is 5 or less on full network (network 1), then the only alternative to automobile is the local or suburban bus. Estimated transit trips are assigned to network 1. If the priority mode is 6 on network 1 and the path in network 1 is identical to the path in network 2 (no rail present), two cases are possible, namely:

1. No connection in network 3 (no express bus present) is found; therefore, no rail alternative to express bus exists between the O-D pair in question. No line-haul choice is analyzed and trips are assigned to network 2.
2. Connection in network 3 is present. If the connection in network 3 has a priority mode of 7 or 8, then the transit split is estimated and trips are further split between network 2 and 3. If the priority mode in network 3 has a priority mode of 5 or less, no line-haul split is estimated and all trips are assigned to the express bus path.

If the priority mode is 7 or 8 on network 1, three cases are possible, namely:

1. No priority mode 6 connection in network 2; in this case no competing express bus service is identified and no line-haul split is performed. All transit trips are assigned to network 3.
2. Paths on network 1 and network 3 are not

identical; in this case, the network 1 path includes both rail and express bus legs, and thus is better than the rail-only path on network 3. No line-haul split is performed. All transit trips are assigned to network 1.

3. Paths on network 1 and network 3 are identical and priority mode on network 2 path is mode 6; in this case there is a choice between express bus and rail. The transit trips are split between two line-haul choices and are assigned to networks 2 and 3.

The determination of number of line-haul paths to be analyzed is done by MSPLIT by using zone-to-zone skim tree matrices produced by computer program TPATH.

### Simulation of Access-Egress Impedance

TPATH trims those legs from the transit path that are considered approach links (access-egress). For pseudoobservations generated between an O-D pair, it is assumed that line-haul disutility components are identical for observations and the variation exists mainly in access-egress components. It is further assumed that the bulk of the intrazonal variability can be described by the variability of distance between trip ends and transit stops or stations. Thus, the input to MSPLIT (13) includes a description of the frequency distributions of distance to transit. Separate distributions can be specified for each zone, transit mode, and residential and nonresidential trip end. The distributions are specified in terms of the type of the distribution function and its parameters. Any of the five distributions can be used--linear, bilinear, step, bounded normal, or bounded exponential.

In the process of generating a pseudoobservation the program samples the distribution that corresponds to the first line-haul mode and the origin zone. The resulting distance is converted into access submodes service measures such as walk time, in-vehicle feeder bus time, and automobile-in-vehicle time by using user-specified zonal speeds. The total access impedance by each of the modes is determined by considering all the other standard components, such as feeder bus waiting time and automobile parking costs, as listed in Table 1. These elements are specified at the zonal level. A similar procedure is used to determine the egress impedance at the destination.

### Determining the Frequency Distributions of Distance to Transit

The Northeast Ohio Areawide Coordinating Agency mode split procedure provides a default method to estimate the distributions based on available or easily obtainable data. The default procedures are sufficiently accurate for most standard cases. They were formulated based on a simulation analysis and validated by comparison to manually derived distributions (16,17). The default procedure is driven by a separate computer program, DFREQ (13). In standard applications the default distributions are used in the majority of cases, with user-determined distributions for areas that have odd-shaped service or are of a special interest.

Two types of transit service are considered--continuous and discrete. Continuous service is characteristic of local buses and express buses that operate in the collector-distributor phase, when they stop frequently to serve passengers. Discrete service is characteristic of rail lines and express buses that operate in the line-haul phase, when they stop only at a few designated locations. Gur showed (5) that frequency distribution of distance to continuous service can best be described as a linear function. The distribution to discrete service can best be described by a bounded normal distribution. DFREQ determines the distributions' parameters.

### Parameters of the Linear Distribution Function and Their Estimation

The parameters of the linear function are as follows:

XMIN--minimum distance to the continuous bus service,
XMAX--maximum distance to the continuous bus service, and
Slope R--ratio of probability to walk distance XMAX to XMIN.

The parameters are estimated as a function of density of service (route miles of service operating per square mile of the zonal area) and activity concentration (that is, the extent to which trip ends are concentrated near the transit service).

The activity concentration factor can either be specified by the user or determined inside the program as a function of the percentage of the developed area in the zone. Another option is to specify different concentration factors for residential and nonresidential trip ends in order to account for the higher propensity of commercial areas to locate in accessible locations.

### Parameters for Bounded Normal Distribution and Their Estimation

The parameters of the bounded normal distribution are as follows:

DMIN--minimum distance to discrete service,
DMAX--maximum distance to discrete service, and
SIGMA--standard deviation of parent complete normal distribution.

The discrete transit service (express bus, rail-rapid transit, or both) available for each traffic-analysis zone is described by specifying up to three nodes for each mode on the transit network that serves the zone in question. A separate station data (SDATA) file is coded, which gives X and Y coordinates of each transit node and zone centroid. The program DFREQ estimates the parameters of the distribution by assuming a square zone and calculating the distribution of distance from the zone's area to the closest transit station. For further details see elsewhere (5).

Depending on the nature of analysis, MSPLIT can be used to estimate either zonal transit trip ends or zone-to-zone transit trips (transit trip table) for assignment purposes. The sampling logic used to generate pseudoobservations is fully described elsewhere (5).

MSPLIT also saves the attributes of automobile and transit modes simulated for a pseudoobservation in a sample file. By manipulating attributes such as travel time or travel cost in the sample file, MSPLIT can be rerun rather inexpensively to assess the impact on mode split.

## TRANSIT TRIP ASSIGNMENT

Since the modeling procedure described uses three sets of paths (full network, network with no rail, and network with no express bus service) and produces three path-specific transit trip tables, a special trip-loading sequence is necessary by using computer program ULOAD (2). The loading job consists of three steps. In the first step the trip table created by using full network is loaded to the paths created by using full network. The resulting partly loaded legs are saved and serve as an input to the next step. In the second step the trip table created by using network without rail is assigned to the partly loaded network from step 1 on the paths described by network with no rail service included. The resulting leg file is used as an input to the last stage of the process, where the trip table created by using network without express bus is assigned, by using paths described by network with no express bus service included. This multiple loading option is facilitated by the LEGS2 option of the UTPS program ULOAD.

## CONCLUSIONS

The modeling process described provides a flexible framework for analyzing multiple options of access-egress modes available to a tripmaker. When present, the process provides a mechanism to split transit travel between two line-haul modes that serve an O-D pair. The disutility expressions used in the nested logit model use explanatory variables that are commonly used in network and trip generation analysis for a metropolitan area and are suited for long-range policy planning as well.

There are a number of obvious advantages to using this modeling process. First, it permits the analysis of policy issues that relate to selecting the service attributes of different transit modes that serve the same areas. Second, the inputs to the program describe easily measurable attributes of the transit system. The procedure relieves much of the weight of the approach link coding, which in standard models is a major determinant of the transit network loading.

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