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GENERAL PLANNING CONSULTANT

TECHNICAL MEMORANDUM 88.3.8

EVALUATION OF ALTERNATIVE TRANSIT CAPACITY RESTRAINED PROCEDURES

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1. INTRODUCTION

The application of capacity restrained transit assignment procedures has been a frequently discussed subject since the networks for financial operating plans and cost-effectiveness analysis were developed and simulated. The Year 2000 transit demands for buses produced from these networks (especially for the all-bus, and the MOS-1 networks) are so high that require bus systems in the scale far exceed available budgets. In order to produce realistic forecasts of transit demand within the context of pre-determined operating budget, capacity restrained process has to be considered.

Currently there are three capacity restrained procedures under consideration:

1. Fixed-Path Procedure (FPP),
2. Multi-Path Procedure (MPP), and
3. Short-Cut Procedure (SCP).

FPP assumes that transit riders when encountering overloaded situation would either continue waiting at the same overloaded stop or switch to automobile mode. No new transit paths are considered by these riders. MPP assumes that these riders instead of waiting at the same stop longer would find alternative paths and switch either to those new paths or to automobile mode. No further waiting at the same stop for the same transit line is assumed by MPP. SCP does not consider how these riders would do in overloaded situation. It simply checks each bus in the system and chops off the excess riders from the overloaded buses.

Both FPP and MPP require running MCHWORK procedure iteratively; thus, require longer time to execute. However, since MCHWORK is run, transit trip table (TT14) will be produced directly. The estimation of transit revenue, travel time savings, and user benefits for financial operating plans and cost-effectiveness analysis can be done more easily with this TT14. As for SCP, however, how it should be applied to estimate these three important indices for financial operating plans and cost-effectiveness analysis is still unclear at the present stage.

The purpose of this memorandum is to document comparatively the conceptual framework for the three procedures, comment on the drawbacks in each of these procedures, and based on the present level of experience and understanding suggest practical decision on capacity restrained procedure be applied at the District.

The remainders of this memorandum are organized as follows. Section 2 outlines the steps of computer operation for each of the three procedures. Section 3 presents a simple network example then applies this example to each of the three capacity restrained methods. By such application, comments on the reasonableness and implications of each of these procedures are made. Section 4 presents a table which shows the relative advantages and disadvantages of these three procedures and suggests tentatively the approach to be adopted by the District.

2. CONCEPTUAL REVIEW

This section reviews the mechanical steps for the three approaches. The original developments of MPP were documented in Technical Memoranda 87.3.4 and 87.3.6. Two further technical memoranda in FY88 are related to the implementation of MPP at SCRTD. Technical Memorandum 88.3.3 documents the key developments of a UTPS compatible software --- Overload Identification and Line Manipulation (UOILM) program. Technical Memorandum 88.3.4 is an interim report describing the results of implementing MPP at the District.

FIXED-PATH PROCEDURE

FPP, originally suggested by Keith Killough then enhanced by UOILM program, is an iterative procedure. This iterative process is described below:

a. Regular simulation process of UNET/UPATH/UFARE/MCH/ULOAD/URAP is executed as usual; a LOADFILE.iterN (n=0 to start with) is created from ULOAD, and the nominal operating cost estimate (NOCE) for RTD buses is reported by URAP.

b. Run UOILM program with LOADFILE.iterN to generate a list of all the overloaded RTD bus lines in the network; set N=N+1.

c. Run ULOAD with the list of overloaded lines produced from (b) as SYSIN to locate all origin-destination (O-D) pairs encountering overloaded bus lines. Increase the first wait time (FWAIT) of these pairs in travel time matrix AM17 by one additional headway. This updating process is performed three times once for each of the three access paths in the AM.

d. Combine the three updated FWAIT in (c) to create a new AM17.iterN Run MCHWORK with this AM17.iterN to create new transit trip table TT14.iterN for HBWORK trips. Because the FWAIT has been increased, TT14.iterN should contain less trips than TT14 in the previous iteration.

e. Run ULOAD/URAP with the new TT14.iterN together with the original TT12 (transit table of HOOOOW trips). ULOAD will produce LOADFILE.ITERN and URAP will report a new NOCE.

f. If the new NOCE exceeds the budget then go to (b); else stop.

Based on the experience of executing this procedure. It generally requires three to four iterations to drive the NOCE of buses from over 580 million dollars down to the range of 525, the budget the District expects. Each iteration take a day or two depending on how busy the computer system is. Thus, it takes about a week for each network to achieve the available budget level.

MULTI-PATH PROCEDURE

MPP, originally formulated by Dr. Yossie Prashka, is another iterative process. The current practice of executing this MPP is to load 100% of HOOOOW trips and 30% of HBWORK trips in the initial step. Then the remaining 70% of HBWORK trips are loaded in a sequence of 7 steps, 10% in each step. The procedure is described in below:

a. Regular simulation process of UNET/UPATH/UFARE/MCH/ULOAD/UPRAS is executed with 100% HOOOOW and 30% HBWORK trips. A LOADFILE.iterN (N=0 to start with) is created from UPRAS. Loaded legs LLTOT.iterN are produced from ULOAD.

b. Run UOILM program with LOADFILE.iterN to generate the list of overloaded stops in the network, set (N=N+1).

c. Run USTOS with the list of overloaded stops produced from (b) as SYSIN to locate all O-D pairs in which an overloaded bus stop is used as boarding stop in the minimum path.

d. Separate a 10% of HBWORK trip table to be loaded to the network in iterN into two groups, one with boarding at overloaded bus stops (OVL.iterN), and one without (NML.iterN). Load NML.iterN trips to the original network. Loaded legs LLNML.iterN are produced from ULOAD.

e. Remove the overloaded lines from the original network, run UNET/UPATH/UFARE/MCH/ULOAD on this reduced network with OVL.iterN loaded to the network. Loaded legs LLOVL.iterN are produced from ULAOD.

f. Set LLTOT.iterN= LLTOT.iter(N-1) + LLOVL.iterN + LLNML.iterN.

g. Run UPRAS on the original network with the combined loaded legs LLTOT.iterN. LOADFILE.iterN is produced by UPRAS.

h. If N<7 then go to (b); otherwise run URAP to report NOCE.

This procedure requires running UPATH/UFARE/MCH/ULOAD eight times, once for the 100% HOOOOW and 30% HBWORK trips, and seven times for the seven 10% HBWORK trips. It is an extremely time-consuming process. For the network tested so far, it generally requires three to four weeks to have this MPP executed. There is no guarantee that the resultant NOCE falls below the expected budget, e.g. 525 million dollars.

SHORT-CUT PROCEDURE

SCP, originally suggested by Kenneth Keltenbach, is a quick-and-dirty process. It was developed to reduce the time and efforts involved in dealing with this capacity restrained problem. The entire process of this procedure is done in URAP. The concept is summarized below:

a. For each bus line in the system, calculate the capacity as N*C, where N is the number of buses in peak hour (i.e. 60 min/ headway) and C is the number of seats on a bus.

b. Compare the peak load of each line with the associated capacity. If the peak load exceeds capacity, set the number of riders to the line capacity; otherwise, set the number of riders to peak load. Vehicle hours (VH), vehicle miles (VM), and peak hour vehicles (PHV) will not be adjusted even peak load exceeds capacity substantially.

c. Calculate the operating cost based on the unadjusted VH, VM, PHV, and the capped number of riders in (b).

The current version of URAP reports operating cost of RTD bus system with two scenarios. In the first scenario, it is assumed that RTD will have unlimited budget to meet the transit demand and produce NOCE based on the nominal system. In the second scenario, it is assumed that the budget is limited and the service frequency cannot be increased to meet the demand. VH, VM, and PHV are fixed as in the coded version of the network. The number of riders is capped by bus capacity.

3. CONCEPTUAL EVALUATION BY AN IDEALIZED EXAMPLE

In this section, a simple example of congested transit network is described. Then each of the three capacity procedures will be applied to this network. The impacts on the utilization of the transit system due to these three methods are identified and reasonableness check on these impacts are performed. The purpose of this section is to use a practical example as tool to examine the reasonableness and identify the flaws in each of the three methods.

AN IDEALIZED EXAMPLE

Figure 1 shows an ideal situation. In this figure there are two trip origin zones, OZ1 and OZ2, going to the same destination DZ. The minimum path for each of the two O-D pairs are

FROM OZ1 TO DZ				FROM OZ2 TO DZ			
FROM	TO	MODE	LINE	FROM	TO	MODE	LINE
OZ1	1000	1	-	OZ2	1001	1	-
1000	1004	4	1	1001	1002	4	2
1004	1006	5	1	1002	1006	5	1
1006	1007	4	3,4	1006	1007	4	3,4
1007	DZ	1	-	1007	DZ	1	-

Now suppose three sections in the network are overloaded. The first is the link between 1002 and 1004 in Line 5(1). It is overloaded in both north-bound and south-bound directions. The second is the link between 1004 and 1006 in Line 5(1). It is overloaded in north-bound direction only. The third is the entire line of 4(3). It is overloaded in both east-bound and west-bound directions. But Line 4(4) is not overloaded.

Under such situation, the traveller from OZ1 to DZ will be able to get on 5(1) at 1004. He/she may have to wait longer at 1006 because only 4(4) has seats available. And if the time waiting for 4(4) turns out to be too long, he/she may switch to automobile modes or to the alternative path: 4(1) to 4(101) then to DZ.

The traveller from OZ2 to DZ will encounter overloaded situation when he/she wishes to transfer at 1002. He/she may either wait longer at 1002 and then 1006 for seats on the overloaded buses, or switch to new paths such as 4(2) to 4(101) then to DZ.

Figure 1   A Hypothetical Situation of Overloaded Trip Interchanges

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                 |                                   |
     OZ2         | 5(1)                              | 4(101)
     |           |                                   |
     |  4(2)     | 4(2)        4(2)        4(2)        |       4(2)
-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
   1001          | 1002                              | 1003
                 |                                   |
                 |                                   |
                 | 5(1)                              | 4(101)
     OZ1         |                                   |
     |           |                                   |
     |  4(1)     | 4(1)        4(1)        4(1)        |       4(1)
-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
   1000          | 1004                              | 1005
                 |                                   |
                 | 5(1)                              | 4(101)
                 |                                   |
                 |                                   |
        4(3,4)   | 4(3,4)      4(3,4)      4(3,4)      |       4(3,4)
-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+-----+
                 | 1006                              | 1007
                 |                                   |
                                                    DZ
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Note: M(l,k) = mode M lines l and k traversing on this link.

The ideal capacity restrained process probably should be able to handle all three possibilities (i.e. wait longer on the same path, switch to new path, and switch to automobile modes) in its procedure. Above example can be served as test case to check how each of the three existing procedures operate.

FIXED-PATH PROCEDURE

In FPP, the traveller, when encountering overloaded situation, is always penalized by FWAIT, the first waiting time in the path. Although the traveller from OZ1 will realistically wait slightly longer at 1006 due to lack of available seats on 4(3). FPP says that this person must wait at 1000. He/she has to keep waiting until seats are available on all buses in the path all the way through.

Such strict requirements is attributed to the practice of using ULOAD to identify the O-D pairs facing overloaded lines. ULOAD takes both 5(1) and 4(3) as SYSIN without mentioning the direction of overloading. Consider the case that Line 4(3) is overloaded in west-bound direction only. The traveller from OZ1 actually can go through the minimum path without any overloaded problems, but FPP still forces the person wait at 1000 until 4(3) and 5(1) are cleared in all directions.

For the traveller from OZ2 to DZ, he/she probably has to wait at 1002, but FPP forces this person wait at 1001 until all lines on the path are cleared. But in reality this person may be able to go through this minimum path as long as 5(1) is cleared, before 4(3) is cleared.

Based upon the above observation we can say that FPP has the tendency of over-penalizing the O-D pairs encountering overloaded lines. Especially when a line is overloaded in one direction, all the O-D pairs using this on the reversed direction will also be penalized. The result of such situation would be over-penalized transit utility, under-estimated transit boarding, and under-estimated revenue estimates.

MULTI-PATH PROCEDURE

In MPP the traveller when encountering overloaded situation in the minimum path, he/she will not wait longer for the same line. A second best path will be sought and used.

For the person from OZ1 to DZ as the first example, since transit is overloaded at 1004 (in north-bound direction), UOILM creates a file containing 1004 for SYSIN to USTOS. And because 1004 is a boarding stop in the minimum path of this O-D pair, USTOS will identify this person as a person using reduced network in subsequent 10% loading.

Thus, this person in a subsequent loading will use new path: 4(1) to 4(101) then to DZ, despite the fact that the person can go through the original path without overloaded situation in his/her travel direction. For the person from OZ2 to DZ, because 1002 is overloaded this person will be using the new minimum path in the reduced network, i.e. 4(2) to 4(101) then to DZ.

Based on above observation, we can see that MPP has the problem of being unable to direct trips to appropriate (the original versus the reduced) networks correctly when the minimum path is encountering directionally overloaded transit lines. While FPP may force travellers wait longer at the first transit stop unnecessarily, MPP on the other hand may push travellers to less efficient transit paths. Forcing riders use inefficient routes may result in poor utilization of transit system and more operating costs may be incurred.

The second problem with the current concept of MPP is that MPP directs the trips to reduced network based on whether overloaded stops are used as boarding stop or not. If all boarding stops are not overloaded MPP allows the person get on the same line, disregarding whether this line will be overloaded later down the path. This practice seems logical since there is no reason why this person will not board the bus in which seats are available. However, the implication of such practice is that allowing this person to board early upstream of the line will increase the peak load of its critical link; thus, worsen situation of overloading and more VH, VM, PHV, and NOCE will be incurred. In other words, the current concept of MPP is not able to drive the NOCE down to the pre-determined operating cost budget through the iterative process.

To fix this problem, the criterion of directing trips to the original versus the reduced networks in each iterations has to be modified. Instead of directing trips to the reduced network based on whether the boarding stop is overloaded or not, we have to direct trips to the reduced network as long as one overloaded stop falls in the current path. In other words, as long as one stop along the original minimum path is overloaded, this path has to be abandoned because allowing any additional boardings to this path will further increase the vehicle requirements of the already overloaded line.

The third problem with MPP is a practical concern. Ideally MPP should be applied incrementally person by person to the network. In each increment, whenever a line is identified as overloaded, this line will be no longer available to all forthcoming trips within the same trip interchange. And the resultant NOCE would fall below the expected budget. Unfortunately, in the planning horizon, Year 2000, there will be over 20 million trips each day. It would not be practical to load all these person trips one by one to the network. In an earlier technical memorandum, it has shown that every 10% of HBWORK trip table loaded in an incremental step is equivalent to about one million person trips, and practically speaking, this is the finest increment we can work with. Because of the fact that we are not able to load the person trips one by one, a number of severely overloaded lines would still be generated by the end of MPP. As a result, there is not a guarantee that the subsequent NOCE from MPP would fall within the expected budget.

SHORT-CUT PROCEDURE

In SCP the procedure chops off excess riders only from the overloaded lines. For the traveller from OZ2 to DZ as an example. SCP will attribute this trip as a boarding to lines 4(2) and 4(4). But it excludes this trip from the boarding to lines 5(1) and 4(3) because these two lines are overloaded. Thus, accepting the trip to 4(2) and 4(4) shows that SCP tends to overestimate the bus boardings. The reduction in bus boardings due to overloading estimated from this method may have to be correct.

4. SUMMARY AND RECOMMENDATIONS

Based on the experience and understanding in these three capacity restrained procedures, we tabulate the relative advantages and disadvantages of these methods in Table1. There are five elements considered in this table:

a. Ability to cap the operating cost within the expected budget,
b. Ability to be used as direct input to revenue estimation, travel time savings and user benefits calculation,
c. Implication on transit utilities and patronage forecasts,
d. Conceptual flaws, and
e. Time required to execute the procedure.

First, in terms of the ability to cap the operating cost within budget, FPP and SCP are capable of generating transit systems within budget constraints. MPP, although conceptually is capable, practically it is not because we can not afford loading very small amount of trips in a large number of increments. FPP through its iterative process can produce several transit systems of different scales, each corresponding with different NOCE below the targeted budget. SCP, on the other hand, is fixed to the coded system. Thus, based on the primary practical concern of capping NOCE FPP is superior to SCP, and SCP is superior to MPP.

Second, in terms of the capability of being used as direct input to revenue estimation and user benefits calculation, FPP and MPP are superior to SCP. It is because the calculations of revenues and user benefits require the availability of transit trips tables together with transit travel time tables and fare tables. By the end of SCP, correct transit trip tables are not produced and these calculations cannot not be performed. Thus, SCP is inferior to FPP and MPP. Comparing FPP and MPP from this point of view, FPP is much better than MPP in the sense that FPP produces one set of trip tables directly from mode choice model while MPP produces eight different sets of trip tables, fare tables, and impedance tables from the eight incremental steps. The calculation of revenues and user benefits based on these eight scattered sets of tables although can be done conceptually, practically will be quite complicated and time-consuming. Thus, FPP appears better than MPP.

Third, in terms of conceptual flaws and implication on transit utilities, it is uncertain which method is superior. Flaws exist in all three methods and none of the methods produces results more accurately than the others. From the current understanding FPP and MPP overpenalize the transit utilities of trip interchanges which contain overloaded lines. Neither MPP nor FPP can handle directional overloading. As a result, the transit patronage forecasts from these methods are underestimated. As for SCP, the transit patronage forecasts are overestimated.

Table 1 Comparison of Alternative Capacity Restrained Methods

	FPP	MPP	SCP
Ability to cap operating cost within budget.	Can be done by iterative process.	Practically can not be done.	Can be done with coded network.
Ability to be used as input to revenue estimation and user benefits calculation.	Outputs one set of transit trip tables readily applicable.	Outputs eight sets of transit trip tables, & travel time/fare tables; complicated for application.	Cannot be done.
Implication on trnsit utility and patronage forecasts.	overpenalized trnsit utility, underestimated patronage.	overpenalized trnsit utility, underestimated patronage.	transit utility not considered, overestimated patronage.
Conceptual flaws.	- no new path considered, - cannot handle directional overload, - all lines in the group are penalized as long as one in the group overloaded.	- no additional waiting, - cannot handle directional overload.	- no behavioral assumptions, method is approximate.
Time required to execute the approach.	1 week.	3 - 4 weeks.	no additional time.

Fourth, in terms of time required for executing these approaches, SCP does not require any additional time beyond a regular simulation process executed for each network. FPP requires about a week, and MPP requires about a month.

Based on above comparison, it is clear that FPP is the only practical procedure that the District can adopt for future capacity restrained processing. MPP requires too long time to execute, and after all the time and efforts were spent for conducting such time-consuming procedure, it would not necessarily produce a transit system within the allowable operating budget. SCP, on the contrary, does not require any extra efforts or time to execute. Its results are produced automatically from URAP. Although its results are on the overestimated side, the annual patronage forecast from SCP are useful for sketch planning and can give us idea on the relative upper bound of the number of riders the coded system can carry.

The present operation of FPP, unlike its old version in which all overloaded lines were coded by hand to the ULOAD.SYSIN file, has been automated by the program UOILM. With UOILM, the ULOAD.SYSIN file together with the needed JCL setups for the ULOAD/UMATRIX procedures are generated automatically. Thus, execution times and potential coding errors are substantially reduced.

There is one modification that can be made to current FPP. It is bus capacity assumed in URAP. Presently, bus capacity is assumed 65 for local buses and 46 for express buses, despite the fact that even in current day's operation, Line 1 (Hollywood Boulevard) is carrying in the peak load of 136 on articulated buses and Line 55 (Wilmington Avenue) is carrying in the peak load of 118 on regular buses. Only recently, the District staff has reviewed the peak load on all buses in the system and suggested modified capacity figures of 72 for local buses and 50 for express buses. If these new capacities were adopted to URAP, FPP may require less iterations and the significance of underestimated patronage level may be lessened.