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GENERAL PLANNING CONSULTANT

TECHNICAL MEMORANDUM 89.3.8

REVISED MODE-OF-ARRIVAL MODEL

USER GUIDE

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Prepared for:

Southern California Rapid Transit District

Prepared by:

Schimpeler • Corradino Associates

in association with

Cordoba Corporation

June, 1989

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1.0 INTRODUCTION

When the design of a rail system in an urban area is undertaken, the characteristics of travel to and from the planned rail stations can be crucial. In many cases, the successful implementation of a rail system depends upon the provision of adequate feeder bus service, automobile drop-off space, and parking spaces. Detailed investigation to determine the requirements of provisions for feeder buses and automobiles is necessary since these requirements are essential parameters in the physical design of stations and, therefore, can substantially affect the capital cost of the system. It is important not only to estimate these characteristics of travel for the entire day, but also by various time periods, especially peak-period travel. The number and types of trips accessing a station in the peak hour, for example, are essential parameters for determining the size of the station in terms of bus bays, entrances, fare gates, and automobile access locations.

Therefore, the primary objective of a mode of access and egress model is to provide a reliable tool to estimate the number of trips entering and leaving each rail station, by mode and time period. This memorandum describes the methodology used to obtain these estimates in the context of the Los Angeles Metro Rail system.

The mode-of-arrival[1] (MOA) procedure reported here was developed by Schimpeler•Corradino Associates, as General Planning Consultant (GPC) to the Southern California Rapid Transit District. It is a major revision to the MOA procedure previously in place, developed and implemented by a consultant team in 1983 (see Transportation Planning and Modeling Services: Technical Memorandum No. 5.1 -- Development of the Mode of Access and Egress Model, March 1983). The old procedure had several shortcomings:

- o The methodology then in use by the District permitted only walk access to transit for midday paths. This necessitated developing a series of "post-processor" mode choice models to reallocate those transit trips that use midday paths (specifically, home-to-other, other-to-other, and other-to-work trip purposes) among all available access modes: walk, bus, kiss-and-ride passengers (KNR), park-and-ride drivers (PND), and park-and-ride passengers (PNP).

- o The mode choice models selected for this purpose were calibrated on Washington, DC and Seattle data. Transferring a model from another geographical area without locally updating alternative-specific constants and parameter scale can lead to serious prediction errors (see F.S. Koppelman, G.-K. Kuah, and C.G. Wilmot, "Transfer Model Updating with Disaggregate Data," **Transportation Research Record 1037**, 1985).

[1] While the term "mode-of-arrival" is used throughout this memorandum for the sake of brevity, the procedure to which it refers also permits estimation of the distribution of departure modes.

- In initially splitting access modes between walk and non-walk, the only criterion is the distance to the nearest rail station. There is no guarantee that the station is actually on the minimum path between a given zone pair.

- In executing the primary mode choice stage, other-to-work (OW) trips are included with home-to-other (HO) and other-to-other (OO) trips. As such, they are assumed to use midday paths, and are subject to a mode choice model <u>different</u> from that used for home-based work (HW) trips. In executing the <u>access</u> mode choice stage for the old method, however, OW trips were grouped with HW trips and assumed to use morning peak paths. There are plausible arguments for grouping OW trips with either HW trips or with HO and OO trips. However, it is preferable to be consistent.

- For the old method, modeling the split between transit and highway access requires computing highway distance and time from each zone centroid to the nearest rail station. Again, there is no assurance that this rail station is the correct one for all zone-to-zone interchanges. In addition, if the underlying highway network is sparsely coded around a given rail station, it may be necessary to add new highway nodes and links - a tedious manual task. Finally, a separate UROAD run is required to generate the highway skims from each zone centroid to the nearest rail station.

- Different models are used depending on whether or not PNR is available for a given station. If PNR is available, non-walk trips are first split between highway and bus using one logit model, and then highway trips are split between PNR and KNR using a second logit model. If PNR is not available, non-walk trips are simply split between KNR and bus, using a piecewise linear (discontinuous) model for which the proportion of KNR trips is a function of highway distance. These two options can give inconsistent results. For example, it has been found that in some instances, more auto access trips are predicted for a station with KNR access only, than when a PNR lot is added to the same station.

- An algorithm was developed to redistribute to other modes the increment of PNR demand which was unfulfilled due to capacity constraints on parking lots. This redistribution process did not possess the Independence of Irrelevant Alternatives property; that is, it did not distribute the excess demand to the other modes (including drive alone and shared-ride modes) in proportion to their existing shares.

- The results of directly running USTOS on a parking-capacity-constrained zone-to-zone trip table to obtain a constrained station-to-station table are not compatible with the MOA output. It is necessary to perform an iterative Fratar adjustment of the USTOS output to make it conform to the MOA output.

- Trip tables resulting from mode-of-arrival are not consistent with the ULOAD results and do not provide corresponding daily and annual statistics to those in ULOAD and URAP.

These shortcomings created the need to overhaul the entire approach to MOA estimation at the District. The new approach is presented in the following section, and the input files needed for the new approach are described in Section 3.

2.0 NEW APPROACH TO ESTIMATING MODE OF ARRIVAL DISTRIBUTIONS

2.1 Improvements Introduced by the New Approach

The new methodology for determining the distribution of modes of arrival and departure contains a number of improvements over the old method:

- o Midday PNR/KNR access paths are explicitly created. This reflects the behavioral reality that midday/non-work transit trips have auto access options as well as walk and feeder bus access. For simplicity, only a combined PNR/KNR path is generated, rather than two separate paths. To see how this works, suppose only KNR is available for path 1 between zones A and B, and PNR and KNR are available for path 2 (it is assumed that KNR is available wherever PNR is, but not vice versa). Normally, path 2 would certainly be retained as the PNR access path, and either path 1 or path 2 (whichever is shorter) would be retained as the KNR access path. For the mode-of-arrival process, however, only one path is selected. If path 2 is the more desirable (minimum impedance) of the two, it will be retained and both modes will be available between A and B. If path 1 is more desirable, it will be retained, and the PNR mode will not be available for the A-B pair.

- o The non-work mode choice modeling procedure is modified to take advantage of the additional midday transit access path. A nested logit formulation is used. First, the original walk access and auto-only paths, and the original mode choice model, are used to split trips between auto and transit. Then the walk access and PNR/KNR access paths, and a simple logit sub-mode choice model, are used to split transit trips among walk/bus[2], PNR, and KNR access modes.

- o A FORTRAN program called READPATH was developed which traces the minimum transit path between each pair of zones. In so doing, it is possible to directly determine:

  - -- which rail station was the actual point of access or egress (rather than assuming it to be the nearest one to the zone centroid); and

  - -- what access/egress mode was actually used on the shortest path (rather than trying to predict which mode was used based on a series of models).

- o The Independence of Irrelevant Alternatives property is used to redistribute excess PNR demand to all other modes, including auto-only modes, in proportion to their relative shares.

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[2] The mode choice models do not distinguish between rail and bus forms of transit. Thus, walk access to transit might mean walk access to rail, or walk to bus and bus to rail. Accordingly, after running the sub-mode choice model, "walk access" trips are further split between walk and bus using the same diversion curves as implemented in the old MOA procedure (see Figure 2 and Table 4).

- All products of the methodology are consistent with each other and with other components of the UTPS simulation stream. In particular, trip tables produced by this MOA procedure are consistent with ULOAD and URAP. Access mode reports, however, are subject to the anomaly discussed in Section 2.2.4 -- that bus trips may be assigned to a zone even when no bus service is available.

2.2 Description of the New Approach

Figure 1 is a flowchart of the new procedure, including the preceding steps leading up to MOA. The letters in the upper-right corners of some of the boxes in the flowchart are the step designations according to District conventions. Steps L (unconstrained parking) and M (constrained parking) are the actual MOA steps. Step O is a new step which builds the midday PNR/KNR path. Step X is also new, consisting of executing the READPATH program.

The major conceptual elements of the new procedure are as follows:

- a new path is built for off-peak auto access trips;
- a sub-mode split model is included at the end of the existing non-work mode split procedure, to split transit trips into park-and-ride driver (PND), park-and-ride passenger (PNP), kiss-and-ride (KNR) and walk (WLK) access modes;
- the minimum paths between each zone pair are read, using a newly developed FORTRAN program;
- walk access trips are split between walk and feeder bus access to rail stations;
- station-to-station trip tables are built to determine rail station trip exchanges;
- diurnal factors are applied to station-to-station trip tables (by period and hour of the day); and
- a newly developed diversion algorithm is used to divert PNR trips in excess of station parking lot capacities to auto-only, KNR access, bus access, and WLK access trips.

These elements are explained further below (also see GPC Technical Memorandum 88.3.9, Mode-of-Arrival - New Procedure, June 1988).

2.2.1 New Path

As part of the effort to improve the accuracy of the methodology, a new path is built and used in the non-work mode split step: in addition to the existing midday walk path (MPTH), an auto access path file combining PNR and KNR paths (APTH) is developed using the midday transit operations and transit network data. USTOS is then applied to APTH, requesting J8 output. This provides a set of 1628 x 1628 tables with certain items of information about the auto-access-to-transit path joining each zone pair. For this application, only two tables are needed, those containing access rail station number and egress rail station number. Of course, if rail is not on the transit path joining a given zone pair, that entry in each table will be zero.

FIGURE 1

NEW MODE-OF-ARRIVAL PROCESS

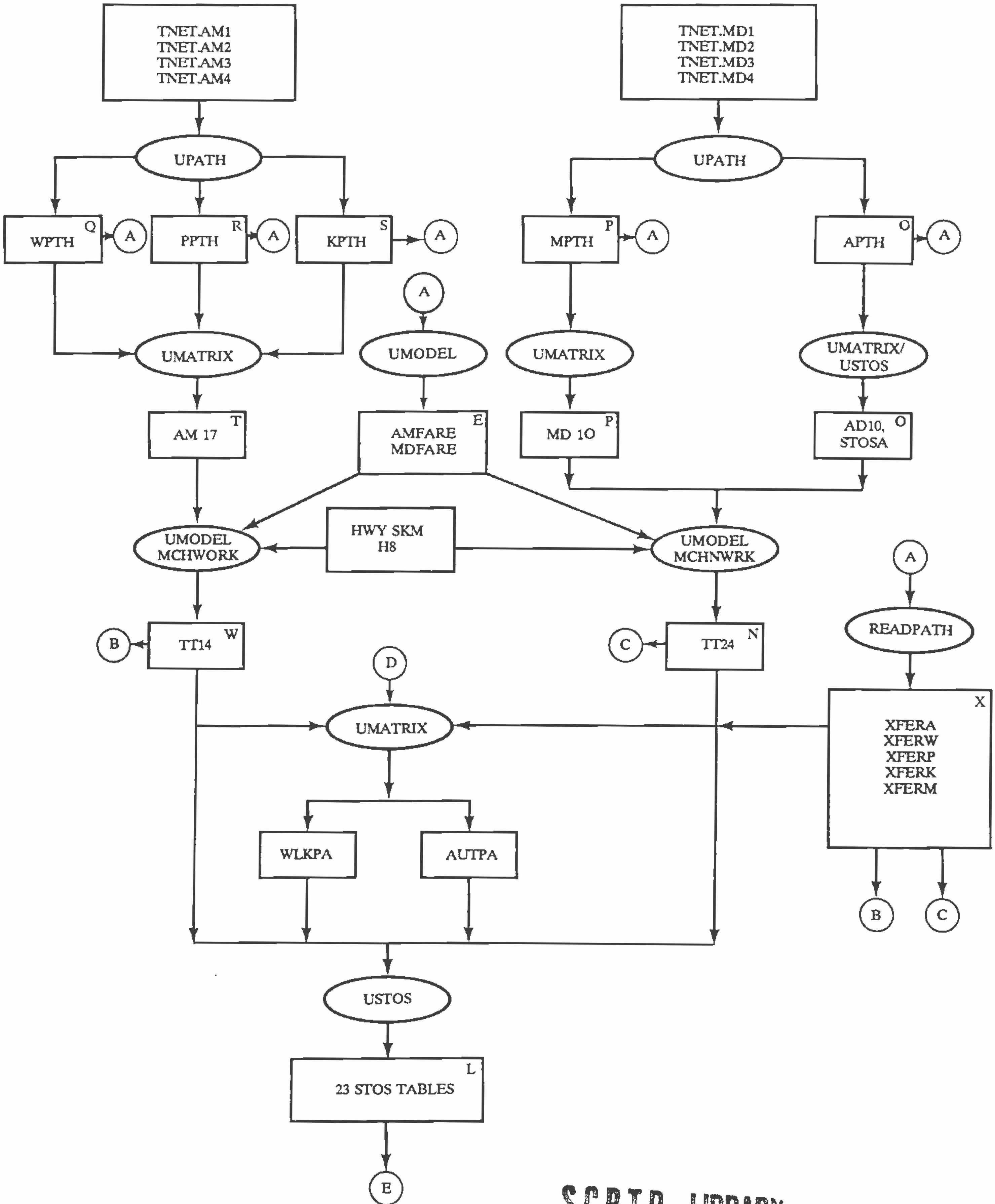
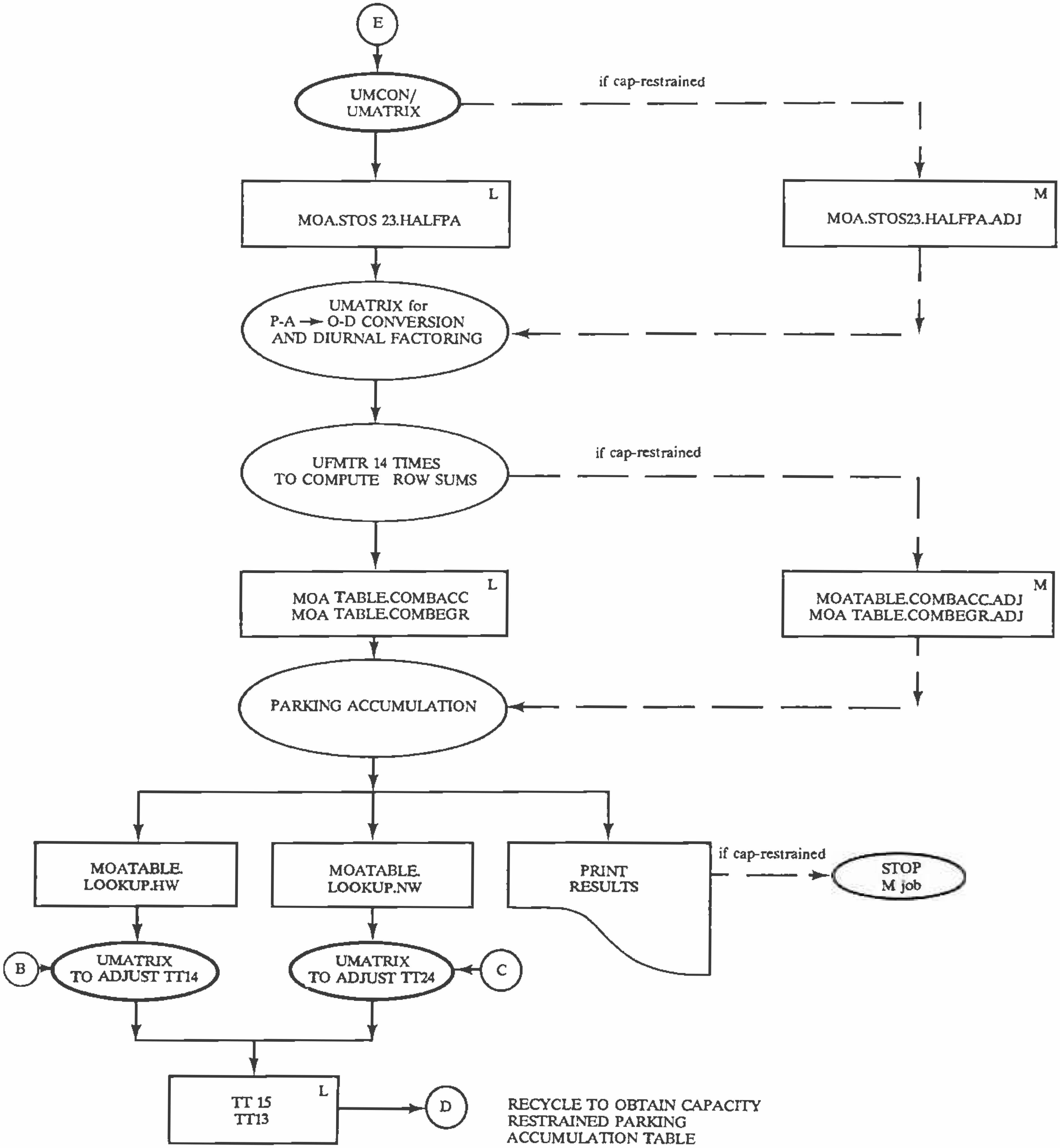


FIGURE 1 (cont'd)



2.2.2 Non-Work Mode Choice

A sub-mode split model was included in the non-work mode choice procedure for the splitting of transit trips originally produced. Previously, the non-work mode choice model only output total transit trips for each of the non-work trip purposes (all considered walk access trips): home-based-other, other-to-other and other-to-work. Each of the above transit trip tables are now further split in the new procedure into four different access mode trips: PND, PNP, KNR and WLK (where WLK actually includes walk <u>and</u> bus access to rail; see Section 2.2.4).

The additional mode splitting of non-HBW transit trips is done through the inclusion of a simple multinomial logit model for the calculation of mode choice probabilities. The equation representing the sub-mode choice model has the following generalized formula:

$$Pr(i) = \exp [U(i)]/[\exp U(k) + \exp U(p) + \exp U(w)],$$

in which Pr(i) is the choice probability of mode (i), and U(i) represents the utility function for mode (i). In the model developed for this procedure, the utility functions have the following formulae:

KNR utility: U(k) = a(k) + b(k)*KNRAT;
PNR utility: U(p) = a(p) + b(p)*PNRAT + c(p)*PKGCST;
WLK utility: U(w) = b(w)*WAT;

where:

KNRAT = KNR access time from zone to station (min);
PNRAT = PNR access time from zone to station (min) = KNRAT+PKGTM;
PKGTM = Parking Time;
WAT = WLK access time (min) = TTWAT/2;
TTWAT = Total walk time (access & egress) in MPTH;
PKGCST= Parking Cost (dollars);
a(i) = bias coefficients (generally used for calibration); and
b,c(i) = coefficients expressing weight of each variable in the equation.

In addition to those variables, two more are implicit in the logit model: the station type, which determines if a given station has a parking lot; and the park-and-ride car average occupancy, used to split PNR trips into PND and PNP trips:

STNTYP = station type
PNROCC = park-and-ride average car occupancy

Non-work mode choice is coded in the UMODEL module of UTPS, which allows the user to change "hard-coded" variable values through the input of UPARMS in the JCL set-up.

The new non-work sub-mode choice model took advantage of that flexibility and allows the input of eight additional UPARMS in addition to the ones in the current coding:

UPARMS	Variable	Default Value
UPARMS(18)	PKGTM	3 min
UPARMS(19)	a(k)	-1.559
UPARMS(20)	a(p)	-0.327
UPARMS(36)	b(p)	-0.180
UPARMS(37)	b(k)	-0.180
UPARMS(38)	b(w)	-0.180
UPARMS(39)	c(p)	-0.100
UPARMS(40)	PNROCC	1.1 pass./veh.

The default values shown above are the first cut values to obtain a mode split of 85% WLK, 10% KNR and 5% PNR access for non-work trips.

In summary, this new non-work mode split model takes person-trips as input and outputs 24 trip tables (TT24), as opposed to the 12 trip tables output by the existing procedure (TT12). TT24 is now compatible with TT14 (output from the work mode split) in terms of types of access modes to transit. The trip tables contained in TT12, TT14 and TT24 are shown in Tables 1 and 2. (The first 12 tables in TT24 are exactly the same ones in TT12, while the last 12 are the result of additional splitting provided by the new procedure.)

TABLE 1
TRIP TABLES IN TT14
(HOME-BASED WORK)

TABLE	DEFINITION
1	TOTAL AUTOMOBILE PERSON-TRIPS
2	AUTO DRIVE ALONE PERSON-TRIPS
3	TWO PERSONS/CAR PERSON-TRIPS
4	THREE+ PERSONS/CAR PERSON-TRIPS
5	TOTAL TRANSIT TRIPS
6	TRANSIT WALK TRIPS
7	TRANSIT PARK-AND-RIDE (DRIVERS) TRIPS
8	TRANSIT PARK-AND-RIDE (PASSENGERS) TRIPS
9	TRANSIT KISS-AND-RIDE TRIPS
10	TOTAL AUTO DRIVER TRIPS
11	DRIVE ALONE & TWO PERSONS/CAR AUTO-DRIVER TRIPS
12	TWO PERSONS/CAR AUTO-DRIVER TRIPS
13	THREE PLUS PERSONS/CAR AUTO DRIVER TRIPS
14	TOTAL AUTO-PASSENGER TRIPS

TABLE 2
TRIP TABLES IN TT12 AND TT24
(NON-WORK)

TABLE	DEFINITION
1	HO AUTO PERSON-TRIPS
2	HO TRANSIT PERSON-TRIPS
3	HO VEHICLE TRIPS
4	OO AUTO PERSON-TRIPS
5	OO TRANSIT PERSON-TRIPS
6	OO VEHICLE TRIPS
7	OW AUTO PERSON-TRIPS
8	OW TRANSIT PERSON-TRIPS
9	OW VEHICLE TRIPS
10	TTL AUTO PERSON-TRIPS
11	TTL TRANSIT PERSON-TRIPS
12	TTL VEHICLE TRIPS
13	HO KNR PERSON-TRIPS
14	HO WLK PERSON-TRIPS
15	HO PND PERSON-TRIPS
16	HO PNP PERSON-TRIPS
17	OO KNR PERSON-TRIPS
18	OO WLK PERSON-TRIPS
19	OO PND PERSON-TRIPS
20	OO PNP PERSON-TRIPS
21	TTL KNR PERSON TRIPS
22	TTL WLK PERSON-TRIPS
23	TTL PND PERSON-TRIPS
24	TTL PNP PERSON-TRIPS

HO = HOME-BASED OTHER
OO = OTHER-TO-OTHER
OW = OTHER-TO-OTHER
TTL = TOTAL (HO + OO + OW)
KNR = KISS-AND-RIDE
PND = PARK-AND-RIDE DRIVER
PNP = PARK-AND-RIDE PASSENGER
WLK = WALK

2.2.3 Read Paths

A FORTRAN program (READPATH) was developed to read UTPS transit paths and produce UTPS-compatible matrices with transit station access information. USTOS could not be used to accomplish this step because of its inability to distinguish between bus and walk access/egress. This is because of the dummy walk links between bus and rail nodes.

A fully detailed account of READPATH is found in General Planning Consultant Technical Memorandum 88.3.6, Program Documentation -- READPATH, April 1988. The output of READPATH is the set of eight tables listed in Table 3. Each table is 1628 x 1628 (for a 1628-zone system), where the entry in cell ij is the appropriate value for the minimum transit path from zone i to zone j.

2.2.4 Splitting Walk Trips

The ij-th element of READPATH Table 1 will be zero if the ij-th element of READPATH Table 2 is non-zero, and vice versa (similarly for READPATH Tables 5 and 6, for egress). That is, either bus access to rail or walk access to rail is part of the minimum walk access path between zones i and j (if rail is on the path at all), but not both. In this procedure, it is assumed that even when one access mode is on the minimum path, there may be a real probability that the other mode is sometimes used to access rail for that trip interchange. While in general this is a realistic assumption, it may occasionally lead to anomalous results. That is, a zone may have some proportion of its trips assigned to the bus access mode even though there is actually no bus access opportunity for the zone. This limitation applies equally to the old and new MOA methods.

Two of the tables generated by READPATH (Tables 4 and 8) were developed specifically for the purpose of further splitting walk access trips (both work and non-work) to walk and feeder bus according to walking distances. READPATH Tables 4 and 8 determine the probability of diversion from walk access to feeder bus access, and are calculated using user-input diversion curves. The curves shown in Figure 2 and defined in Table 4 were input to the READPATH procedure for the test runs and were taken from the previous MOA procedure (see Mode of Access User's Guide, prepared by Peat, Marwick, Mitchell & Co. for the Metropolitan Washington Council of Governments, or the SCRTD Transportation Planning and Modeling Services Technical Memorandum 5.1 cited earlier).

Although the above splitting methodology is similar in both the previous and the new methods, the calculation of zone-to-station distances is different. The previous procedure computed zone-to-station distances based on a minimum distance calculation procedure called UMINDIST, on the assumption that zones will always access the closest station. On the other hand, the new procedure calculates the distance between the coordinates of the zone and the access station actually found on the transit path.

The above tables, in conjunction with access and egress station tables, are used in Step 5 to perform the diversion. Hence, mode split is actually only completed in Step 5.

TABLE 3
TABLES IN READPATH OUTPUT

TABLE	NAME	CONTENTS
1	B-R XFER	RAIL STATION NODE, IF BUS-TO-RAIL TRANSFER EXISTS; 0, OTHERWISE
2	Z-R DIRECT	RAIL STATION NODE, IF ZONE-TO-RAIL DIRECT ACCESS EXISTS; 0, OTHERWISE
3	Z-R DIST	ZONE TO DIRECT ACCESS RAIL STATION DISTANCE IF TABLE 2 > 0; 0, OTHERWISE
4	Z-R DVRSN	PROPORTION OF ZONE-DIRECT-TO-RAIL WALK ACCESS TRIPS TO RAIL; 0, OTHERWISE
5	R-B XFER	RAIL STATION NODE, IF RAIL-TO-BUS TRANSFER EXISTS; 0, OTHERWISE
6	R-Z DIRECT	RAIL STATION NODE, IF RAIL-TO-ZONE DIRECT ACCESS EXISTS; 0, OTHERWISE
7	R-Z DIST	RAIL STATION TO DIRECT ACCESS ZONE DISTANCE IF TABLE 6 > 0; 0, OTHERWISE
8	R-Z DVRSN	PROPORTION OF RAIL-DIRECT-TO-ZONE WALK EGRESS TRIPS FROM RAIL; 0, OTHERWISE

FIGURE 2

ZONE-TO-STATION WALK ACCESS DIVERSION CURVES

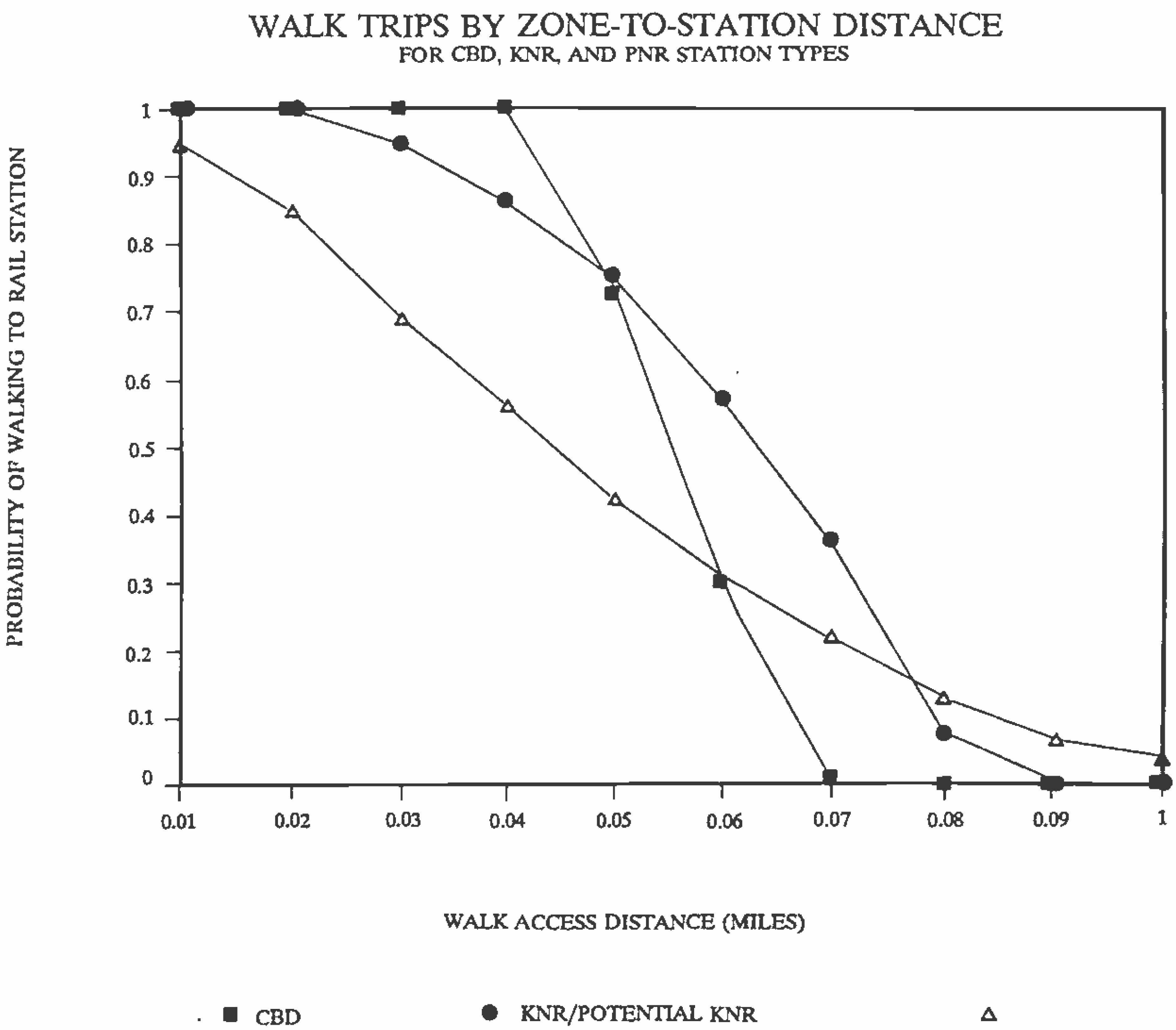


TABLE 4

WALK/NON-WALK MODEL DIVERSION

Type of Station[(1)]	Proportion of Walk Trips for Each Zone-to-Station Distance (Miles)									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
1	1.0	1.0	1.0	1.0	0.73	0.30	0.01	0.0	0.0	0.0
2	1.0	1.0	0.95	0.86	0.75	0.57	0.36	0.08	0.05	0.0
3	1.0	1.0	0.95	0.86	0.75	0.57	0.36	0.08	0.05	0.0
4	0.95	0.85	0.69	0.56	0.42	0.31	0.22	0.13	0.07	0.04

[(1)]Type of Station definitions:

1. A station where no highway access of any type is anticipated, such as a station in the central business district.

2. A station where the only highway access anticipated is the drop-off mode (i.e., kiss-and-ride).

3. A station where the access is walk or bus, but potential kiss-and-ride trips would go to another type 2 station.

4. A station where all types of highway access are anticipated and which has some parking facilities.

Source: Mode of Access User's Guide, prepared by Peat, Marwick, Mitchell & Co. for the Metropolitan Washington Council of Governments. Reprinted in Transportation Planning and Modeling Services Technical Memorandum No. 5.1.

2.2.5 Station-to-Station Trips

This step starts with WLK, PND, PNP, and KNR non-work trip tables (tables 22, 23, 24, and 21; respectively, of TT24), and WLK, PND, PNR, and KNR home-based work trip tables (tables 6, 7, 8, and 9, respectively, of TT14). The output of this step is the set of 23 station-to-station trip tables shown in Table 5. Three distinct activities are performed in this step: a UMATRIX operation, a USTOS operation, and an UMCON/UMATRIX operation. Figure 3 helps to illustrate the process.

UMATRIX

This operation accomplishes two things: (i) it splits walk access and egress trips into walk and bus access/egress, and (ii) it consolidates trip tables when identical paths are involved. These are explained further below.

(i) In this step, the diversion proportions computed as described in Section 2.2.4 are applied to walk access and egress trips. Consider the WLK trip table of TT24 (actually, the sum of tables 14 [H-O], 18 [O-O], 22 [O-W]). First, it is split into a walk access trip table and a bus access trip table. Then, the same table is split again to divide walk egress trips into walk egress and bus egress (using the same diversion curves). Similar procedures are performed on the WLK trip table of TT14 (home-based-work trips). This results in 8 zone-to-zone trip tables, referred to in Figure 1 as WLKPA. They are:

(1) walk access for the WLK table of TT24 (non-work),
(2) bus access for the WLK table of TT24,
(3) walk egress for the WLK table of TT24
(4) bus egress for the WLK table of TT24,
(5) walk access for the WLK table of TT14 (home-based-work),
(6) bus access for the WLK table of TT14,
(7) walk egress for the WLK table of TT14, and
(8) bus egress for the WLK table of TT14.

PNR/KNR access trips also have walk egress. This is because it is assumed PNR/KNR is not available at the egress rail station. Thus, it is necessary to split the egress modes for auto access trips between bus and walk, as well. This initially results in 12 egress trip tables for auto access trips (3 access modes x 2 egress modes x 2 trip types), but some of these are combined, as explained in (ii) below.

(ii) Consider the PND and PNP trip tables of TT14 (home-based-work trips). Each of these tables will be divided between those PNR trips accessing rail directly (PND-R and PNP-R of Figure 3), and those PNR trips accessing feeder bus first (B-R of Figure 3). For the purposes of designing rail station parking lots and analyzing the effect of parking capacity constraints, it is important to continue to distinguish PND and PNP direct access to rail. But

TABLE 5

TRIP TABLES IN FILE "HALFPA"

TABLE	TRIP PURPOSE	INITIAL ACC MODE	FINAL ACCESS/ EGRESS MODE
1	HBW	WALK	WLK-TO-RAIL
2	HBW	WALK	BUS-TO-RAIL
3	HBW	PND	PNR-TO-RAIL
4	HBW	PNP	PNR-TO-RAIL
5	HBW	PNR/P&D	BUS-TO-RAIL
6	HBW	KNR	KNR-TO-RAIL
7	HBW	KNR	BUS-TO-RAIL
8	HOOOOW	WALK	WLK-TO-RAIL
9	HOOOOW	WALK	BUS-TO-RAIL
10	HOOOOW	PNP	PNR-TO-RAIL
11	HOOOOW	PND	PNR-TO-RAIL
12	HOOOOW	KNR	KNR-TO-RAIL
13	HOOOOW	AUTO	BUS-TO-RAIL
14	HBW	WALK	RAIL-TO-WLK
15	HBW	WALK	RAIL-TO-BUS
16	HBW	PNR/P&D	RAIL-TO-WLK
17	HBW	PNR/P&D	RAIL-TO-BUS
18	HBW	KNR	RAIL-TO-WLK
19	HBW	KNR	RAIL-TO-BUS

TABLE 5

TRIP TABLES IN FILE "HALFPA"

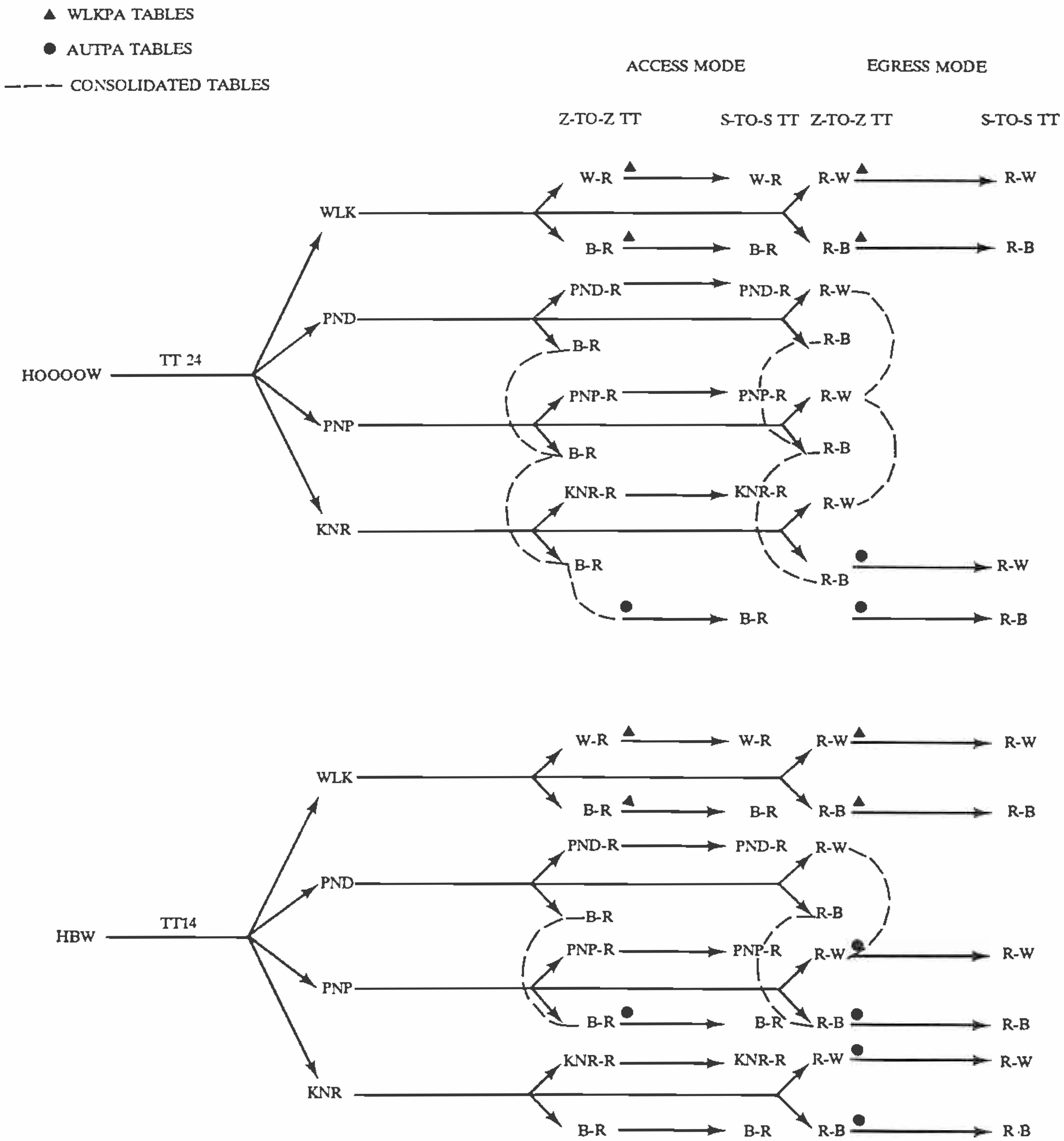
CONTINUED

TABLE	TRIP PURPOSE	INITIAL ACC MODE	FINAL ACC/ EGRESS MODE
20	HOOOOW	WALK	RAIL-TO-WLK
21	HOOOOW	WALK	RAIL-TO-BUS
22	HOOOOW	AUTO	RAIL-TO-WLK
23	HOOOOW	AUTO	RAIL-TO-BUS

HBW = HOME-BASED WORK
HOOOOW = HO+OO+OW
HO = HOME-BASED OTHER
OO = OTHER-TO-OTHER
OW = OTHER-TO-WORK
KNR = KISS-AND-RIDE
PND = PARK-AND-RIDE DRIVER
PNP = PARK-AND-RIDE PASSENGER
PNR/P&D = PARK-AND-RIDE PASSENGER+DRIVER

FIGURE 3

TRIP TABLE DEVELOPMENT BY ACCESS/EGRESS MODES



there is no compelling reason to distinguish PND and PNP access to feeder bus, and it saves computer time and space to merge them. PND-bus and PNP-bus trips use exactly the same network path, so they may be combined with no loss of accuracy. This step accomplishes that combining. Similarly, at the egress end of the PNR access trips, there is no reason to distinguish between walk egress of a PND access trip and walk egress of a PNP access trip, so those tables are combined. Also, bus egress for PND and PNP is combined into one table.

For non-work trips, the same kind of consolidation is done. This time, however, the KNR path is identical to the PNR paths, so all three sets of auto-access-to-feeder-bus-to-rail trips are combined, three sets of walk egress trips are combined, and three sets of bus egress trips are combined.

Altogether, 8 zone-to-zone trip tables related to auto access are produced by this step, referred to as AUTPA in Figure 1. They are:

(1) PNR-to-bus access for home-based work trips,
(2) walk egress for PNR-access HW trips,
(3) bus egress for PNR-access HW trips,
(4) walk egress for KNR-access HW trips,
(5) bus egress for KNR-access HW trips,
(6) PNR/KNR-to-bus access for non-work trips,
(7) walk egress for PNR/KNR-access NW trips, and
(8) bus egress for PNR/KNR-access NW trips.

Besides the 16 tables in WLKPA and AUTPA, the other 7 zone-to-zone trip tables shown in Figure 3 (i.e. PND-R, PNP-R, KNR-R for NW trips; and PND-R, PNP-R, KNR-R, and B-R for HW trips) are constructed directly in the USTOS step. This is done by selecting only the desired "arrive" mode to rail, which is obtained from the READPATH step performed earlier. For example, consider the PND table of TT24, representing all non-work trips with PND access to transit. Three cases are possible:

- o PND access directly to rail (arrive mode = 2);
- o PND access to feeder bus which connects to rail (arrive mode = 1, because there is a dummy walk link connecting the bus node to the rail station node);
- o and PND access to bus with no rail in the trip (in which case that trip interchange is of no interest here).

Selecting arrive mode = 2, then, produces the PND-R zone-to-zone trip table.

<u>USTOS</u>

USTOS is applied to each of the 23 (after consolidation) zone-to-zone trip tables indicated by Figure 3, with the J9 output option requested. For this option, USTOS converts a zone-to-zone trip table into a station-to-station trip table, for which the ij-th entry is the number of trips entering at (strictly speaking, "produced" at) station i and leaving at ("attracted" at) station j. Thus, the 23 station-to-station trip tables generated by this step are each n x n, where n is the total number of rail stations in a particular network alternative. For instance, for the CORE3CA6 alternative, each of the tables is 19 x 19.

UMCON/UMATRIX

The final activity in Step 5 is merging 23 separate files, each with one station-to-station trip table, into one file with 23 tables. At the same time, each of the 23 tables is divided by two, in preparation for diurnal factoring. The resulting file is called HALFPA; the 23 tables it contains are shown in Table 5 (and also under the "S-TO-S TT" columns of Figure 3).

2.2.6 Diurnal Factoring

UMATRIX

The zone-to-zone trip tables used as inputs to step 5 are in production-attraction (PA) format. That is, a round trip from zone i to zone j to zone i is listed as 2 trips produced from zone i and 2 trips attracted to zone j. Accordingly, the station-to-station trip tables generated in step 5 are also in PA format, that is, each round trip--from access, to station k, to station l, to egress--is given as two trips produced at station k and two trips attracted at station l. For design purposes, it is important to convert these tables to origin-destination (OD) format, that is, to know how many passengers actually enter station k and leave station l by time-of-day, and how many passengers enter station l and leave station k by time-of-day.

For a 24-hour period, the formula for converting matrix X from PA format to OD format is:

$$X_{OD} = (X_{PA} + X_{PA}^{T})/2,$$

where the superscript T stands for matrix transposition.

But it is critical to know arrivals and departures more accurately than that. Period-level factors have been developed empirically, and are shown in Table 6. If WPA is the 24-hour HW trip table in PA format, WOD_{AM} is the AM peak period trip table in OD format, and WOD_{PM} is the PM peak OD trip table, then

$$WOD_{AM} = (0.782\ WPA + 0.018\ WPA^{T})/2$$

$$WOD_{PM} = (0.032\ WPA + 0.608\ WPA^{T})/2$$

and so on.

Within each period, arrivals and departures are assumed to be uniformly distributed. For example, for the 3-hour morning peak, it is assumed that 1/3 of all morning arrivals occurs each hour.

TABLE 6

DIURNAL FACTORS APPLIED TO DAILY TRIPS

---

1. 78.2% OF WORK TRIPS ARRIVE IN AM PEAK PERIOD
2. 13.6% OF WORK TRIPS ARRIVE IN MIDDAY PERIOD
3. 3.2% OF WORK TRIPS ARRIVE IN PM PEAK PERIOD
4. 5.0% OF WORK TRIPS ARRIVE IN EVENING PERIOD

---

5. 1.8% OF WORK TRIPS LEAVE IN AM PEAK PERIOD
6. 19.8% OF WORK TRIPS LEAVE IN MIDDAY PERIOD
7. 60.8% OF WORK TRIPS LEAVE IN PM PEAK PERIOD
8. 17.6% OF WORK TRIPS LEAVE IN EVENING PERIOD

---

9. 25.0% OF NWRK TRIPS ARRIVE IN AM PEAK PERIOD
10. 48.6% OF NWRK TRIPS ARRIVE IN MIDDAY PERIOD
11. 17.4% OF NWRK TRIPS ARRIVE IN PM PEAK PERIOD
12. 9.0% OF NWRK TRIPS ARRIVE IN EVENING PERIOD

---

13. 5.0% OF NWRK TRIPS LEAVE IN AM PEAK PERIOD
14. 51.4% OF NWRK TRIPS LEAVE IN MIDDAY PERIOD
15. 32.6% OF NWRK TRIPS LEAVE IN PM PEAK PERIOD
16. 11.0% OF NWRK TRIPS LEAVE IN EVENING PERIOD

---

17. TRIPS ARE UNIFORMLY DISTRIBUTED WITHIN EACH PERIOD

The result of the diurnal factoring operation is a number of station-to-station trip tables, distinguished by period and by mode. Those matrices are then added across modes to produce station-to-station trip tables by period.

UFMTR

If the ij-th element of a station-to-station trip table is the number of trips accessing rail at station i and egressing from rail at station j, then the sum across the i-th row is the total number of trips accessing rail at station i. In this step, UFMTR is used to obtain the row sums for each station-to-station trip table. Row sums of the transpose are also obtained, providing the total number of trips leaving each rail station (by period).

2.2.7 Capacity Restraint

Until now, it has been assumed that PNR demand is unconstrained by parking capacity--i.e., that infinite parking is available. In reality, however, parking demand may exceed supply at some rail stations. In that case, the excess demand will be redistributed to other modes. This step determines and reassigns that excess demand. Operations performed in this step are explained below.

PKGACCS

The PKGACCS (for Short-term ParKinG ACCumulation) program does the following three things:

(i) Reads the UFMTR output from the previous step and prints it out in an easily readable format;
(ii) Creates a parking accumulation table for non-work trips, on the assumption that NW trips will use short-term parking, for a duration of 3 hours; and
(iii) Identifies, by hour, the number of NW PNR trips that cannot find short-term parking.

PKGACCL

The PKGACCL (Long-term ParKinG ACCumulation) program does two things:

(i) Combines the excess demand from step (iii) of the PKGACCS program (with an assumed 3-hour parking duration) with the home-based work PNR arrivals (with an assumed 9-hour parking duration) to create an accumulation table for long-term parking. Thus, it is assumed that the excess short-term demand is diverted to long-term parking if there is long-term capacity available; and
(ii) Hour by hour, calculates how many HW and NW trips can find parking. The proportion of trips to be retained as PNR trips for each station is written to two separate files: MOATABLE.LOOKUP.HW and MOATABLE.LOOKUP.NW. The look-up table has the format shown in Table 7.

Inspection of Table 7 indicates that demand exceeded capacity at stations 8000 (Union Station) and 8012 (Wilshire/Fairfax). At Union Station, for example, the parking could accommodate only 48.4% of the demand. Wilshire/Fairfax parking met 21.9% of the demand; parking at the other stations met 100% of the demand.

UMATRIX

UMATRIX compares the above look-up table with Table 2 from READPATH and substitutes the match-up number in the cells if any of the above station numbers are found; else, uses the value for "misses." Thus, the result will be a 1628 by 1628 table in which the cells contain, for each origin-destination pair, the retention factor by which to multiply the PND and PNP access trip tables. The trips that are removed from those tables are redistributed to the auto-only, KNR, and WLK tables (i.e., tables 1, 6, and 9 of TT14, and tables 10, 21, and 22 of TT24) in proportion to the existing shares of those modes. An adjusted TT15 is produced, containing the trip tables shown in Table 8. Finally, the adjusted trip tables are recycled once through steps 5 and 6 to obtain the parking-capacity-restrained MOA trips.

TABLE 7

SAMPLE OUTPUT FROM PKGACCL PROGRAM

```
   1      M  1000         STATION VS. PND FACTOR LOOKUP TABLE FOR UMATRIX
8000    484  8001  1000  8003  1000  8004  1000  8006  1000  8007  1000
8008   1000  8009  1000  8010  1000  8011  1000  8012   219  8020  1000
8021   1000  8094  1000  8095  1000  8096  1000  8097  1000  8058  1000
8059   1000
```

where:

1 = Table #
M = Type of lookup table in UMATRIX (M = "match-up")
1000 = value for misses†
8000 = rail station #
484 = (station capacity/PND demand)*1000
(fraction given in thousandths)†

† Fractions were multiplied by 1000 to overcome the UMATRIX '79 limitation of only accepting integer cell values. In further UMATRIX operations, these factors are divided by 1000.

TABLE 8

PARKING CONSTRAINED TRIP TABLES IN TT15

TABLE	DEFINITION
1	HW TRN PND
2	HW TRN PNP
3	HW TRN WLK
4	HW TRN KNR
5	HW TRN PSN
6	HW AUT DA
7	HW AUT SR2
8	HW AUT SR3+
9	HW AUT PSN
10	NW TRN PND
11	NW TRN PNP
12	NW TRN WLK
13	NW TRN KNR
14	NW TRN PSN
15	NW AUT PSN

HW = HOME-BASED WORK
NW = HO + OO + OW (NON-WORK)
TRN = TRANSIT
AUT = AUTO
PND = PARK-AND-RIDE DRIVER
PNP = PARK-AND-RIDE PASSENGER

WLK = WALK
KNR = KISS-AND-RIDE
PSN = PERSON-TRIPS
DA = DRIVE ALONE
SR2 = SHARED RIDE--2 PERSONS
SR3+ = SHARED RIDE--3+ PERSONS

3.0 INPUT FILES FOR THE NEW MODE OF ARRIVAL PROCESS

There are three different types of input files to the mode of arrival process. The first type of input file includes those produced from the foregoing batch jobs in the JCL stream. All these files are written on tapes and will be mounted to tape drives whenever requested. In total, there are twelve such files; they are listed in Table 9.

The second type of input file includes user-prepared input files. These files generally vary with the alignment of the rail network under study. The user must code these files before the MOA procedure is submitted. Otherwise, a JCL error will occur because these files cannot be found. Table 10 summarizes all these user-prepared files. The coding formats for each of these five files are given in Tables 11 to 15.

The third type of input file includes the system files that do not vary with the alignment of the rail network. For any alternative alignment, the same files always will be used. These files are saved in the MRP.MOA.SYSIN library and are described in Table 16.

TABLE 9

INPUT TAPE FILES TO THE MODE-OF-ARRIVAL PROCESS

DSN	PRODUCED FROM	INPUT TO	CONTENTS
APTH	MD AUT SKM	USTOS23	Midday auto access minimum paths
MPTH	MD WLK SKM	USTOS23	Midday walk access minimum paths
WPTH	AM WLK SKM	USTOS23	A.M. walk access minimum paths
PPTH	AM PNR SKM	USTOS23	A.M. PNR access minimum paths
KPTH	AM KNR SKM	USTOS23	A.M. KNR access minimum paths
TT14	MCHWORK	AUTPA WLKPA, & USTOS23	Transit and highway trip tables for HBWORK Trips
TT24	MCHNWRK	AUTPA WLKPA, & USTOS23	Transit and highway trip tables for HOOOOW trips
XFERA	READPATH	ADJTT24	Xfer tables from READPATH on APTH
XFERM	READPATH	ADJTT24	Xfer tables from READPATH on MPTH
XFERW	READPATH	ADJTT14	Xfer tables from READPATH on WPTH
XFERP	READPATH	ADJTT14	Xfer tables from READPATH on PPTH
XFERK	READPATH	ADJTT14	Xfer tables from READPATH on KPTH

TABLE 10

USER-PREPARED INPUT FILES

FILE NAME	DDNAME/STEP	CONTENTS
MRP.MOA.STATION. DATA (MYEARALT)	FT11F001/PKGACCM	Parking capacity, parking cost, accessibility, and identification of each rail station
MRP.MOA.STATION. LIST.DATA (MYEARALT)	FT05F001/USTOS	Number of rail stations and a list of node numbers for each station --- input to USTOS program
MRP.STATION.NODE. DATA (MYEARALT)	FT12F001/PKGACCM	Correspondence between UTPS node number and user-defined station number
MRP.NETWORK. MYEARALT.DATA (NSTATION)	FT05F001/UMATRIX	Number of stations given in &PARAM keywork format --- input to UMATRIX program
MRP.NETWORK. MYEARALT.DATA (MOAUFMTR)	FT05F001/UFMTR	Number of stations given in &SELECT keyword format --- input to UFMTR program

TABLE 11

MRP.MOA.STATION.DATA (MYEARALT) DATA CARD FORMAT		
COLUMNS	FORMAT	CONTENTS
1 - 4	I4	Station number
6 - 10	I5	Long-term parking capacity
11 - 15	I5	Long-term parking cost in cents
16 - 20	I5	Long-term parking terminal time for park-and-ride trips in minutes
21 - 25	I5	Long-term parking terminal time for kiss-and-ride trips in minutes
26 - 30	I5	Short-term parking capacity
31 - 35	I5	Short-term parking cost in cents
36 - 40	I5	Short-term parking terminal time for park-and-ride trips in minutes
41 - 45	I5	Short-term parking terminal time for kiss-and-ride trips in minutes
50 - 50	I1	Station type: 1 = CBD 2 = Official kiss-and-ride 3 = Unofficial kiss-and-ride 4 = Park-and-ride
53 - 72	A20	Station ID

TABLE 12

MRP.MOA.STATION.LIST.DATA (MYEARALT) DATA CARD FORMAT

RECORD	COLUMNS	FORMAT	CONTENTS
1	2 - 72	FREE	Number of stations in USTOS NAMELIST "&PARAM STOP" keyword format (e.g., STOPS = 5, if there are 5 rail stations)
2	2 - 72	FREE	List of rail stations in USTOS PROGRAM "&PARAM STOP" keyword format (e.g., STOP(1) = 8000,8001,8002,8003,8004 &END for 5 rail stations)

TABLE 13

MRP.STATION.NODE.DATA (MYEARALT) DATA CARD FORMAT

COLUMNS	FORMAT	CONTENTS
1 - 4	I4	UTPS node number (usually above 8000)
5 - 8	I4	Corresponding rail station number, usually from 1 to the number of rail stations

TABLE 14

MRP.NETWORK.MYEARALT.DATA (NSTATION) DATA CARD FORMAT

COLUMNS	FORMAT	CONTENTS
2 - 72	FREE	Number of rail stations in UMATRIX NAMELIST "&PARAM ZONES" keyword format (e.g., &PARAM ZONES = 5)

TABLE 15

MRP.NETWORK.MYEARALT.DATA (MOAUFMTR) DATA CARD FORMAT

COLUMNS	FORMAT	CONTENTS
2 - 72	FREE	Number of rail stations in UFMTR NAMELIST "& SELECT" format (e.g., &SELECT I1 = 1, -5, J1 = 1, -5, REPORT = 3)

TABLE 16

CONTENTS OF MRP.MOA.SYSIN FILES

MRP.MOA.SYSIN MEMBERS

MEMBER	SIZE	INPUT TO	CONTENTS
WLKPA	12	UMATRIX	Control cards to create &&WLKPA
AUTPA	28	UMATRIX	Control cards to create && AUTPA
A01WLKWR	3	USTOS	Control cards to the 23 USTOS procedures in the unconstrained MOA process
A02WLKBR	3	USTOS	
A03PNDDR	3	USTOS	
A04PNPPR	3	USTOS	
A05PNRBR	3	USTOS	
A06KNRKR	3	USTOS	
A07KNRBR	3	USTOS	
A08WLKWR	3	USTOS	
A09WLKBR	3	USTOS	
A10PNRPR	3	USTOS	
A11PNRDR	3	USTOS	
A12KNRKR	3	USTOS	
A13AUTBR	3	USTOS	
A14WLKRW	3	USTOS	
A15WLKRB	3	USTOS	
A16PNRRW	3	USTOS	
A17PNRRB	3	USTOS	
A18KNRRW	3	USTOS	
A19KNRRB	3	USTOS	
A20WLKRW	3	USTOS	
A21WLKRB	3	USTOS	
A22AUTRW	3	USTOS	
A23AUTRB	3	USTOS	
B03PNDDR	3	USTOS	Control cards updating the 23 USTOS procedures in the constrained MOA process
B04PNPPR	3	USTOS	
B06KNRKR	3	USTOS	
B07KNRBR	3	USTOS	
B10PNRPR	3	USTOS	
B11PNRDR	3	USTOS	
B12KNRKR	3	USTOS	

TABLE 16 (continued)

CONTENTS OF MRP.MOA.SYSIN FILES

MRP.MOA.SYSIN MEMBERS			
MEMBER	SIZE	INPUT TO	CONTENTS
MERGE1	5	UMCON	Control cards to combine the 23 station-to-station trip tables into one STOS23.HALFPA file
MERGE2	5	UMCON	
MERGE3	5	UMCON	
MERGEF	17	UMATRIX	
M1PASAE	65	UMATRIX	Control cards to perform diurnal factoring. Results will be station-to-station trip tables by access mode by time period
M2WLKAE	33	UMATRIX	
M3BUSAE	33	UMATRIX	
M4KNRAE	33	UMATRIX	
M5PNDAE	33	UMATRIX	
M6PNPAE	33	UMATRIX	
UFM01	2	UFMTR	Control cards to calculate column sums and row sums for each station-to-station trip table by access mode and by time period.
UFM02	2	UFMTR	
UFM03	2	UFMTR	
UFM04	2	UFMTR	
UFM05	2	UFMTR	
UFM06	2	UFMTR	
UFM07	2	UFMTR	
UFM08	2	UFMTR	
UFM09	2	UFMTR	
UFM10	2	UFMTR	
UFM11	2	UFMTR	
UFM12	2	UFMTR	
UFM13	2	UFMTR	
UFM14	2	UFMTR	