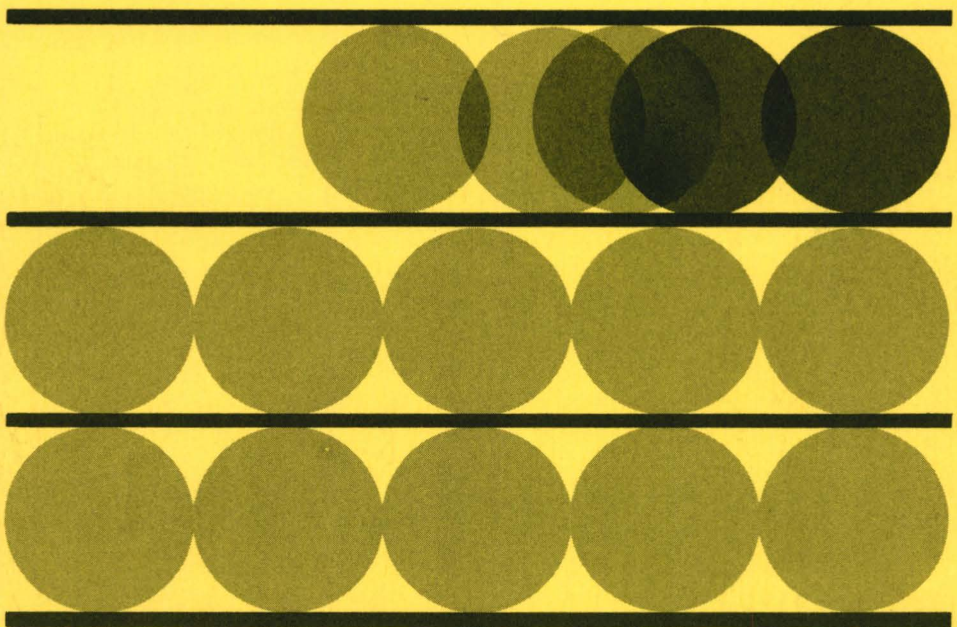
A COMPUTER SIMULATION MODEL FOR EVALUATING PRIORITY OPERATIONS ON FREEWAYS



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A COMPUTER SIMULATION MODEL FOR EVALUATING PRIORITY OPERATIONS ON FREEWAYS

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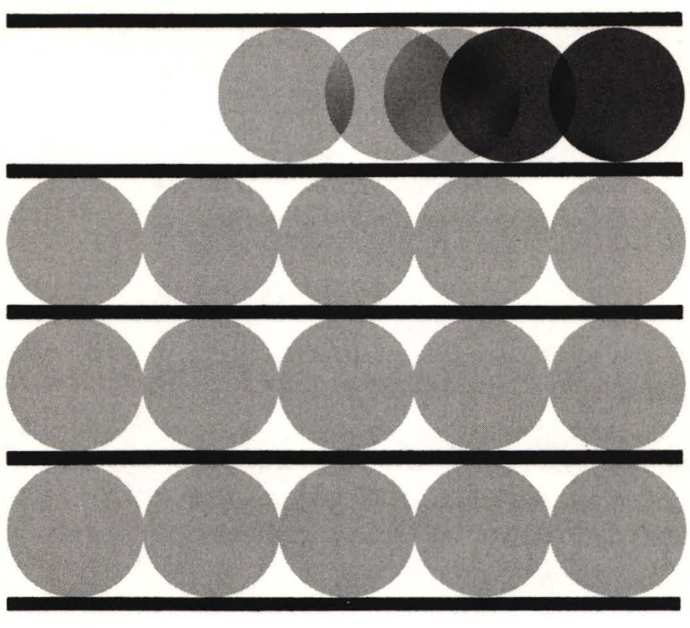

PREPARED FOR:
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

The PRIFRE computer program and this documentation were developed and written for a CDC 6400 computer. An IBM 360 version is available. Contact the Urban Planning Division, Federal Highway Administration, Washington, D.C., 20590, for information.

ACKNOWLEDGMENTS

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Mr. Richard Blankenhorn assisted in making program changes and minor additions, as well as counseling the authors on the intricacies of computer programming. He was also responsible for punching the program card decks, putting the program up on tapes, and printing the program listing, inputs, and outputs found in the Appendices.

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1. INTRODUCTION

The urban freeway-expressway networks of our cities typically contain congested segments during peak periods. If widened, these segments are frequently soon congested again; additionally, these segments may be bridges or tunnels for which the costs of providing increased vehicular capacity or parallel links are likely to be prohibitive. Automobile storage in the central city during working hours is also limited, and it is doubtful that much additional parking capacity can be provided. Lastly, public attention today is being focused more and more on the esthetic and ecological disbenefits of the automobile in the mass, with some observers calling for an outright ban on the automobile in central cities.

One means to alleviate these problems is to explore all methods to facilitate the movement of persons rather than vehicles. Although entirely new systems to transport passengers could be constructed at considerable cost, the existing highway network could accommodate many more persons at much lower cost if a proper redistribution of passengers into higher occupancy vehicles could be achieved. The reserved lane concept is one method attempting to achieve this goal; high occupancy vehicles are given preference in congested segments of highways. This is accomplished by establishing separate lanes for these vehicles, bypassing traffic bottlenecks[2*]. These reserved

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* These numbers appearing in the text refer to references in the annotated bibliography, Appendix J.

lanes could be simply exclusive bus lanes; however, in most instances a single lane reserved exclusively for buses would be considerably under-utilized from a vehicular as well as a person capacity stand point. Thus it will usually be more practical to use priority lanes in which buses plus carpools are permitted to use the reserved lanes and thereby obtain greater benefits.

Since 1968 a series of analytical models have been developed at the Institute of Transportation and Traffic Engineering (ITTE) at the University of California in Berkeley to assist in the evaluation of reserved lane schemes. These models differ only in their degree of sophistication and exhaustiveness of applicability; the basic philosophy of each is the same: the total travel time (passenger-hours) for the normal operating condition (no reserved lanes) is compared to the sum of the separate total travel times in the reserved and unreserved lanes for priority operation. The passenger demand for both operations is assumed to remain constant during the peak period.

The first of these models, which sets the outline for the remaining models, was an exclusive bus lane model developed in 1968 by A. D. May[4]. It was a rudimentary model; the peak period demand was assumed constant in time and space, and a simple Greenshields flow submodel was employed.

In 1969, W. A. Stock[6] improved the model by incorporating the option of a more realistic peak period demand over time; piecewise linear, triangular, or trapezoidal demand curves could be used. Additionally, a wide variety of speed/flow submodels could be used, including some based upon curves given in Fig. 9.1 of the 1965 Highway Capacity Manual[5]. This model was known as EXCBUS.

Next, G. Sparks and A. May[8] in 1969-70 broadened Stock's model for the Federal Highway Administration to a full priority lane model, permitting the evaluation of the mixed use of reserved lanes by both buses and carpools. The model, although now both a bus and carpool model, retained the EXCBUS name. Also, fairly extensive model validation was done, and the model was applied to a typical situation: the San Francisco-Oakland Bay Bridge. The effects of occupancy shifts, induced by the better level of service in the priority lanes, were also investigated for the first time. The Sparks-May model was used by Alan M. Voorhees and Associates in a feasibility analysis for the Department of Transportation of priority lanes on a segment of I-90 in Cleveland, Ohio[15].

As convenient as the above models were to use, they lacked the realism of having a demand pattern which could change over distance, as actually happens at the off- and on-ramps of a freeway. In addition, the existing priority lane models did not consider the effects of capacity changes over distance, such as will occur due to grades, lane drops, ramp merges and diverges, weaving, etc. Thus the need for a more realistic model was apparent. Such a model for normal freeway operations had been developed at ITTE by Makigami, Woodie, and May[10] as an aid for the evaluation of freeway improvements in connection with the Bay Area Freeway Operations Study (BAFO Study) for the California Division of Highways. This model, known as the Freeway Model, or FREEQ, does consider the effects of changing demands and capacities, both over time and distance.

Two studies have already been done using FREEQ to evaluate the use of priority lanes. The first, by Allen and May[11], was done in 1970 as part of the BAFO Study, and was a general study using FREEQ to analyze present and future freeway operations on the San Francisco-Oakland Bay Bridge. As such, it briefly considered priority lanes as a part of the much broader picture of improving freeway operations on the bridge. Emphasis was on the eastbound traffic during the evening peak period. The second study, by Stock, Wang, and May[13] 1970-71, for the Division of Bay Toll Crossings, was also of the Bay Bridge. Since only priority lane operations were considered, its study of this problem was considerably more detailed than the previous study. Both westbound A.M. and eastbound P.M. peak-hour traffic were analyzed. The eastbound P.M. direction was found to be unfavorable for priority lanes, while the westbound A.M. direction with no occupancy redistribution was found to be at best only marginally favorable to priority lanes. However, with a 5 to 10 percent occupancy shift into priority vehicles, the westbound A.M. direction was found to be rather favorable for priority lanes. Partially as a result of the above study, the Division of Bay Toll Crossings established, on December 8, 1971, the nation's first use of priority lanes for buses and carpools of 3 or more occupants on a freeway-type facility[14]. As an added inducement for motorists to form carpools, the priority lanes were initially free, while the unreserved lanes continue to have a 50¢ toll. As of this writing, the priority lanes are still in use, and some occupancy shift has been noted.

The above two studies manually converted FREEQ in order to evaluate priority lanes. This manual interfacing severely reduced the number of alternatives which could be considered, due to the high cost in man-hours for each alternative to be evaluated. Thus, the latest priority lane model, PRIFRE, the subject of this report, has been developed. Essentially, PRIFRE automates the methodology used in the above two studies. It combines the philosophy of the earlier EXCBUS model of Sparks and May with the realism of the FREEQ model.

PRIFRE was developed primarily to evaluate one-way "normal" priority lane operations, i.e., reserved lane(s) on the same side of the freeway median as the unreserved lanes. However, with some manual interfacing, PRIFRE can be used to evaluate wrong-way reversible lanes, separate bus roadways, freeway design improvement strategies, and ramp control schemes affording priority entry to high-occupancy vehicles.

PRIFRE can calculate total travel time expended under normal freeway operations and total travel time expended under any number of different priority operation strategies, and compare the two. Any travel time difference (savings or losses) is noted in the final output. Similarly, PRIFRE can also calculate total vehicle-miles accumulated under normal and priority operations, and compare the two. Any variety of occupancy shifts, number of priority lanes, modal splits, and growth periods can be input to the program and results calculated and compared using PRIFRE. It is felt that the Model as it now exists represents the most comprehensive analytical tool available for evaluating priority operations on freeways.

2. MODEL STRUCTURE

A. Basic Assumptions

This chapter describes the development of PRIFRE. The reader will be referred to Bay Area Freeway Operations Study - Final Report; Analytic Techniques for Evaluating Freeway Improvements. Part I of III: The Freeway Model (throughout this report, the above report will be referred to as the FREEQ report)[10].

The following basic assumptions carry over from the FREEQ report:

1. Traffic is treated as a compressible fluid where vehicles are not considered individually.
2. Within any time interval, traffic demands remain constant and do not fluctuate within that time interval.
3. Once the traffic demands are loaded onto the freeway, the demands propagate downstream instantaneously, subject of course to capacity constraints.
4. Capacities of subsections, including weaving sections and merging points, are estimated using the Highway Capacity Manual methods.

The following additional assumptions were adopted for PRIFRE:

5. No weaving will be allowed between priority lanes and non-priority lanes; the reasoning behind this is that no effective formula has been devised to calculate the weaving effect between two lanes moving at differential speeds of 20-30 mph. Thus throughout PRIFRE (the priority lane model), the priority sections are treated as an isolated roadway with no entry or exit except at the beginning and end of the

section.

6. FREEQ is indeed an accurate model of a freeway under non-priority operations.

7. No queueing will be allowed at the entrance to the priority lanes. That is, if the demand exceeds capacity for a priority lane, the excess vehicles will be demoted to non-priority status.

B. Basic Data

1. Physical Condition of Freeway

In order to make a reasonable estimation of the travel time on a freeway, it is necessary to know the physical and operational characteristics of the freeway and to put them into an approximate numerical expression.

In general, freeway sections exhibit a number of varying design and operational features. Thus, to establish a meaningful relationship of the average speed of traffic as a function of freeway capacity and traffic demand, it becomes necessary to divide the freeway section into homogeneous subsections which exhibit the properties of constant capacity and demand over their lengths. It is also necessary to itemize the features which affect the capacity of each subsection such as design speed, number of lanes, lane width, volume of buses, percent of grade, grade length, number of priority lanes, and location of on- and off-ramps. Traffic factors, such as percent of trucks, which affect subsection capacities and which are hypothesized to be constant over the peak period, should also be listed in the same table. It is convenient for later analysis to list all of these elements in the format shown in Fig. 1. These elements are used to calculate the capacity of each subsection.

2. Traffic Demand

Traffic demands are introduced into the study section in the form of origin-destination (O-D) tables. The entry into the study section and each on-ramp are considered as origins, and each off-ramp and the exit from the study section as destinations. The origins and destinations are numbered consecutively from upstream to downstream as shown in Fig. 1.

Considering the fact that traffic demands during a peak period usually vary, the peak period should be divided into a number of smaller time intervals. In general, a 15 minute time interval should be used because 15 minutes is short enough to simulate the traffic demand change during the peak period and is still a reasonable time interval for predicting traffic demand patterns in the near future. It is therefore necessary to input O-D tables for each time interval during the study period. One O-D table is required for buses and another for non-buses (autos and trucks). See Tables 1 and 2.

This method of treating traffic demand, although adding complexity, yields the following desirable characteristics:

a. Actual demand patterns are more realistically simulated.

b. Travel times for individual O-D movements can be readily obtained and are essential for evaluating the effectiveness of such improvements as ramp control.

SUBSECTION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LENGTH IN FEET	1630	1960	1550	1960	600	4790	3030	2160	2030	1250	900	1320	720	2610	1660
NUMBER OF LANES	←5→			←4→								←3→			
NUMBER OF PRIORITY LANES	←0→			←2→						←0→					
BUS VOLUME	←20→								←15→						
PEAK HOUR FACTOR	0.91														
LANE WIDTH	12.0														
OBSTRUCTION DIST.	6	6	6	6		6	6	6	6	6	6	4	6	6	6
% OF GRADE	0	0	0	0		0	0	0	0	0	0	0	0	0	0
LENGTH OF GRADE	-	-	-	-		-	-	-	-	-	-	-	-	-	-
% OF TRUCKS	6	4	4	5		4	4	4	4	3	5	4	4	3	3
AVG. HIGHWAY SPEED	70.0														

SUBSECTION NUMBER	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
LENGTH IN FEET	1890	2310	1460	3800	1100	660	1440	1480	800	4690	2190	[illegible]	830	1180	2560
NUMBER OF LANES															→
NUMBER OF PRIORITY LANES	→	←1→				←0→									
BUS VOLUME		→	←10→						←8→						
PEAK HOUR FACTOR															
LANE WIDTH															
OBSTRUCTION DIST.	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
% OF GRADE	0	2	0	0	2	0	0	0	0	0	0	0	3	4	4
LENGTH OF GRADE	-	2310 (0.44)	-	-	1100 (.206)	-	-	-	-	-	-	-	1280 (.24)	2440 (.46)	5000 (.94)
% OF TRUCKS	3	3	2	3	3	3	3	2	2	4	3	4	2	2	4
AVG. HIGHWAY SPEED															

STATION NUMBER: 601-602-603-605-607—608—609—610—611—612—613—614-615—616—617—618—619-620—621—622-623—624-625—626-627-628—629—

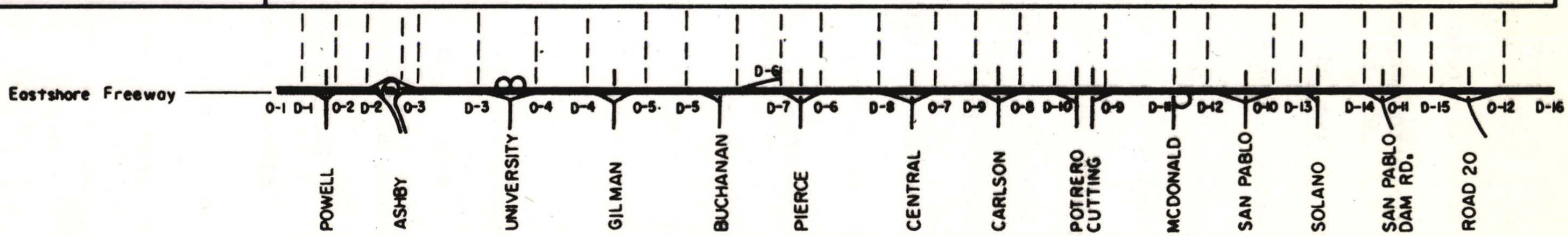


Figure 1 FREEWAY SUBSECTION PARAMETERS

SAMPLE O-D TABLES FOR PRIFRE

ONE TIME INTERVAL

TABLE 1. NON-BUS (AUTO) O-D TABLE IN PERSONS/HR

ON-RAMP NO.	OFF-RAMP NO. 1	2	3	4	5	6	7	8	9	10*
1*	65	41	154	235	85	53	198	212	147	151
2	239	107	339	446	146	91	328	288	192	194
3		49	154	207	68	43	154	136	91	52
4			55	76	25	16	56	45	32	20
5				113	37	23	84	76	51	33
6						21	77	68	45	39
7							53	37	36	36
8							91	64	61	63
9								87	87	117
10									36	53
11									77	392
12										403

TABLE 2. BUS O-D TABLE IN BUSES/HR

ON-RAMP NO.	OFF-RAMP NO. 1	2	3	4	5	6	7	8	9	10*
1*	0	0	0	8	0	0	0	4	0	1
2			2	0	0	4	0	0	0	0
3				2	0	0	0	1	0	0
4					0	0	0	0	0	0
5						3	0	2	0	5
6							0	0	0	0
7							0	4	0	1
8							0	4	0	0
9								2	5	2
10								2	0	1
11									0	10
12										2

* On-ramp #1 and off-ramp #10 are the freeway input and output stations, respectively.

c. The resultant freeway priority lane model exhibits a flexibility which will facilitate considerations of network traffic movements and patterns.

d. It facilitates future growth forecasts since each O-D movement can be multiplied by a common factor.

C. Model Development

1. Demand Calculation

An O-D table format is used to input traffic demand. Let TRIPS (I, J, K) be the traffic demand (number of trips) between the I^{th} origin and the J^{th} destination. K = 1 corresponds to the bus O-D tables and K = 2 to the non-bus O-D tables. The demand at the I^{th} origin (on-ramp) and the J^{th} destination (off-ramp) can be calculated as follows:

$$\text{TØSUM}(I, 1) = \sum_k \sum_j \text{TRIPS}(I, j, k)$$

$$\text{TØSUM}(J, 2) = \sum_k \sum_i \text{TRIPS}(i, J, k)$$

where TØSUM (I, 1) is the I^{th} on-ramp demand and TØSUM (J, 2) is the J^{th} off-ramp demand.

From basic assumptions (2) and (3), the subsection demand between the I^{th} origin and the J^{th} destination can be calculated as follows:

$$\text{VØL}(L) = \sum_{i=1}^{I} \text{TØSUM}(i, 1) - \sum_{j=1}^{J-1} \text{TØSUM}(j, 2) \qquad (1)$$

where L is any subsection number between the I^{th} on-ramp and J^{th} off-ramp.

2. Capacity Analysis

The Institute of Transportation and Traffic Engineering has already developed a series of computer programs for capacity analysis in accordance with the 1965 Highway Capacity Manual. Therefore, the efforts of the FREEQ study were directed toward fitting these programs into the system of the freeway model, and as was already mentioned, FREEQ formed the basis of PRIFRE.

a. Freeway Capacity. Freeway capacities can be calculated manually or by an ITTE developed computer program. The basic relationship of the Freeway Capacity Program is

$$SV = 2{,}000 \cdot N \cdot W \cdot T \cdot (v/c)$$

where

SV = service volume in vehicles per hour

N = number of directional lanes

W = adjustment factor for lane width and lateral clearance

T = truck factor

v/c = volume to capacity ratio

This program (Freeway Capacity Submodel) can be used as an independent submodel, and the outputs, such as freeway capacity and truck factor, can be used as the inputs for PRIFRE. Special consideration is required for those subsections with an auxiliary lane and subsections where the number of lanes changes, because the Freeway

Capacity Submodel cannot automatically handle capacity analysis for subsections with unusual geometric features.

b. Ramp Capacity Since the freeway priority lane model is normally to be used to analyze traffic flows during peak periods, the ramp capacity analysis is based on the D-E method outlined in the HCM which is used for levels of service D and E.

Traffic demands at on-ramps are compared with ramp limits, and if the demand exceeds the ramp limit at the on-ramp, the delay time and queue length at the entrance to the ramp are computed following the usual queueing theory. Ramp limits are set to the general ramp limit--say 1500 vph--for usual ramps. By reducing this value to the ramp metering rate, it is possible to evaluate the effect of ramp control plans on freeway traffic.

The D-E method cannot handle ramp capacity analysis for unusual ramp design features such as left side ramps and the two-lane ramps; therefore, several check systems are included in the ramp capacity analysis subroutines in order to supplement the merging volume analysis which is based on the D-E method. There are three kinds of input data for this check system:

(1) special ramp indicators, (2) on-ramp limits, and (3) off-ramp limits.

If there are any left-side ramps or two-lane ramps, the special ramp indicator should be coded 1 or 2 respectively, and the capacities of those ramps may be input to the computer in the form of ramp limits. The ramp limits, in this case, should be the best estimates of capacities for those special ramps.

In the ramp merging volume analysis, the lane one volumes at merging points (500 feet downstream of each on-ramp) are compared with the merging capacity which is assumed to be 2,000 vehicles per hour. If the lane one volumes at the merging point are found to be greater than the merging capacity, the excess demand is stored at the merging point and the queue length and the delay time caused by the merging restriction are computed following the usual queueing theory.

Off-ramp demands are merely compared with ramp limits. If the demands exceed the ramp limits at certain off-ramps, a statement is printed in the computer output to show the excess demands at those off-ramps; there are no particular computation procedures for the queue length or the delay time evaluation for the off-ramp excess demands. This is to alert the user of operational problems not handled by the present model.

c. Weaving Capacity For a given weaving section, the length of the weaving section is found from the freeway subsection parameter table, and the weaving volumes are calculated from the O-D tables for each time interval. Then the value of the weaving influence factor k is found following the procedures used in Fig. 7.4 of the Highway Capacity Manual. If k is greater than one, the maximum volumes for the designated levels of service can be calculated, using the formula given in the Manual:

$$SV = \frac{V + (k - 1) \cdot W_2}{N}$$

where

k = weaving influence factor

V = total volume in vph

N = number of directional lanes

SV = service volume in vph/lane

W_2 = smaller weaving volume in vph

Taking the upper limit of level of service E,

$$SV_E = \frac{C}{N}$$

$$\therefore N \cdot SV_E = C$$

then, adjusted capacity C' would be

$$C' = C - (k - 1) \cdot W_2 \qquad (2)$$

The various types of weaving sections that can be handled by the freeway priority lane model include both left and right-hand ramp weaving situations. For multiple weaving sections, a maximum of two adjacent weaving sections can be analyzed.

As stated in basic assumption (5), the priority lanes are separated from the non-priority lanes; however, weaving analysis might still be needed at the entrance and exit of the priority lane. This can either be ignored, assuming sufficient signing and controls extend far enough upstream so that lane-changing, and not weaving, takes place; or an adjustment to the input capacity of that section can be made following a simple weaving analysis suiting the user's individual situations.

3. Total Travel Time in Non-queueing Situation

a. Estimation of Average Speed. The average speed of each subsection is estimated from the relationship between the v/c (volume/capacity) ratio and the operating speed shown in the Highway Capacity Manual. In Fig. 9-1 of the Highway Capacity Manual the operating speed is expressed as a function of the v/c ratio, number of lanes in one direction, and design speed of the freeway. See Fig. 2.

For convenience of computer operation, all the curves in Fig. 9-1 in the Manual are fitted by various polynomials. The operating speed is then converted to the average speed by

$$V_A = V_O - DS/10 \cdot (1 - \frac{v}{c}) \quad (3)$$

where V_O is the operating speed in mph, and DS is the design speed of the freeway in mph.

In addition the user can specify his own speed-flow curves by inputting a set of speed-v/c conditions which will be used instead of the Highway Capacity Manual Curves. A straight linear interpolation is performed on these curves to compute the average speed. The interpolation is done between the two closest specified v/c ratios and necessitates the user giving average speeds for v/c ratios of

SPEED CALCULATION

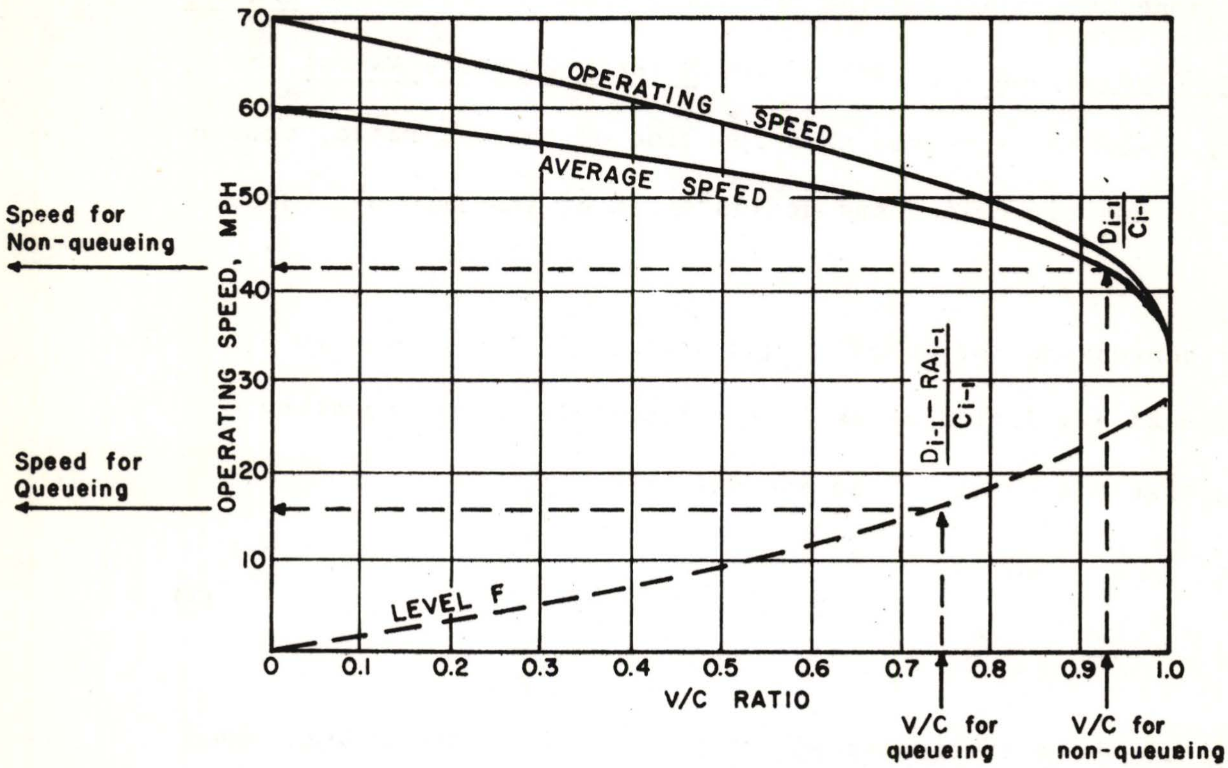


FIG. 2 SPEED-FLOW/CAPACITY CURVES

0.0, 1.0, -1.0, and -0.0. The negative values correspond to queueing calculations, positive values to non-queueing calculations. Each subsection can have its own speed-flow relationship.

b. Travel Time Calculations As long as the capacity is greater than the demand, the travel time for a given subsection and a given time period can be calculated as follows:

$$TT = \frac{L}{5280 \cdot V_A} \cdot D \cdot T_o$$

while

$$D = V_A \cdot d$$

then

$$TT = \frac{d \cdot L}{5280} \cdot T_o \qquad (4)$$

where:

TT = travel time in vehicle hours

V_A = average speed in miles per hour

D = demand for a given time period in hourly rate of flow

L = length of subsection in feet

T_o = time interval in hours

d = density in vehicles per mile

Since the flow of traffic under either queueing or nonqueueing conditions is simply the product of the density and the speed, the density of subsection i can be found from the expression

$$d_i = \text{volume}_i/\text{speed}_i \qquad (5)$$

4. Queueing Extension of PRIFRE (See Fig. 3)

When demands exceed capacities for certain subsections, physical queues occur upstream of these bottleneck subsections. A bottleneck subsection operates at capacity, and the demands of downstream subsections are modified. Then the physical queue length can be estimated from the rate at which vehicles are stored in the queue and the "excess density" of the queue. The number of vehicles in the queue equals the rate at which vehicles are being stored times the length of time interval. Also, the number of vehicles in the queue is equal to the length of the queue times the increase in density due to queueing. Equating these two expressions and dividing by the excess density, one obtains the expression for the length of the queue:

$$H_{i-1} = \frac{T_o RA_{i-1}}{(d'_{i-1} - d_{i-1})} , \qquad (6)$$

where

$$RA_{i-1} = D_i - C_i$$

according to the following definitions:

RA_{i-1} = net rate of change of the number of vehicles in subsection i-1 (vph)

D_i = demand for the bottleneck subsection i (vph)

C_i = capacity of subsection i (vph)

H_{i-1} = the length of the physical queue formed upstream of subsection i (in miles)

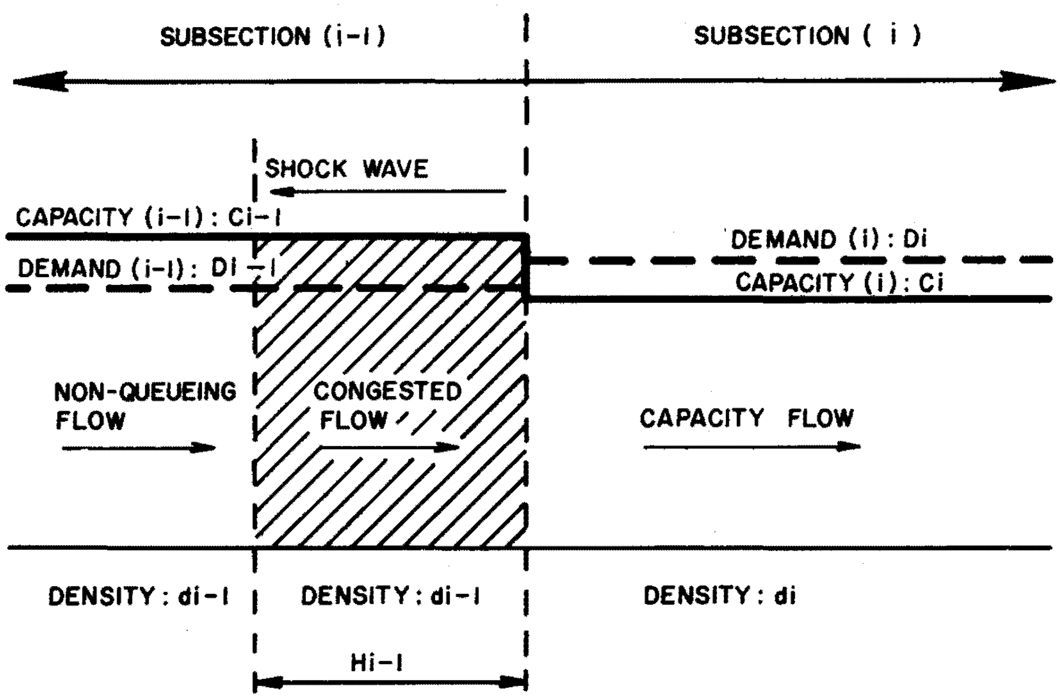


FIG. 3 QUEUE EVOLUTION

d'_{i-1} = queueing density in subsection i-1 (vpm)

d_{i-1} = nonqueueing density in subsection i-1 (vpm)

Then, the traffic speed in the queueing density situation is determined, and it is possible to evaluate the delay time caused by the bottleneck and the effect of the bottleneck on the total travel time.

Density and travel speeds in queueing situations can be estimated by using the relationship between the v/c ratio and average speed, as was done for nonqueueing situations. If, for a certain time interval, the demand exceeds the capacity in subsection i, the flow rate in subsection i should be equal to the rate of capacity flow, and the average speed of traffic in capacity flow should have the value corresponding to v/c = 1 on the curves in Fig. 9-1 of the Highway Capacity Manual. The demands of downstream subsections should be recalculated, based on the capacity flow rate of subsection i.

The traffic volume upstream of subsection i, for example, at the exit of subsection i-1, should be

$$U_{i-1} = D_{i-1} - RA_{i-1}$$

where

U_{i-1} = volume of traffic leaving subsection i-1

D_{i-1} = demand for subsection i-1 at this time interval;

then, if

$$D_{i-1} < C_{i-1} ,$$

the travel speed in subsection i-1 can be estimated by reading the value of the speed corresponding to $v/c = (D_{i-1} - RA_{i-1})/C_{i-1}$ on the dotted line for level F in Fig. 9-1 of the Highway Capacity Manual. (See Fig. 3 of this report). Then the physical queue length at the end of this time interval can be calculated from Eq. (6).

If the physical queue length exceeds the length of subsection i-1, the physical queue should be extended into further upstream subsections and should be considered in the same way.

Then travel time for subsection i-1 can be expressed as:

$$TT = t \cdot d_{i-1} \cdot L_{i-1} + (d'_{i-1} - d_{i-1}) \cdot 1/2 \cdot t^2 r + (T_o - t) \cdot d'_{i-1} \cdot L_{i-1} \tag{7}$$

where

$$r = \frac{RA_{i-1}}{d'_{i-1} - d_{i-1}} = \text{speed of shock wave}$$

$$t = \min \left| \frac{L_{i-1}}{r}, T_o \right|$$

L_{i-1} = the length of subsection i-1

T_o = time interval (.25 for 15-minute interval)

The derivation of Eq. (7) is shown in Appendix A of the Freeway Model (FREEQ) report.

If $D_{i-1} > C_{i-1}$ the excess demand of subsection i-1 is added to RA, and the computer proceeds to subsections further upstream, following the procedure described above, until the computer finds a nonsaturated subsection.

When the demand becomes less than the capacity at subsection i, but physical queues still remain in upstream subsections i-1, i-2,..., stored vehicles are discharged into downstream subsection i at the rate of RA_{i-1}, where

$$RA_{i-1} = D_i - C_i ,$$

and the travel speed in queueing densities, the decrease of the physical queue length, and the travel time can all be calculated using the methods described above.

3. PROGRAM DESCRIPTION

This chapter describes the operation of the freeway priority lane model computer program, named PRIFRE. This program provides an analytical method for estimating freeway travel times under normal and priority lane operations. It is under these conditions that the operation of possible priority lane schemes are of interest for the purpose of reducing total freeway travel time during peak traffic demand periods. The purpose of this chapter is to provide a detailed description of program operation, input data formats, and the possible output formats and statements.

A. Description of Program Operation

The main program of the freeway priority lane model is the calling routine named PRIFRE. A calling routine is a program which has mostly call statements. In this manner, the subprograms which are called do almost all of the computations while the calling routine coordinates them. One variable name which appears in this chapter and is used in PRIFRE to communicate information from the subprograms concerning program control is ITRIG, often called ITX in the subroutines. A flow chart of PRIFRE is shown in Fig. 4, and a listing of the program can be found in Appendix C. Each of the subroutines will be described in this section.

1. Capacity Data Input

The first subroutine called by PRIFRE is READIT. READIT actually reads all of the input data and stores the data on a physical

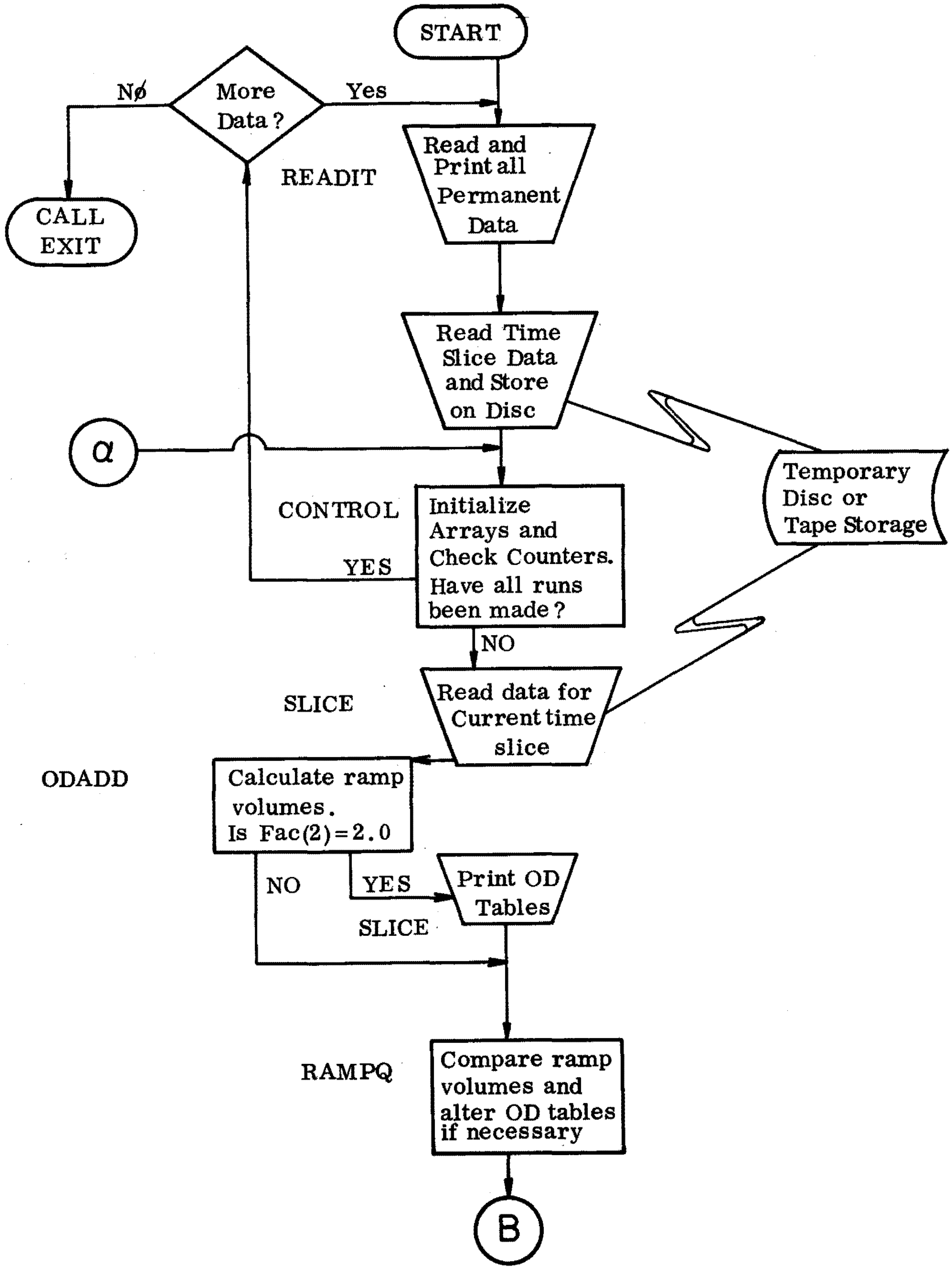
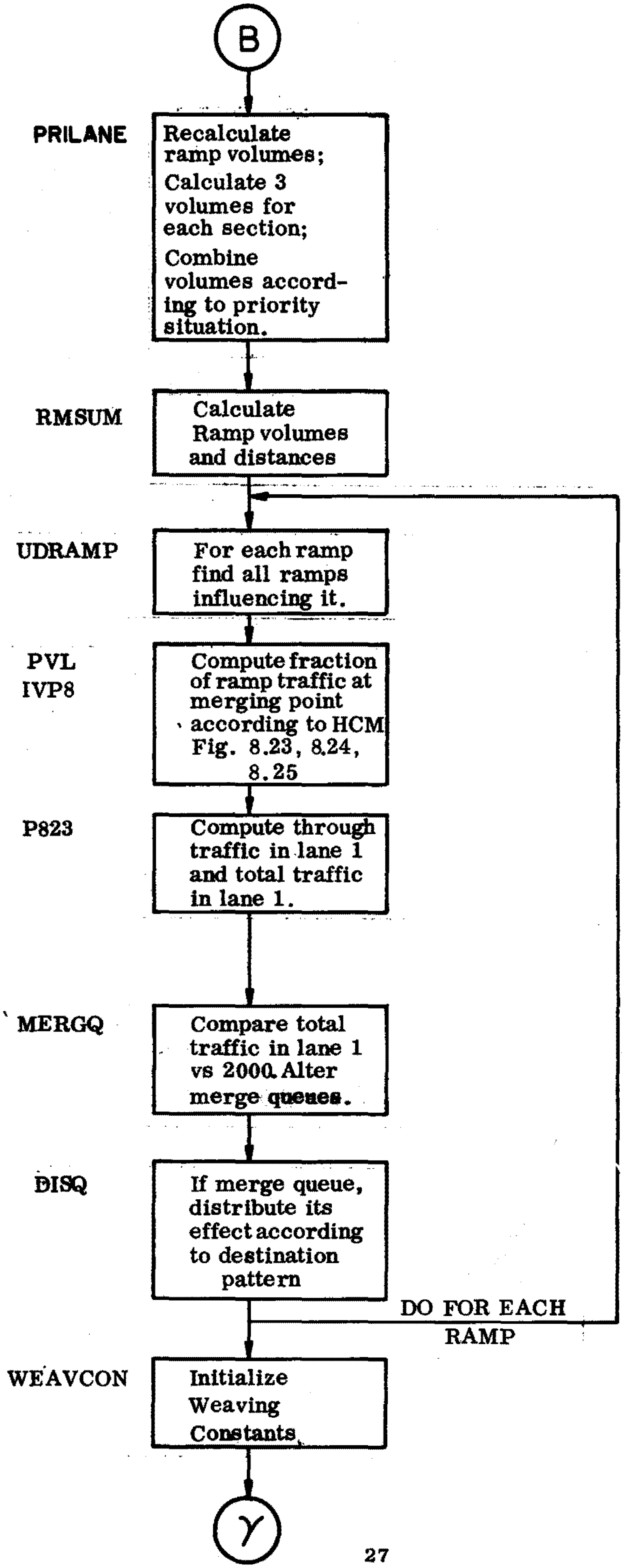
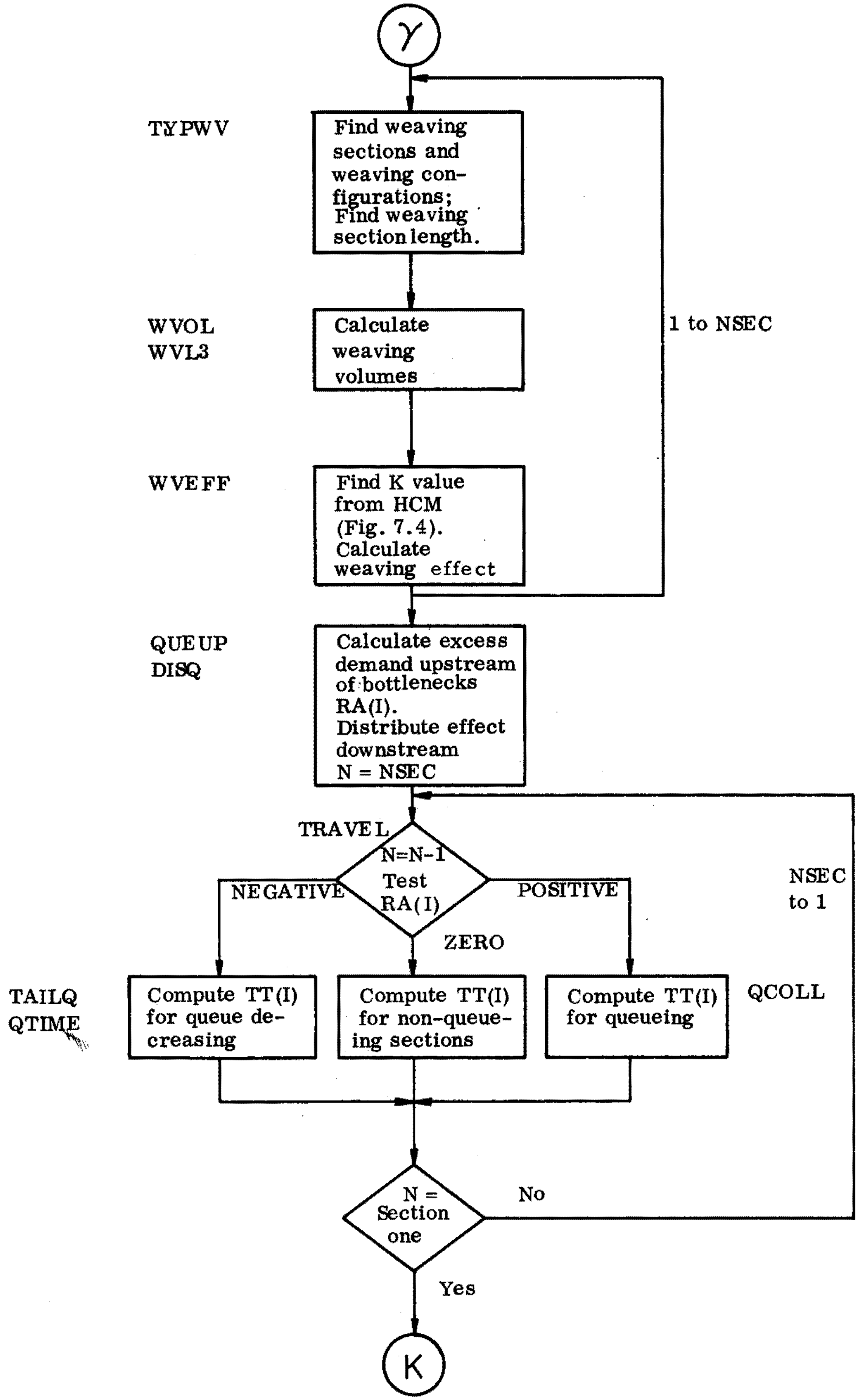


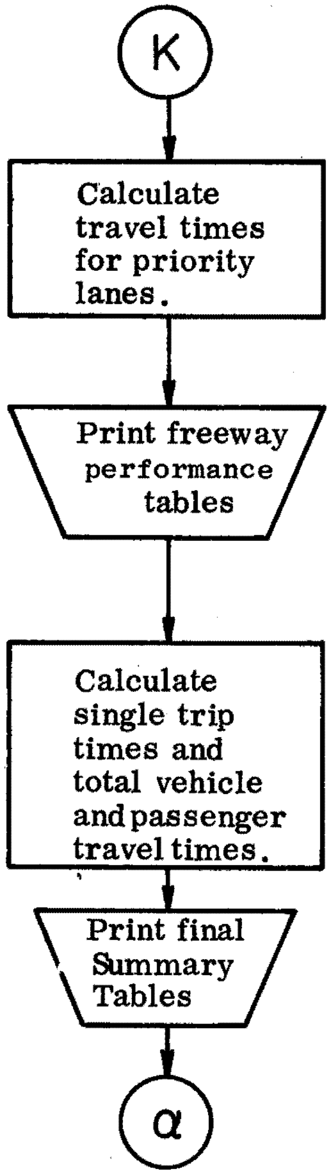
Figure 4. PRIFRE Program Flow Chart


B
PRILANE
Recalculate ramp volumes; Calculate 3 volumes for each section; Combine volumes according to priority situation.
RMSUM
Calculate Ramp volumes and distances
UDRAMP
For each ramp find all ramps influencing it.
PVL
IVP8
Compute fraction of ramp traffic at merging point according to HCM Fig. 8.23, 8.24, 8.25
P823
Compute through traffic in lane 1 and total traffic in lane 1.
MERGQ
Compare total traffic in lane 1 vs 2000. Alter merge queues.
DISQ
If merge queue, distribute its effect according to destination pattern
DO FOR EACH RAMP
WEAVCON
Initialize Weaving Constants.
γ


γ
TYPWV
Find weaving sections and weaving configurations; Find weaving section length.
1 to NSEC
WVOL
WVL3
Calculate weaving volumes
WVEFF
Find K value from HCM (Fig. 7.4). Calculate weaving effect
QUEUP
DISQ
Calculate excess demand upstream of bottlenecks RA(I). Distribute effect downstream N = NSEC
TRAVEL
N=N-1 Test RA(I)
NEGATIVE
POSITIVE
ZERO
NSEC to 1
TAILQ
QTIME
Compute TT(I) for queue decreasing
Compute TT(I) for non-queueing sections
Compute TT(I) for queueing
QCOLL
N = Section one
No
Yes
K

OUTIT

TIMEOUT



storage device (i.e., a disk or magnetic tape). The first section of READIT reads the main title card, parameter card, and the freeway characteristics (i.e., the subsection cards and ramp limits). READIT then checks for illegal parameters and design characteristics; if none are found READIT prints the title, parameters, and freeway characteristics. All of these permanent values are not written on the temporary tape or disc storage device as they are constant for all time slices, and thus remain in the memory of the computer.

2. Origin-Destination Tables

As mentioned earlier, there are two O-D tables for each time slice, one for buses and one for non-buses. There are also the revised ramp limits which will remain in effect over the remaining time slices or until reset, and the occupancy cards (the number depending on the IOCS - No. of occupancy shifts - option). Thus for each time slice, the title and all tables and revisions are written onto the storage device. After all time slices have been read, the storage device is rewound and control returned to the main program.

PRIFRE will then call the subroutine CONTROL with parameter IFLAG. CONTROL initializes all the values used during the simulation for each criterion. Depending on the values of IOP-the no. of priority lanes selector - and NGP - the no. of growth periods CONTROL will determine if all the requested criteria have been exhausted and, if this is the case, IFLAG will be set to 2 and PRIFRE will use this to call READIT again for a new freeway section to be studied. If there are still time slices to evaluate or if a new criterion is to be started, CONTROL will return to PRIFRE and PRIFRE will call SLICE.

SLICE's purpose is to read from the storage device each individual time slice's data, print the O-D tables with the corresponding occupancy cards, and to call ODADD which finds the input and output volumes for each on-ramp and off-ramp. It should be mentioned that the O-D tables for buses are in vehicles per hour and the O-D tables for non-buses are in persons per hour. The O-D tables for the non-buses are converted into vehicles by the use of vehicle occupancy data. SLICE also reads any revised ramp limits and modifies the ramp limit arrays. Now that all arrays are initialized, the actual simulation can begin.

3. Ramp Queueing

The subroutine RAMPQ is then called. This subroutine compares all on-ramp demands (computed in ODADD) with the on-ramp limits (which were initialized in CONTROL and possibly modified in SLICE). If the ramp demands exceed the ramp limits, then RAMPQ will reduce the O-D table appropriately and recompute the ramp demands. (Truncation errors may occur in this process since the O-D table is made of relatively small numbers.) The number of vehicles not allowed to enter are stored in the ramp queue and the ramp delay is computed.

If the on-ramp demand is less than the ramp limit, and there is no queue present from a previous time period, nothing further needs to be done. But if there already is a queue present, the ramp demand is increased either to the ramp limit or to the rate which would discharge the entire ramp queue in 1/4 hour, whichever is the smaller. Again, the ramp delay is computed.

4. Volume Calculations

After all the on-ramp demands have been compared with their ramp limits, all sections have two volumes computed by PRILANE (VNPR - Volume of non-priority vehicles - and VPRI - Volume of priority vehicles). PRILANE finds out how many priority sections there are and in which subsections they start and end.

If a priority lane starts in a given subsection, any vehicle that enters the freeway in that subsection or in downstream subsections, and any vehicle which will exit in a subsection where the priority section still exists are refused entry to the priority lanes and demoted to non-priority status for that priority study section. PRILANE will also compute the array POFF (I, J). POFF (I, 1) has for the I^{th} priority situation the number of vehicles entering the priority lane(s). POFF (I, 2) is the accompanying subsection number. POFF (I + 1, 1) equals the number of vehicles returning to the unreserved lanes of the freeway after the priority lane has ended.

5. Ramp Merging Analysis

There are seven subprograms which contribute to the ramp merging analysis. RMSUM is the first of the seven ramp programs and creates the arrays RVOL(J) and RDIS(J). RVOL(J) is the volume of the J^{th} ramp, counting both on- and off-ramps. If the J^{th} ramp is an off-ramp, then RVOL(J) will have a negative value. The existence of this array removes the need to locate a ramp by subsection number and then search for the next section containing a ramp.

The array RDIS(J) contains the distance from the beginning of the study section to the J^{th} ramp nose in feet. This array removes the need to add up lengths of subsections from one ramp to another. If the J^{th} ramp is a left-side ramp, RDIS(J) is made negative. Therefore, before RDIS(J) is used, it is tested for sign.

The second subprogram is UDRAMP. The purpose of UDRAMP is to search upstream and downstream from on-ramp RVOL(L) and locate those influencing ramps which are within 4,000 feet of it. The ramp numbers of those ramps which have influence on ramp L are stored in array LX for use by subprogram PVL. UDRAMP also checks for an auxiliary lane condition and uses the variable ITYP to indicate the presence of an auxiliary lane.

If no ramp numbers are entered into array LX, then subprogram PVL is not called, and ITRIG = 3 in PRIFRE after UDRAMP. But if LX has one or more entries, then subprogram PVL will compute the percentage of ramp traffic still in lane one at the merge point (or already in lane one if it is a downstream off-ramp). PVL also subtracts the ramp traffic from the total freeway traffic to obtain the value of the through traffic on the freeway at that point. The method of subprogram PVL is based on Fig. 8.24 of the Highway Capacity Manual.

After the ramp traffic in lane one is computed, subprogram IVP8 uses values from Table 8.3 of the Highway Capacity Manual to calculate VOL1, the total volume in lane one at the merge point, which is composed of ramp traffic and through traffic.

Next subprogram P823 is called; and if ITYP = 1 (no auxiliary lane), P823 does nothing. But if ITYP = 2, P823 will recompute the percentage of on-ramp traffic already in lane one under the auxiliary lane condition. Then it will add to VOL1 the percentage of off-ramp traffic at the merge point.

If VOL1 - volume in lane 1 - exceeds 2,000 vph under the assumptions of the model, a queue will form on the freeway, while all the ramp traffic is free to enter. This queue is assumed to have no physical length, but rather the cars are thought to be stored in a vertical queue. This is the simplest assumption to make in computing merge point delay. Subprogram MERGQ will compare VOL1 with 2,000 vph and increase the queue if necessary; or, if a queue was already present and VOL1 is less than 2,000 vph, decrease it.

An increase in the length of a merge point queue implies that some of the through traffic was not allowed to flow. This means that downstream subsections should reflect the existence of the queue by lower demands through them. The purpose of subprogram DISQ is to compute the destination pattern of the traffic in the queue (assumed to be the same as the pattern of through traffic at that point) and reduce the demand (VNPR(I)) of downstream subsections. If the merge queue is decreasing, the demand of downstream subsections will be increased according to the destination pattern. DISQ is also used in another part of the program to distribute the effect of queues caused by freeway capacity restraint. This completes the description of the ramp analysis subprograms.

6. Weaving Analysis

There are five subprograms which perform the calculations of the weaving effect for each subsection. The first, WEAVCON, is the calling routine for the other four.

The second one, TYPEWV searches from upstream to downstream for possible weaving sections of 8,000 feet and less and identifies them by type. There are three possible types: (1) simple weaving, on-off, ITY = 1; (2) multiple weaving, on-on-off, ITY = 2; and (3) multiple weaving, on-off-off, ITY = 3.

Next, the individual weaving movements are calculated in subprogram WVOL if ITY = 1 or 2 (or WVL3 if ITY = 3). The left hand ramp indicators are tested and the geometry of the weaving section is determined. For simple weaving sections, only two weaving movements are computed; for multiple weaving, four.

The last of the five weaving subprograms is WVEFF. This routine computes the total weaving volume and lengths of either simple or multiple weaving sections according to the method described in Chapter 7 of the Highway Capacity Manual. Then, using data from Fig. 7.4 of the Manual, the weaving influence factors are determined and combined with the weaving volumes to yield the total weaving effect, the reduction in capacity due to weaving, in vehicles per hour. These values are stored in EFF(I) for subsection I. Program control is then returned to TYPEWV via WEAVCON, and the next weaving section found.

Again, it is emphasized that no weaving calculations are performed for entrance into or exit from a priority lane(s). This is so because no accurate weaving formula could be found which takes into account the many variables associated with the many different priority weaving situations.

When all weaving sections have been calculated, WEAVCON returns control to PRIFRE.

7. Queueing Subprograms

Up to this point, the only changes made to the subsection demands were in DISQ in the case of a merge point queue. A check must now be made in each subsection, however, to see if the demand exceeds the effective capacity (input subsection capacity minus weaving effect), and appropriate action taken if it does. This is the task of QUEUP and DISQ. After subsection demands are limited to their capacities, the queues will increase, decrease, or remain unchanged. Queues may collide or they may split. All of these possibilities, along with travel time and travel distance calculations, are handled in subprograms TRAVEL, TAILQ, QTIME, and QCOLL.

Subprogram QUEUP begins by finding IO and ID, the origin and destination ramp indicators for subsection I to be used by DISQ in case a queue is present. Then RA(I-1) is set to zero to clear out any values left over from the previous time interval. CN, a possible value of RA(I-1), is computed by subtracting the effective capacity from the demand in subsection I. If CN is positive, then a queue must grow from the junction between subsections I and I-1. Since subsection I is the bottleneck, it will operate at capacity and under nonqueueing conditions, while subsection I-1 will operate below capacity and encounter queueing conditions. (There are special conditions, such as a more restricted downstream bottleneck, which will allow the bottleneck subsection to operate with queueing such as in the case of a queue split.) So, if CN is positive, this value is put into RA(I-1) and QUEUP returns to PRIFRE, which calls DISQ to distribute the effect of CN to downstream subsections. Then PRIFRE calls QUEUP again and processing continues downstream.

If QUEUP computes CN and finds it to be negative, the procedure is more complicated. If a queue is not present in subsection I-1, there is no problem for QUEUP. But if subsection I has a queue over its entire length, a queue in I-1 cannot be discharged, so RA(I-1) is not changed. If a queue in I-1 can be discharged, another check is made to see if the value of CN added to the demand would make the total demand exceed the effective capacity of I-1. If this is true, then subsection I-1 becomes the bottleneck subsection operating under queueing conditions, with the value of CN chosen so that the resultant volume equals capacity.

Assume that it has been determined that a queue is going to be discharged at rate CN. There are still two additional situations to be considered before RA(I-1) can be set equal to CN: (1) queue split and (2) a short queue.

A queue split occurs when one subsection containing part of the queue cannot provide the necessary rate of flow to satisfy the demand volume in the downstream subsection by the amount CN. The queue-split condition can happen only at the beginning of a time slice, since demand is a constant within each time slice. When a queue split is found, the subsection pointer I is set equal to the subsection following the new bottleneck, a message is punched, and the queue in subsection I is reduced by a small distance (.0002 miles) so that QUEUP can now recognize two distinct queues. Processing then continues in QUEUP on the upstream queue first.

The problem of the short queue arises from a basic assumption of the freeway priority lane model which says that demand is constant over any time slice. Therefore, a short queue might be dispersed completely in, say, .01 hours; however, the bottleneck subsection would still have to operate at capacity for the full .25 hours. This means that vehicles would be fictitiously generated for .24 hours at the rate RA(I-1), which can be quite large. The procedure developed to overcome this problem is to estimate the excess number of vehicles stored upstream of the bottleneck by using the differences in vehicle density between queueing and nonqueueing conditions. For each subsection, the difference in density is multiplied by the length of the subsection and a running total of vehicles is kept. Since there is only an estimate, however, there is no guarantee that the queue length will be exactly zero at the end of .25 hours. Therefore, when this condition occurs, the subsection number is stored; and if a queue still remains at the end of .25 hours, it is cleared and a message is printed giving the length of queue cleared. If the queue disperses before .25 hours, a message is printed giving the time it dispersed.

After QUEUP and DISQ have computed the new values of VNPR(I) and RA(I), PRIFRE calls TRAVEL which will control the evolution of queues by stepping from downstream to upstream subsection and testing the value of RA(I). Under nonqueueing conditions, RA(I) is zero, so TRAVEL calculates the travel time (veh-hrs.) and the travel distance (veh-mi.) for subsection I, reduces the value of I by one, and then returns to test RA(I) again.

If RA(I) is found to be negative, TRAVEL will call TAILQ and then QTIME. TAILQ does nothing concerning a change in queue length; its primary function is to find the upstream boundary of the queue. Also, TAILQ solves for travel time and travel distance for all subsections which are fully congested on the assumption that they will remain fully congested for the entire time interval.

Subprogram QTIME operates from upstream to downstream, just the opposite of TRAVEL and QCOLL. Also, QTIME has the unique property of having a variable time interval.

First, QTIME checks for the upstream boundary of the queue in subsection 1, and, if the first subsection is completely filled by a queue, it will discharge the queue from RQ(1,1), the main on-ramp queue, either until RQ(1,1) = 0, or until the time equals the value stored in SS, the length of time interval in QTIME. SS will usually contain the value .25(1/4 hour). If, however, subprogram QCOLL has found a queue collision with this decreasing queue, SS will contain the time of queue collision.

Next, QTIME computes the shock-wave velocity of the upstream boundary of the queue based on the value of RA(I) and the differences of density between nonqueueing and queueing conditions. It then recomputes the travel time and travel distance based upon the queue dynamics, and this value replaces the calculation done by TAILQ for subsection I. When the time reaches SS, or when the queue length reaches zero, QTIME will not perform any travel time calculations beyond the subsection being processed. The last step is a check on the subsection number to see if QUEUP had set a pointer to this subsection to indicate a queue which should have been completely depleted. QTIME then returns control to TRAVEL which continues processing with the subsection upstream of the one in which the upstream boundary of the queue originally fell.

If TRAVEL finds that RA(I) is positive, it will call subprogram QCOLL. QCOLL will then compute the shock wave velocity of the queue and the time that the queue leaves subsection I and enters subsection I-1. If the time is greater than .25 hours, this means that the tail of the queue does not leave subsection I, so the time is set to .25 and I will be the last subsection to be processed by QCOLL. If, however, the upstream boundary of the queue leaves subsection I, and if subsection I-1 already has a queue, then a queue collision occurs and a message is printed. If the second queue has a positive value of RA(I-1), then QCOLL can handle the calculations alone. But if RA(I-1) is negative, QCOLL will first set SS(the length of time interval in QTIME) to the time of queue collision and then call TAILQ and QTIME. The reason for this procedure is to have the queue behave according to the basic assumptions as closely as possible. If this were not done, the second queue would not, at the time of queue collision, have had a chance to decrease from time zero to time SS. After TAILQ and QTIME have reduced the queue, the new value of RA(I-1) may be positive or negative, depending on the relative values of RA(I) and RA(I-1) before collision. If the result is a positive RA, QCOLL continues processing in subsection I-1. But if the new RA(I-1) is negative, SS will be set to the remainder of the time, .25 - SS, and QCOLL will return control to TRAVEL, which will call TAILQ and QTIME again.

When the resultant RA(I-1) is positive and greater than RA(I), QCOLL allows for the growth of the second queue by recomputing the value of the time of the queue collision. The collision time is reduced by multiplying by the factor

$$1 - \frac{RA(I-1)}{RA(I) + RA(I-1)} .$$

This factor was determined so that the length of the second queue would be the same at the end of .25 hours after queue collision as it would have been if it had grown at the old rate RA(I-1) until the time of queue collision and then at the new rate of RA(I-1) for the remainder of the time slice. This is based on the simplifying assumption that the shock wave velocity of the queue is a linear function of RA. QCOLL then continues to compute the times that the queue enters upstream subsections. When the time exceeds .25, QCOLL, without processing any more subsections, returns control to TRAVEL.

When all subsections have been processed, control is returned to PRIFRE.

8. Speed Flow/Capacity Curves

Throughout the above queueing routines, whenever the density or travel time is required, the function SPEED is called to compute them. The parameters to SPEED are the section number, the volume/capacity ratio, and IFLAG. As will be mentioned under the input card setup, each subsection has three design speeds: one for normal lane operation, one for reserved lane operation, and one for unreserved lane operation. The value of IFLAG tells SPEED which design speed to use for each subsection when it is called. If the value of design speed, DS, is a number 1-5, then SPEED knows that it must look for and interpolate user supplied speed curves.

For the user-supplied speed-volume/capacity coordinates a straight linear interpolation is performed, and this necessitates the user supplying average speed values for at least four points for the v/c ratios of 0,1, -1, -0.0. The values for 1 and -1.0 may be the same, but there must be two entries on the speed flow cards. The speeds for the negative ratios correspond to the speed during queueing (see Fig. 3). Also available to the user are the design speeds of 50, 60, and 70 mph from Fig. 9-1 of the Highway Capacity Manual and the ITTE specially developed 65 mph curve for the I-80 Eastshore Freeway. If the program has trouble finding the user supplied curves or the necessary values are not found, a message is printed and the design speed is set to 70 mph.

9. Output

The preceding subroutines have calculated the travel times and queue lengths for all normal lanes and unreserved lanes. The subroutine OUTIT is now called to compute the travel time for the priority lanes and outputs the information to the user. OUTIT will print a summary table whose format depends on the freeway operation scheme selected. Each summary table contains the final on- and off-ramp demands as calculated by PRIFRE and a list of what the total volumes would have been if there had been no queueing. In this manner the user can compare the number of vehicles that actually traversed the section to the number of vehicles that desired to traversed the distance and calculate the number of vehicles stored through freeway capacity restraints.

Then, the demand volume of each subsection is reduced by the value of RA for that subsection, and if RA exceeds the volume, a warning message is printed. If a queue is present in any subsection, a star is printed for that subsection so that queues are visually more apparent. Also, the average speed, travel time, and density are computed for each subsection. A warning message is also printed if the demand exceeds the capacity of any priority lane, and states the number of vehicles demoted to non-priority status.

After the summary table is printed, OUTIT then checks all of the on-ramp delays and prints any non-zero on-ramp delay with the associated queue lengths, OUTIT then returns control to PRIFRE.

PRIFRE then calls TIMEOUT which first checks for excess off-ramp demand and prints the offending off-ramp number and capacity. The actual volume can be read off the summary table. Then, depending on a non-zero value of FAC(2), TIMEOUT prints two OD type tables giving single-trip times for priority and non-priority vehicles. TIMEOUT also sums the ramp delays, subsection travel times, and subsection travel distances, and computes the passenger hours and cumulative values and prints these values for priority and non-priority vehicles. If there are no priority lanes, then the table corresponding to the priority situation is deleted. TIMEOUT then returns to PRIFRE which calls CONTROL and the next iteration proceeds. See Sample Output in Appendix E. See Sample Input in Appendix D.

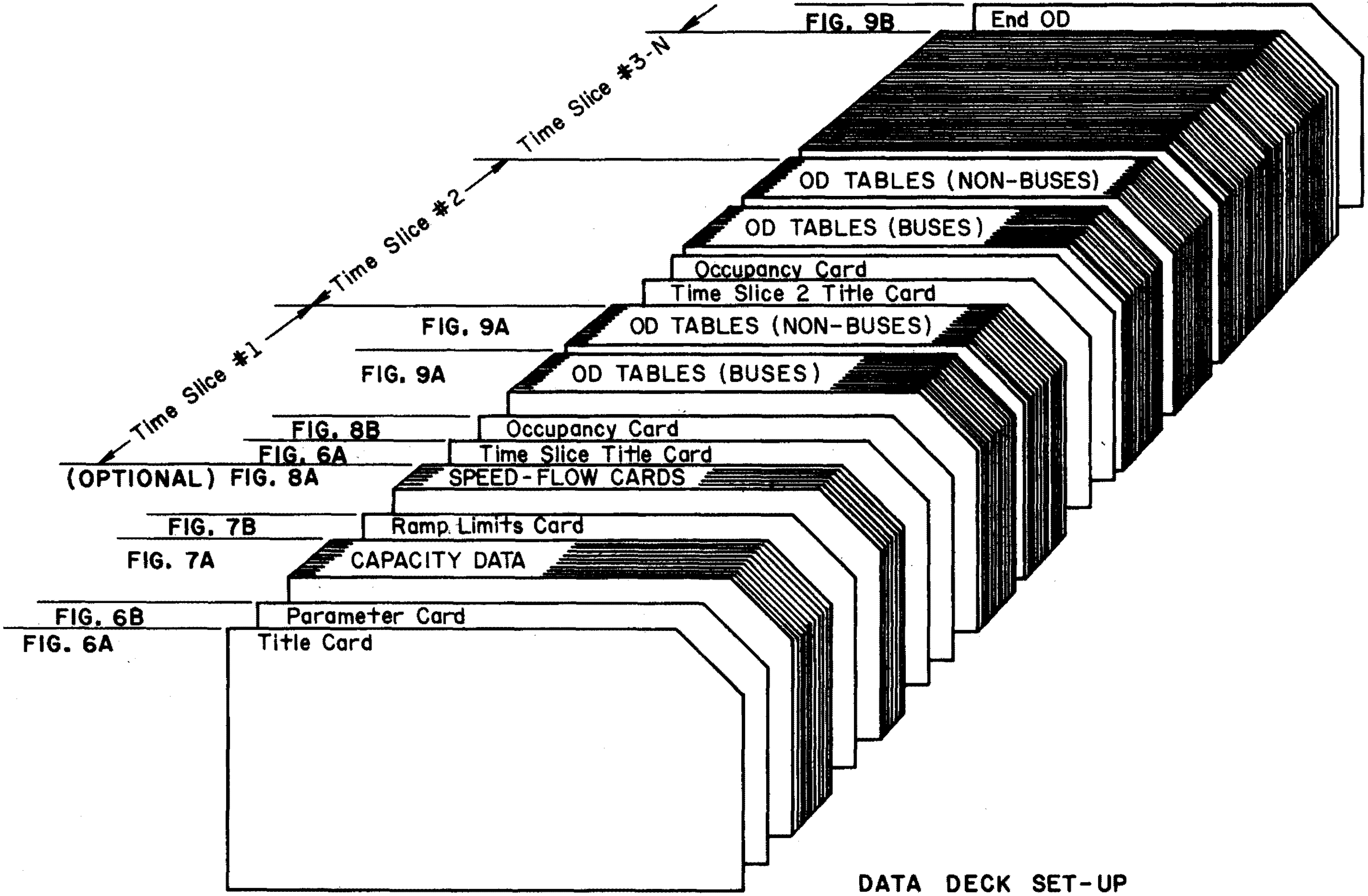
B. Input Data Formats (See Appendix D)

The cards required to constitute a complete run on the CDC 6400 are naturally divided into three categories: (1) system control cards, (2) object deck, and (3) input data. If the object deck were loaded via tape, for instance, then a complete run would be a deck of two parts plus one tape. Also, every computer system requires a different set of control cards. Appendix D deals exclusively with the formats needed to specify input data. Also an example of CDC 6400 control cards will be found in Appendix B.

Figure 5 shows an input data deck set-up which would constitute a complete run: that is, one set of input parameters and capacity data, followed by a number of O-D data decks. The seven card formats which are acceptable to the priority lane model are shown below:

1. Title Card

Figure 6(a) shows the title card format. This card may have



DATA DECK SET-UP

Figure 5

Identification and Description of the Freeway Section being studied, priority strategy selected, occupancy shifts, etc.

Card Columns	Contents	Format
1–80	ANY ALPHANUMERIC DATA	8A10

(a.) TITLE CARD

Description	Variable	Card Columns	Example	Format
Number of Sections	NSEC	1–4	28	I4
Number of Time Slices per hour	FAC(1)	5–9	4.	F5.0
Selection of Output Format	FAC(2)	10–14	2.	F5.0
Minimum Occupancy for Pri. Status	PLC	15–19	2.	F5.0
Frwy. Scheme Selector	IOP	20–21	6	I2
Number of Growth Periods	NGP	22–26	1	I5
Growth Factor	GF	27–31	1.07	F5.2
No. of Occ. Shifts	IOCS	32–34	1	I3
Bus Equiv. Factor Normal Lns	EBN	35–39	2.00	F5.2
Bus Equiv. Factor Priority Lns	EBL	40–44	1.60	F5.2
		45–80		

(b.) PARAMETER CARD

Figure 6

any valid keypunch characters anywhere on the card. The purpose of this card is to provide the user with a description of the data, which will appear on the printed output unaltered. The title card must occur as the first card of the data set.

2. Parameter Card

Figure 6(b) shows how the parameter card must be prepared. This card does not appear on the printed output unaltered, as the title card did. NSEC is the number of subsections (50 maximum allowed) and must be exactly equal to the number of capacity cards for the run. FAC(1) is the number of time slices per hour. At ITTE, O-D tables were prepared on a 15-minute time basis, so FAC(1) = 4. These two parameters are the only ones on this card which must not be left blank.

FAC(2) is an output control parameter. If FAC(2) = 0, only the summary table for the subsections will be punched. FAC(2) = 1 will additionally cause single trip travel times in an O-D table format to be printed. If FAC(2) = 2, the original O-D tables will be printed also.

PLC is the minimum vehicle occupancy level at which priority status commences (e.g., if PLC = 2, all vehicles with 2 or more occupants have priority status). The case of PLC = 6 corresponds to bus-only priority status.

IOP is the freeway operations scheme selector. The values of IOP are:

IOP = 0	= normal operation only	(1 option)
1	= 1 priority lane only	(1 option)

2 = 2 priority lanes only (1 option)

3 = normal and 1 priority lane (2 options)

4 = normal and 2 priority lanes (2 options)

5 = 1 priority lane and 2 priority lanes (2 options)

6 = normal, 1 priority lane and 2 priority lanes (3 options)

NGP is the number of growth periods and may be any decimal integer, including zero (blank). NGP = 1 means that there is one growth period. GF is the growth factor by which each entry in the O-D tables is multiplied for successive growth periods, and it should be greater than one. (All O-D tables are assumed to grow uniformly at the same rate.)

IOCS is the number of occupancy sets considered, and may range from 0 (blank) to 5. The numbers 1, 0, or blank are all treated the same. If IOCS is greater than 1, there must be a corresponding number of occupancy distribution cards in each time slice card set-up. The user must supply the data for each occupancy shift on the occupancy distribution card which is discussed in a following section.

Bus equivalency factors (EBN and EBL) are introduced to allow the user to modify the effect of buses on traffic and capacity by multiplying by a car-equivalency factor. EBN is an equivalency factor for buses in normal, mixed traffic, while EBL is an equivalency factor for buses in priority lanes. If the user does not supply any values, the program automatically adopts EBN = 2.0 and EBL = 1.6 equivalent vehicles.

3. Capacity Card

The capacity card is shown in Fig. 7(a). Due to storage constraints a maximum of 50 subsections are allowed. The first field, SUB SECT, is the section number. If IP = P this section can have a priority lane(s) and if IP = b̸ (blank), this section is always a "normal" section (i.e., no priority lane). NLANE = number of lanes. If there is an auxiliary lane, the value of NLANE should be one greater than the number of through lanes, and subprogram UDRAMP will automatically detect the auxiliary lane. CAPACITY = capacity of this section (precalculated); and PRI-CAP, the capacity for each priority lane = 1,500 vehicles per lane if left blank. Capacity is for one direction (one side) of the freeway only; also there must be no fewer than 2 unreserved lanes in each direction of the freeway at all times.

In a priority lane situation, the capacity of the unreserved lanes will now have a capacity equal to ((NLANE-NPL)/NLANE) * CAPACITY vehicles per hour. NPL is the number of priority lanes adopted for this section. XLENGF is length of subsection in feet. The next three fields are design speeds. NOR = design speed if this is a "normal" section (IP = b̸ blank). RES and UNR refer to design speeds for reserved and unreserved lanes, respectively, and (IP = P). These three fields must contain either the design speed of 50, 60, 65, or 70 mph or the number of a user speed curve. If any design speed field has a value of 1 - 5, special speed-flow data supplied by the user is substituted for HCM data and inserted after the ramp cards. TRK FAC is only used to calculate the bus and truck

No. of Sub.Sec.	Pri. Sec.?	No. of Lns	Capacity of Normal Roadway	Capacity of each Pri. Lane	Length of of Section	Design Speeds Normal, Unreserved, Reserved Lanes			Truck Factor for Weaving		Identify Ramps in Section			Section name Identification
SUB SEC	IP	NLANE	CAPACITY	PRI-CAP	XLENGF	NOR	UNR	RES	TRK FAC		O	D	SP	DESCRIPTION
1 2 3	4	5 6	7 8 9 10 11	12 13 14 15 16	17 18 19 20 21	22 23 24	25 26 27	28 29 30	31 32 33 34 35	36 37	38	39	40	41 42 43 … 77 78 79 80
5	P	4	6000	1450	3000	65	65	1	.95		O	D	I	DESCRIP
I3	AI	I2	F5.0	F5.0	F5.0	I3	I3	I3	F5.3	2X	AI	AI	II	4A10

(a.) CAPACITY CARD

General	Special Ramp Limits										
	OFF-RAMPS						ON-RAMPS				
RMP LMT	I1	LMT 1	I2	LMT 2	I3	LMT 3	I4	LMT 4		LMT 9	
1 2 3 4 5 6	7 8 9	10 11 12 13 14	15 16 17	18 19 20 21 22	23 24 25	26 27 28 29 30	31 32 33	34 35 36 37 38	39 … 72 73	74 75 76 77 78	79 80
1500	3	4000	6	1200	12	1800	8	2000			
F6.0	I3	F5.0	I3	F5.0	I3	F5.0	I3	F5.0		F5.0	

(b.) RAMP LIMITS CARD

Figure 7

effect on capacity due to weaving losses. The truck factor is computed using the percent trucks, percent grade, and length of grade according to Table 9.5 of the Highway Capacity Manual.

Next the origin and destination indicators are coded. If the subsection has an on-ramp, an O should be punched in column 38 of the capacity card. If it has an off-ramp, a D should be punched in column 39. If a subsection has a special ramp (two-lane on-ramp or left-hand on- or off ramp), there can be only one ramp in that subsection, because the special ramp indicator applies to the whole subsection and not to a particular ramp. The coding of SP should be a one in column 40 if the ramp is a left-hand ramp, or a 2 in column 40 if it is a two-lane on-ramp. If the subsection has no special ramp, then this data field should be left blank.

The remainder of the parameter card can be used for any descriptive information which the user would like to have appear on the printed output, such as section names, key ramp names, etc.

4. Ramp Limits Card

In order to test queueing at on-ramps and off-ramps caused by ramp demands exceeding ramp capacities, PRIFRE can assign up to six on-ramp limits and three off-ramp limits which are different from the general ramp limit. Figure 7(b) shows the format of the ramp limits card. The first data field of six columns contains the general ramp limit; this value is assigned to every ramp, both on and off, except for those listed in the remaining fields on this card, or those additional fields listed on the first occupancy card.

The remainder of the card indicates the exceptions to this value in the following way. The first three columns indicate which off-ramp (counting only off-ramps) is to have the ramp limit replaced; the next five columns are for the ramp limits. The first three sets of eight-column fields pertain to off-ramps and the remaining six sets pertain to on-ramps.

5. Speed-Flow/Capacity Card

This card(s) is for user designed speed-flow/capacity data (see Fig. 8(a)). The first field (NCRV) is the curve number (1-5). The remainder of the card consists of at least four X(V/C ratio) values and corresponding Y (average speed, mph) values. There is an upper limit of 20 points (five cards) per curve with a minimum of 2 points for the upper and 2 points for the lower parts of the curve (Upper curve for non-queueing and lower curve for queueing), as mentioned in Section 3-A-8. If the user inserts any speed-flow/capacity coordinates, a blank card must follow the last speed-flow/capacity card. If no user-supplied data are to be used, then the ramp limits card should be immediately followed by the first time slice card.

6. Time Slice Data - Title Card

The time slice title card follows the same format as the main title card (Fig. 6(a)); however, the card may not have the word END within the first four columns. For example, this card could be coded, "Exclusive Bus Lane - Marin - US 101. Northbound, PM Peak. Time Slice 1, 3:30".

NO. OF CURVE	USER SUPPLIED DATA: V/C RATIO	AVERAGE SPEED						
NCRV	X_1	Y_1	X_2	Y_2	X_3	Y_3	X_4	
1–4	5–11	12–18	19–25	26–32	33–39	40–41	47–53	79–80
1	0.0	70.0	.50	45.0	1.00		-1.00	
I4	F7.0	F7.0	F7.0	F7.0	F7.0		F7.0	

(a.) SPEED-FLOW/CAPACITY CARD(S)

BUS OCC.	CAR OCCUPANCIES					ADDITIONAL SPECIAL RAMP LIMITS				
BUS OCC.	% 1	% 2	% 3	% 4	% 5	I1	LMT 1	I2	LMT 2	. . .
1–5	6–10	11–15	16–20	21–25	26–30	31–33	34–38	39–41	42–4	8, 79, 80
51.	70.	20.	5.0	3.0	2.0	6	2000.	7	16	
F5.0	F5.1	F5.1	F5.1	F5.1	F5.1	I3	F5.0	I3	F5.0	

(b.) OCCUPANCY CARD

Figure 8

7. Occupancy Card

Figure 8(b) shows the format of the occupancy card. BUS OCC is the average passenger occupancy of buses. The number of bus passengers therefore is equal to total number of buses from the bus O-D tables for this time period times this factor. The next five fields are for the distribution of the passenger occupancies for the non-bus O-D table. If the total of the percentages from the five fields is more or less than 100%, the run is aborted.

There are also 5 sets of ramp limit fields for revision or addition of on-ramp limits on the first occupancy card. These are exactly the same as the ramp limits cards, except no revised off-ramp limits are allowed. The need for including revised on-ramp limits was found if the capacity of a ramp varies over time, and for use in developing ramp control strategies.

8. Origin-Destination Card

As mentioned previously, there are two distinct O-D tables per time slice. The O-D table for buses (in vehicles per hour) must be placed first, and must be followed by the O-D table for non-buses (in persons per hour). Inputs are always in hourly flow rates for each 15-minute time interval. If there are no demands for a particular origin, a blank card must be placed in the deck, as the program requires an O-D card for each input station (origin or on-ramp) to maintain proper sequence.

The O-D table is prepared according to the format shown in Fig. 9(a). This card shows the number of trips from input station (on-ramp) number one to all following output stations (off-ramps).

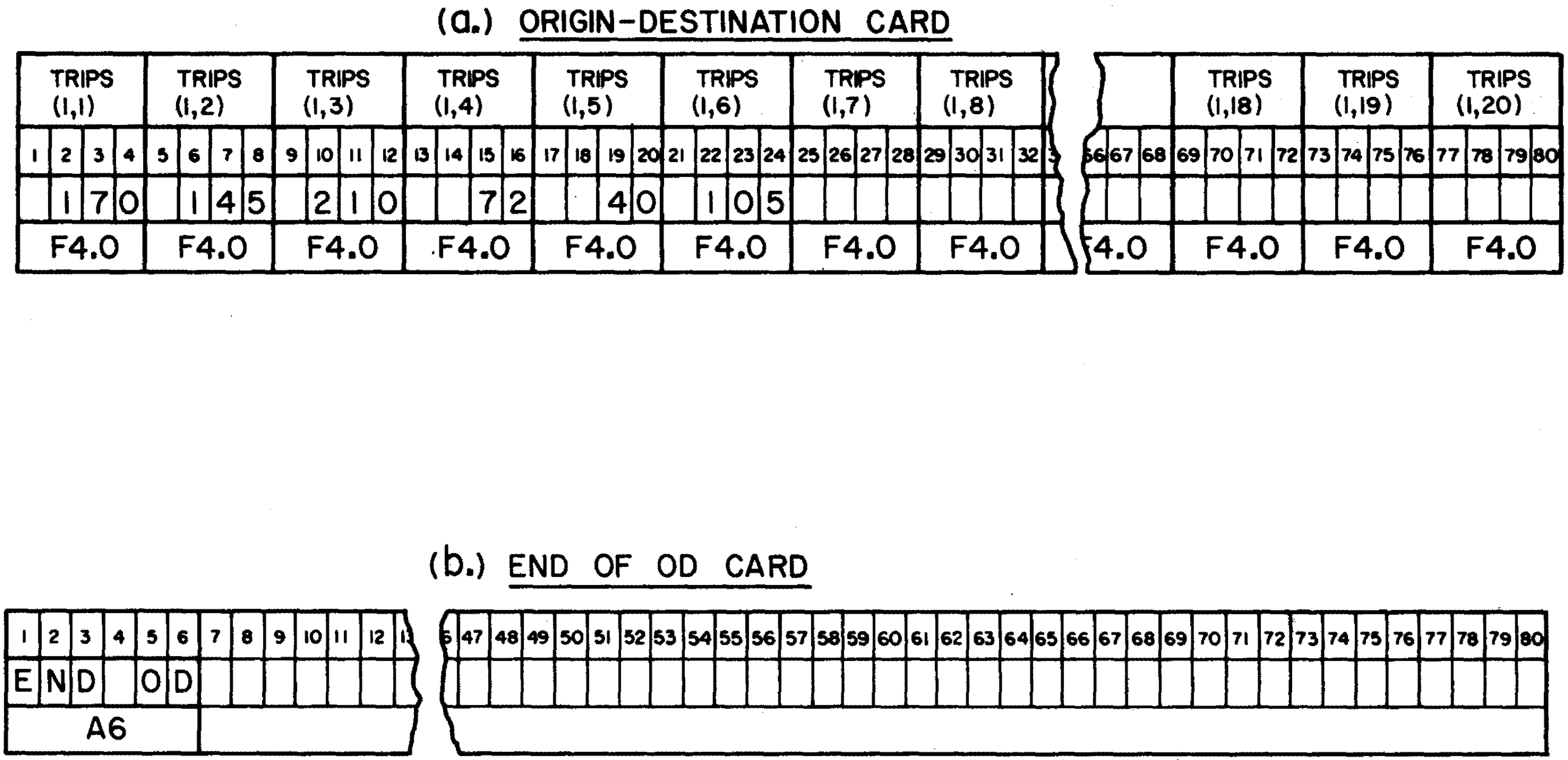

(a.) ORIGIN-DESTINATION CARD
TRIPS (1,1)
TRIPS (1,2)
TRIPS (1,3)
TRIPS (1,4)
TRIPS (1,5)
TRIPS (1,6)
TRIPS (1,7)
TRIPS (1,8)
TRIPS (1,18)
TRIPS (1,19)
TRIPS (1,20)
170
145
210
72
40
105
F4.0
(b.) END OF OD CARD
END OD
A6

Figure 9

The second card of the O-D table would have the number of trips from on-ramp number two to all following off-ramps, etc. There are exactly as many cards in the O-D table as there are on-ramps, including the mainline freeway input. Most study sections will have roughly triangular O-D tables, the on-ramps normally alternating with the off-ramps.

9. End of O-D Card

Figure 9(b) shows the form of the card to be used after the last O-D table; READIT will know that all the time slices have been read and the simulation can begin.

C. Output Data (For example, see Appendix E)

The output from PRIFRE falls into four groups: (1) a listing of input data, (2) messages concerning the queues, (3) summary table of numerical results, and (4) travel times.

1. Listing of Input Data

The first line of output is always the title card which is the first card of the data deck. This card is reproduced without change. The second line of output is always a description of the data contained on the parameter card.

A column heading for the subsection capacity cards is then punched, followed by all of the subsection capacity cards essentially unchanged. Also, at this point if READIT detects an error in freeway design, a message on the nature of the error will be printed and the execution will halt. After the capacity data, the ramp limits are punched, followed by a page skip to begin the output for the first time slice.

The first line of output of each time slice is the time slice title card description, followed by the occupancy and the revised on-ramp limits, if there are any. At this point, if FAC(2) was set equal to 2, the next output would be the original O-D tables input. If FAC(2) was set equal to 0 or 1, there would be no O-D tables, and the next possible output would be information about the queues.

2. Queue Messages

There are four possible messages pertaining to queues occuring in the current time slice. A message such as "QUEUE COLLISION 6 T2 = .106" is initiated in the QCOLL subprogram. The number 6 means that the queue in subsection 6 was growing and left the subsection at time T2 = .106 of an hour after the current time slice began. In subsection 5 another queue already existed and this caused a queue collision. [If the value of RA(I) is positive in subsection 5, then the time is reset to a value earlier than .106 of an hour before analyzing subsection 5. If the resultant RA of subsection 5 is positive, but smaller than RA of 6, then QCOLL would have called TAILQ and QTIME with SS = .106, as described in the section on program operation with the remainder of the analysis of the upstream subsections being done in QCOLL. If the new value of RA is negative at subsection 5, then QCOLL would have called TAILQ and QTIME would have tested RA(5) after the queue collision, would have set the value of SS = .25 - T2, and then would have returned control to TRAVEL. From TRAVEL, TAILQ and QTIME would have let the discharging queue run out for the remainder of the time interval.]

The next queue message could be "QUEUE SPLIT 7". This message is printed from subprogram QUEUP. It means that, in what was one queue, an additional capacity restraint forced a division into two queues. Since this always happens at the beginning of a time slice, there is no special problem for TAILQ and QTIME. The number 7 means that subsection 7 was not able to carry the sum of demand vehicles plus discharging vehicles. Therefore, subsection 7 cannot discharge the queue, and at the same time it becomes the bottleneck of the new queue.

The other two types of queueing messages pertain to the conditions where the queue is in the final time slice of a decreasing queue situation. As mentioned in the program description, because demand cannot change during one time interval, the negative value of RA during the final time slice must be adjusted so that the queue length will reach zero as close to the end of the time slice (.25 hours) as possible. Therefore, there are two possibilities: (1) the queue length can reach zero before .25 hours, or (2) the queue will still remain after .25 hours have elapsed.

The message "SEC 12 T2 = .231" means that the queue length reached zero at .231 hours. For the remainder of the time interval, vehicles continued to be discharged. The other message is "SEC 12 CLEAR 153." In this case, after .25 hours, there still remained 153 feet of queue, which was simply cleared. In both of these cases the v/c ratio of the bottleneck subsection is less than one, and these should be only conditions under which the bottleneck subsection operates with v/c different from one.

3. Summary Table of Numerical Results

The remaining output conveys the calculated results to the user. In the case where there are no priority lanes, a column heading is printed for the subsection summary table which consists of 15 or 24 columns. (Fig. 10A shows the normal operations output, and Fig. 10B the output under priority operations.)

The first column is the subsection number. The second, third, and fourth columns give the final on-ramp, final off-ramp, and original subsection demands in vehicles per hour. The fifth column gives the volume of traffic leaving each subsection during the time interval. Next, column six, is the effective freeway capacity (after subtracting the weaving effect), and the weaving effect is given in column seven in vehicles per hour. Then, in column eight, the v/c value of the subsection is listed, followed by the density (vehicles per mile per lane) and the time average speed (mph). Column eleven contains either an asterisk, if a queue is present in the subsection, or a blank, if no queue is present. Occasionally, a column of asterisks signifying a queue may actually be two or more queues, since each subsection must be completely queued in order to be one continuous queue. Therefore, if one column of asterisks represents two queues, then one of the subsections will show a queue length which is less than the subsection length.

Column twelve gives the average individual travel time through each subsection in minutes. Column thirteen gives the length of the subsection in feet, followed by the queue length in feet. The last

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SUB SEC	FINAL ORG	DEMAND DES	ORIG. TOTAL	VOL	FWRY CAP	WEAVE EFF	V/C	DENS V/M/L	MPH		TRAV TIME	LENG	QUEUE FEET	RA
1	5966.	0.	5966	5966.	10000.	0.	.60	39.	38.		.06	200.	0	0.
2	0.	0.	5966	5966.	7200.	0.	.83	32.	47.		.10	400.	0	0.
3	0.	0.	5966	5824.	7200.	0.	.81	33.	44.	*	1.42	5400.	731	142.
4	0.	0.	5966	5824.	6890.	0.	.85	63.	23.	*	.30	600.	600	142.
5	0.	0.	5966	5824.	6751.	0.	.86	67.	22.	*	.16	300.	300	142.
6	0.	194.	5966	5824.	6752.	0.	.86	67.	22.	*	.31	600.	600	142.
7	0.	0.	5772	5630.	6500.	0.	.87	64.	22.	*	.31	600.	600	142.
8	40.	0.	5812	5670.	6500.	0.	.87	64.	22.	*	1.54	3000.	3000	142.
9	0.	0.	5812	5670.	6400.	0.	.89	63.	23.	*	.53	1050.	1050	142.
10	0.	491.	5812	5670.	6500.	0.	.87	64.	22.	*	.82	1600.	1600	142.
11	0.	0.	5321	5179.	6961.	0.	.74	72.	18.	*	1.47	2320.	2320	142.
12	291.	19.	5612	5470.	5470.	0.	1.00	61.	30.		.95	2500.	0	0.
13	0.	0.	5592	5451.	5470.	0.	1.00	61.	30.		.21	550.	0	0.
14	0.	63.	5592	5451.	5470.	0.	1.00	61.	30.		1.84	4850.	0	0.
15	0.	0.	5528	5388.	5470.	0.	.98	55.	32.		.46	1300.	0	0.
16	511.	831.	6039	5809.	6560.	910.	.89	42.	46.		.25	1000.	0	0.
17	0.	0.	5175	4979.	5470.	0.	.91	37.	44.		.36	1400.	0	0.
18	180.	379.	5355	5159.	5470.	0.	.94	44.	39.		.87	3000.	0	0.
19	0.	0.	4963	4780.	5820.	0.	.82	34.	47.		.19	800.	0	0.
20	120.	4900.	5083	4900.	5820.	0.	.84	35.	47.		.88	3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	190.50	44.85
		TOTAL	190.50	44.85

FIGURE 10A- SAMPLE PRIFRE SUBROUTINE OUTPUT FOR NORMAL FREEWAY OPERATIONS

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QUEUE COLLISION 9 T2= .000
QUEUE COLLISION 8 T2= .000
QUEUE COLLISION 7 T2= .000
QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF SEC 1

				RESERVED PRIORITY OPERATIONS							UNRESERVED OR NORMAL OPERATIONS												
SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	5303.	0.	5303								N	4	2559.	10000.	0.	.26	29.	22.	.10	*	200.	200	2744.
2	0	0.	5303	2	1158	3000.	.39	14.	42.	.11	U	2	1400.	3600.	0.	.39	32.	22.	.21	*	400.	400	2200.
3	0.	0.	5303	2	1158.	3000.	.39	11.	51.	1.20	U	2	1400.	3600.	0.	.39	110.	6.	9.61	*	5400.	5400	2200.
4	0.	0.	5303	2	1158.	3000.	.39	11.	51.	.13	U	2	1400.	3445.	0.	.41	101.	7.	.98	*	600.	600	2045.
5	0.	0.	5303	2	1158.	3000.	.39	11.	51.	.07	U	2	1400.	3375.	0.	.41	97.	7.	.47	*	300.	300	1976.
6	0.	119.	5303	2	1158.	3000.	.39	11.	51.	.13	U	2	1400.	3376.	0.	.41	97.	7.	.94	*	600.	600	1976.
7	0.	0.	5164	2	1158.	3000.	.39	11.	51.	.13	U	2	1281.	3250.	0.	.39	98.	7.	1.04	*	600.	600	1969.
8	136.	0.	5300	2	1158.	3000.	.39	11.	51.	.67	U	2	1417.	3250.	0.	.44	89.	8.	4.30	*	3000.	3000	1833.
9	0.	0.	5300	2	1158.	3000.	.39	11.	51.	.23	U	2	1417.	3200.	0.	.44	87.	8.	1.47	*	1050.	1050	1783.
10	0.	98.	5300	2	1158.	3000.	.39	11.	51.	.36	U	2	1417.	3250.	0.	.44	89.	8.	2.30	*	1600.	1600	1783.
11	0.	0.	5180	2	1158.	3000.	.39	11.	51.	.52	U	2	1319.	3480.	0.	.38	109.	6.	4.35	*	2320.	2320	1783.
12	39.	33.	5219	2	1158.	3000.	.39	11.	51.	.56	U	2	1358.	3647.	0.	.37	116.	6.	4.86	*	2500.	2500	1783.
13	0	0.	5180	2	1158.	3000.	.39	11.	51.	.12	U	2	1325.	3647.	0.	.36	119.	6.	1.12	*	550.	550	1783.
14	6.	85.	5186	2	1158.	3000.	.39	11.	51.	1.08	U	2	1331.	3647.	0.	.36	119.	6.	9.82	*	4850.	4850	1783.
15	0.	0.	5086	2	1158.	3000.	.39	11.	51.	.29	U	2	1246.	3647.	0.	.34	128.	5.	3.04	*	1300.	1300	1783.
16	626.	327.	5712	2	1158.	3000.	.39	11.	51.	.22	U	1	1294.	1294.	1196.	1.00	43.	30.	.38		1000.	0	0.
17	0.	0.	4860	2	1158.	3000.	.39	11.	51.	.31	U	2	967.	3647.	0.	.27	9.	52.	.30		1400.	0	0.
18	198.	140.	5058								N	4	2325.	7294.	0.	.32	11.	52.	.66		3000.	0	0.
19	0.	0.	4751								N	3	2184.	5820.	0.	.38	14.	51.	.18		800.	0	0.
20	779.	2963.	5530								N	3	2963.	5820.	0.	.51	20.	50.	.82		3600.	0	0.

↑ Subsection number
↑ Adjusted on-ramp volume (equiv.-veh)
↑ Adjusted off-ramp volume (equiv.-veh)
↑ Original demands assuming normal operations (equiv.-veh)
↑ Number of priority lanes
↑ Priority lane volume (equiv.-veh)
↑ Reserved priority lane capacity
↑ v/c for reserved lane
↑ Density
↑ Average speed
↑ Single trip travel time (minutes)
↑ Type of section N = Normal U = Reserved
↑ Number of lanes
↑ Subsection volume (equiv.-veh.)
↑ Adjusted capacity
↑ Weaving effect
↑ v/c for normal and unreserved sections
↑ Density (veh/mile/lane)
↑ Average speed
↑ Single trip travel time (minutes)
↑ Queue indicator
↑ Subsection length (feet)
↑ Queue length in subsection
↑ Rate of flow of excess demand (vph)

FIGURE 10B - SAMPLE PRIFRE OUTPUT FOR PRIORITY LANE OPERATIONS column in the summary table, column fifteen, gives the value of RA(rate of flow of excess demand), in vehicles per hour.

During priority simulations, the format for the summary table also includes the number of priority lanes, their volume, capacity, v/c ratio, density, average speed, and the subsection travel times.

The next possible output is a warning message telling the user that the value of RA is greater than the demand for a particular subsection. "***Warning***RA exceeds demand in section 18. This causes negative volume. Reduce temporary on-ramp limits for one or more downstream ramps and re-run." If this condition arises, the user must reduce the revised downstream on-ramp limits so that the ramps will have more queueing and the freeway less queueing, and then rerun the set of data.

Then the number of vehicles in queues are listed for all on-ramps and merge points which have non-zero total delay for that time slice. If on-ramps and merge points have zero total ramp delay, then no column headings will be printed.

If any off-ramp flow exceeded its corresponding off-ramp limit, a warning message to that effect is given at this point. There is no effort made to evaluate any off-ramp queueing. "***Warning***At off-ramp no. 8 demand exceeds 1500 vehicles per hour."

If any priority lane demand exceeds its capacity, a warning message is printed: "****Warning for the Ith Priority Section starting in Section I the capacity of X was exceeded by Y Cars and Z Equivalent Vehicle Buses. They have been demoted to non-priority status."

4. Travel Times

The next line of output depends on the value of FAC(2). If FAC(2) is zero, there will be no page skip or tables. If FAC(2) is one or two, a page skip followed by two OD-type tables will be printed. The first table gives the single trip time for each O-D movement in hundredths of a minute. Under normal operations, the second table is the simple product of the single trip time matrix multiplied by the O-D table, giving the total travel time in hundreths of vehicle-hours for each O-D movement. When a priority lane situation exists, only single trip times will be printed out. One table will give individual travel times for non-priority trips, and a second table will give individual travel times for priority trips. The next output, which is always printed, is a summary table of incremental and accumulated freeway travel time, input delay, and total travel distance for both priority and non-priority vehicles. See Fig. 11.

The first two columns of this table are values for the current time interval in terms of vehicle-hours and passenger-hours, while the last two columns have cumulative values for the first time slice through the present time slice in terms of vehicle-hours and passenger-hours. The next-to-last line, giving the total distance traveled, has units of vehicle-miles for columns one and three and passenger-miles for columns two and four.

The final output lists the "Total Travel Time Under Priority Operations," the "Total Travel Time Under Non-Priority Operations," and the difference between the two, or "Travel Time Savings Over

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TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	501.	886.	1243.	1651.	1793.	1894.	1993.
2	0.	348.	705.	1112.	1254.	1355.	1455.
3	0.	0.	189.	597.	739.	839.	939.
4	0.	0.	0.	366.	508.	609.	708.
5	0.	0.	0.	0.	38.	138.	238.
6	0.	0.	0.	0.	0.	67.	167.
7	0.	0.	0.	0.	0.	0.	82.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	164.	295.	396.	509.	557.	653.	753.
2	0.	118.	219.	332.	380.	476.	576.
3	0.	0.	52.	165.	213.	310.	409.
4	0.	0.	0.	101.	150.	246.	346.
5	0.	0.	0.	0.	21.	117.	217.
6	0.	0.	0.	0.	0.	67.	167.
7	0.	0.	0.	0.	0.	0.	82.

	CURRENT TIME INTERVAL				CUMULATIVE VALUES			
FREEWAY TRAVEL TIME (NOR)	21.	VEH-HRS	32.	PASS-HRS	289.	VEH-HRS	444.	PASS-HRS
FREEWAY TRAVEL TIME (UNR)	186.	VEH-HRS	233.	PASS-HRS	2123.	VEH-HRS	2699.	PASS-HRS
FREEWAY TRAVEL TIME (RES)	5.	VEH-HRS	19.	PASS-HRS	102.	VEH-HRS	448.	PASS-HRS
INPUT DELAY (NOR)	1886.	VEH-HRS	2828.	PASS-HRS	9686.	VEH-HRS	14447.	PASS-HRS
INPUT DELAY (UNR)	265.	VEH-HRS	405.	PASS-HRS	3190.	VEH-HRS	4856.	PASS-HRS
TOTAL TRAVEL DISTANCE	4534.	VEH-MI.	6631.	PASS-MI.	72566.	VEH-MI.	113257.	PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	2363.	VEH-HRS	3516.	PASS-HRS	15391.	VEH-HRS	22894.	PASS-HRS
TOTAL TRAVEL TIME UNDER NON-PRIORITY OPERATIONS					18126.	VEH-HRS	25475.	PASS-HRS
TRAVEL TIME SAVINGS OVER NON-PRIORITY OPERATION =					2735.1	VEH-HRS	2580.4	PASS-HRS

FIGURE 11 - SAMPLE PRIFRE OUTPUT - TRAVEL TIME SUMMARY TABLE

Non-Priority Operations." A positive value indicates that priority lane operations will result in a time savings and a negative value indicates a time loss. Total vehicle-hour savings appear in the first column, followed by total passenger-hour savings in the second column.

4. MODEL VALIDATION AND VERIFICATION

Validation of the computer program was undertaken to assure that the Priority Lane Model would derive approximately the same results as those obtained from FREEQ, EXCBUS, and manual calculations. Much emphasis was placed on extensive program checking so that the potential user of PRIFRE would have confidence in the model's performance and output, while also becoming aware of the assumptions and limitations of the model.

A. Component Checks and Corrections

PRIFRE was first run for several hundred different situations designed to isolate and test the different subroutines in the program. Special hypothetical problems were input and each of the 30 subroutines thoroughly tested. After making several initial runs with PRIFRE, some deficiencies began to show up. The major corrections to the program are discussed below:

1. Bus Equivalency Factors - the original PRIFRE versions showed bus vehicles to be equivalent to cars. EXCBUS uses bus equivalency factors; therefore PRIFRE was corrected by giving the user the option of inputting two bus equivalency factors, one for normal, mixed traffic and one for reserved, priority traffic.

2. Calculation of Weaving Effects - at the entrance and exit of the priority lane. Since weaving analyses could not be found to cover all of the many complex weaving situations that could occur at the entrance and exit of different priority

lane schemes, the decision was made not to attempt such an analysis in the PRIFRE program. The user can still make adjustments manually for these weaving effects and input them in the program in the form of reduced roadway capacities.

3. Calculation of the Capacity of the Unreserved Lanes - the original version assumed the new capacity of the unreserved lanes to be the original roadway capacity minus the capacity of the removed priority lane(s). The corrected formula was inserted into the program, calling for the new capacity of the unreserved lanes to be the capacity of the original road section times the number of original lanes minus the number of priority lanes all divided by the original number of lanes.

4. Difficulty was encountered in applying the correct bus equivalency factor to the buses as they proceeded from normal, mixed traffic into priority traffic and back out again into normal traffic. This problem was solved so that the buses will acquire the correct vehicle equivalency factor as they move in and out of different reserved lane situations. Equivalency factors are applied the moment a bus is generated at an on ramp.

5. Excess Demand for the Priority Lane(s) - for situations arising where the assumed capacity of the priority lanes is exceeded by the demand, the decision was made to allow the program to continue the evaluation, but a warning message would be outputted alerting the user to this fact. No

queueing is allowed in the priority lane or at its entrance in the PRIFRE model; instead the excess number of vehicles are demoted to non-priority status in the unreserved lanes. Buses and carpools alike are diverted in direct proportion to their numbers in the priority traffic demand.

6. Vehicles Caught in a Queue - vehicles caught in a queue as a time slice ends will still be in a queue as the next time slice begins. They will then be distributed downstream according to the destination pattern for this new time slice.

7. Travel Time Output - the original format for the computer output - vehicle hours and passenger hours - were calculated and printed separately for priority and non-priority vehicles and passengers. Errors introduced by the approximations used for this approach may have been avoided by introducing additional memory arrays to keep track of the destination pattern of the two classes of vehicles. The decision was made instead to output the total travel time and total travel distance for each type of roadway operation - normal, reserved, and unreserved - for both priority and non-priority vehicles. The total travel time array (in .01 vehicle hours), which was printed for both priority and non-priority vehicles, was discontinued because correct values could not be calculated without using considerable additional computer memory space. The individual trip time arrays are still outputted, and the user can multiply these times by the corresponding number of

persons making each trip from the two O-D tables.

8. Final Output Format - the form of the final output was augmented with the valuable addition of the total travel time savings (or losses) expended with this particular priority operation. Immediately below this value is reprinted the value of the total travel time expended under normal freeway operations.

9. Average Occupancy of Subsections - the combined average occupancies of the normal, reserved, and unreserved lanes of the subsections are now corrected to reflect the proper values for passenger hours and passenger miles. See formula calculations for combined bus plus carpool plus non-carpool car occupancies in Appendix G.

10. Queueing Calculations - component checks were repeated for hypothetical freeway queueing situations using PRIFRE and compared with the results from an equivalent FREEQ simulation. Queue lengths, queue collisions, and the queue splits were eventually made identical for both programs by correcting PRIFRE's subroutines until they performed the same as those of its parent, FREEQ.

11. Merge Queues - with the addition of an on-ramp in a bottleneck subsection after the priority lane had begun, it was found that merging and on-ramp queueing delays were incorrectly calculated. PRIFRE was corrected and re-checked successfully.

12. Weaving Effects in a Queueing Situation - the calculation of weaving effects (reductions in roadway capacities) was also

found to be initially in error, and the program corrected so as to give results compatible with FREEQ.

B. Comparison of PRIFRE with FREEQ

As mentioned before, PRIFRE has two main parents - FREEQ and EXCBUS. It was considered desirable to check PRIFRE results against these two tried and tested models, and to compare results. FREEQ comparisons will be discussed and shown here, and EXCBUS comparisons in the section immediately following.

There are numerous subroutines in the PRIFRE program which have been borrowed from FREEQ, with some slight modifications, and so the first checks were made to determine if these subroutines were compatible and outputted similar results. A portion of the Eastshore Freeway (I-80) in the SF Bay Area was selected for the comparison check, as nearly all possible situations for computing total travel time are encountered on this freeway section during peak hours, and FREEQ results had been verified by field observations for this section. See Fig. 1 for Eastshore Freeway example.

A comparison run with both programs revealed that some slight differences between the two existed. Tables 3 and 4 summarize the main subroutine calculations and final outputs. As can be seen, there are no individual values that differ by more than 1%, and most of these are due to rounding. The total queue lengths are virtually identical, differing by only 2' in 27,520'. Travel times (min/veh.) are identical. Very small differences are noted in Table 4 for total travel times and total travel distances, which are the main objective

Table 3 Comparison of PRIFRE and FREEQ Subroutines — Eastshore I-80 Data

SUB SECTION	WEAVING EFFECT	TRAVEL TIME (MIN./VEH.)	QUEUE FEET	EXCESS DEMAND-RA
1		.33 / .33		
2		.39 / .39		
3	806 / 806	.31 / .31		
4		.52 / .52	595 / 592	96 / 95
5	274 / 273	.16 / .16		
6	274 / 273	2.61 / 2.60	2381 / 2292	2880 / 2869
7		1.75 / 1.74	3030 / 3029	2880 / 2869
8	294 / 293	1.26 / 1.25	2160 / 2159	2499 / 2489
9		1.12 / 1.12	2030 / 2029	2499 / 2489
10	1522 / 1522	.58 / .58	1250 / 1249	1667 / 1656
11	278 / 277	.37 / .37	900 / 899	1667 / 1656
12		.72 / .72	1320 / 1319	1667 / 1656
13		.38 / .38	720 / 719	1667 / 1656
14		1.54 / 1.54	2610 / 2609	1652 / 1646
15		1.08 / 1.08	1660 / 1659	1652 / 1646
16		1.24 / 1.23	1890 / 1889	1652 / 1646
17		1.67 / 1.67	2310 / 2309	1652 / 1646
18	240 / 239	1.02 / 1.02	1460 / 1459	1580 / 1578
19		3.31 / 3.31	3800 / 3799	1580 / 1578
20	872 / 872	.36 / .36		
21	872 / 872	.17 / .17		
22	212 / 212	.30 / .30		
23		.30 / .30		
24	660 / 659	.16 / .16		
25		.96 / .96		
26		.44 / .44		
27		.46 / .46		
28		.17 / .17		
29		.24 / .24		
30		.52 / .52		
TOTALS			27520 / 27418	
Maximum % Difference (Individual)	0.4%	0.8%	0.4%	0.7%

Note: PRIFRE values are shown in the upper triangles; FREEQ values in the lower triangles.

TABLE 4 COMPARISON OF PRIFRE AND FREEQ OUTPUTS

TIME SLICE	TOTAL TRAVEL TIME		TOTAL TRAVEL DISTANCE	
	VEH./HR.	PASS./HR.	VEH./MI.	PASS./MI.
1	203 / 203	407 / 407	11674 / 11674	23348 / 23348
2	301 / 300	601 / 601	15150 / 15149	30300 / 30297
3	298 / 298	596 / 596	14402 / 14402	28803 / 28804
4	449 / 448	898 / 895	14199 / 14201	28397 / 28403
5	546 / 545	1093 / 1091	12540 / 12538	25080 / 25077
6	626 / 625	1251 / 1250	12944 / 12945	25889 / 25890
7	533 / 532	1065 / 1064	14292 / 14293	28584 / 28587
8	352 / 352	704 / 703	13313 / 13319	26627 / 26639
9	187 / 188	374 / 375	9274 / 9280	18549 / 18561
10	150 / 150	300 / 300	8804 / 8804	17609 / 17609
TOTALS	3645 / 3641	7290 / 7283	126593 / 126607	253186 / 253214
Maximum % Difference (Individual)	0.5%	0.3%	0.06%	0.06%

Note: PRIFRE values are shown in the upper triangles;
FREEQ values are shown in the lower triangles.

TABLE 5 COMPARISON OF PRIFRE AND FREEQ MESSAGES

SUBROUTINE MESSAGES		PRIFRE		FREEQ	
Queue Collision	18	$T_2 = 0.005$		$T_2 = 0.005$	
Queue Collision	14	$T_2 = 0.129$		$T_2 = 0.130$	
Queue Collision	10	$T_2 = 0.192$		$T_2 = 0.194$	
Queue Collision	8	$T_2 = 0.187$		$T_2 = 0.188$	
ON RAMP 10		Queue Length (Vehicles) 11.02	Delay (Veh-Hrs) 1.38	Queue Length (Vehicles) 10	Delay (0.1 Veh-Hrs) 13

functions for both programs. Table 5 shows queue message comparisons.

Two areas of differences showed up in testing the special conditions of an auxiliary lane and in the two lane on-ramp. Changes were made to PRIFRE after it was determined that FREEQ's calculations were indeed accurate.

C. Comparison of EXCBUS and PRIFRE

In order to further verify results obtained from the PRIFRE program, several comparison runs were initiated for PRIFRE and EXCBUS, PRIFRE's other parent. Although there are many major differences between the two programs, they both have similar philosophies for evaluating total travel time on freeways involving various priority lane strategies for buses and carpools.

The specific input parameters for a hypothetical freeway situation used in the comparison runs are illustrated in Table 6. A five mile section of an 8-lane freeway (4 lanes in each direction) was selected and assigned a roadway capacity of 9000 vph and an average speed-flow/capacity relationship ranging from 50 mph at 0 v/c to 37 mph at 1.0 v/c. The peak period selected was of $\frac{1}{2}$ hours duration, and the ratio of pre-peak and post-peak demands to the peak demand was 0.4. Peak period lasted $\frac{1}{2}$ hour (2 - 15 min. time slices). Peak period demands were 500 buses (50 pass./bus) and 6800 cars (avg. occ. = 1.4). Minimum occupancy for priority status was varied between 2 and 5 passengers per vehicle, and the number of priority lanes varied between 1 and 2.

Table 7 shows complete summary results from both programs using a 1-4 priority lane strategy, i.e., one reserved lane for buses and cars with 4 or more passengers.

TABLE 6 COMPARISON OF EXCBUS AND PRIFRE

		INPUT PARAMETER					
		EXCBUS			PRIFRE		
CAPACITY (eq. veh.)		9000			9000		
LENGTH (MILES)		5.0			5.0		
NO. OF LANES (one direction)		4			4		
SPEED-FLOW DATA POINT	Non-Queueing Speed	V	Speed		v/c	Speed	
		00.	50.0		0.00	50.0	
		1800.	49.0		0.80	49.0	
		1935.	48.0		0.86	48.0	
		2025.	47.0		0.90	47.0	
		2160.	44.0		0.96	44.0	
		2205.	42.0		0.98	42.0	
		2250.	37.0		1.00	37.0	
	Queueing Speed	--	--		-1.0	37.0	
		--	--		-0.0	0.0	
DEMAND			VEH	EQ. VEH	TS	VEH	EQ. VEH
	PRIOR PEAK (0.0 HR)	RATIO PRE PEAK/PEAK = 0.4 RATIO POST PEAK/PEAK = 0.4	500B 2420C	3420	--	--	--
	PEAK (0.5 HR)		500B 6800C	7800	1	500B 6800C	7800
					2	500B 6800C	7800
	POST PEAK (1.0 HR)		500B 2420C	3420	3	500B 2420C	3420
					4	500B 2420C	3420
					5	500B 2420C	3420
					6	500B 2420C	3420
CAR OCCUP. DISTRIBUTION	PASS.	% CAR			% CAR		
	1	70.			70.		
	2	20.			20.		
	3	5.			5.		
	4	4.			4.		
	5	1.			1.		
BUS-OCCUPANCY		50 PASS./BUS			50 PASS./BUS		

TABLE 7 COMPARISON OF EXCBUS AND PRIFRE

THREE UNRESERVED LANES AND ONE RESERVED LANE (BUSES AND AUTOS WITH FOUR OR MORE PASS. IN RESERVED LANE)				
OUTPUT PARAMETERS	EXCBUS	PRIFRE	UNIT	% DIFFER.
Avg. Lane Demand During Peak (NOR)	1950	1950	E.V./HR	0.00
Avg. Lane Demand During Peak (RES)	1340	1340	E.V./HR	0.00
Avg. Lane Demand During Peak (UNRES)	2153	2153	E.V./HR	0.00
TT Prior Peak Demand (NOR)	6.06	6.06	MIN/VEH	0.00
TT During Peak Demand (NOR)	6.27	6.27	MIN/VEH	0.00
TT Post Peak Demand (NOR)	6.06	6.06	MIN/VEH	0.00
TT Prior Peak (UNRES)	6.06	6.05	MIN/VEH	0.16
TT During Peak (UNRES)	6.80	6.80	MIN/VEH	0.00
TT Post Peak (UNRES)	6.06	6.05	MIN/VEH	0.16
TT Prior Peak (RES)	6.06	6.08	MIN/VEH	0.32
TT During Peak (RES)	6.09	6.09	MIN/VEH	0.00
TT Post Peak (RES)	6.06	6.08	MIN/VEH	0.32
TTT (NOR)	4709.0	4707.0	pass-hr	0.0%
TTT (RES)	3797.0	3924.0	pass-hr	−3.2%
TTT (UNRES)	824.0	786.0	pass-hr	+4.7%
TTT (PRIORITY OPERATION)	4621.0	4711.0	pass-hr	−1.9%
SAVING - TTT	86.0	- 4.0	pass-hr	

The individual trip times (TT) are very close - almost exact for this non-queueing situation. Differences between the two are less than 1%. However, larger differences show up in the total travel times (TTT) for the reserved and unreserved trips on the freeway. Since the individual trip times are virtually identical, this can only mean that there must be some differences in the manner in which each program calculates average occupancy. EXCBUS underestimates TTT in the reserved lane by 3.2% and overestimates TTT in the unreserved lanes by 4.7%. Manual checks proved PRIFRE to be fully correct in its final travel times, while EXCBUS was shown to have small errors due to the approximated method required for inputting the number of passengers into the reserved and unreserved lanes in the EXCBUS model.

When the total travel times for the entire freeway are added together, the plus and minus differences serve to cancel each other out, so that there is only about a 2% difference in the final output. This last output result is the figure used to compare various priority lane schemes with normal operations, and evaluate any potential travel time savings. EXCBUS showed 86 pass.-hrs. saved by this 1-4 scheme over normal operations, while PRIFRE showed 4 pass.-hrs. lost. This 90 pass.-hrs. difference is small, however, when compared to the TTT of 4700 pass.-hrs. -- less than 2%.

1. Comparison under Non-queueing Conditions

Table 8 summarizes all the results from both programs involving priority strategies in non-queueing situations. It can be noted that as the minimum occupancy for priority status is raised from 3 to 5, the

TABLE 8 SUMMARY RESULTS COMPARISON OF

EXCBUS AND PRIFRE MODEL (NON-QUEUEING)

CASE	PARAMETER	EXCBUS	PRIFRE	% ERROR	QUEUEING SITUATION
1-3*	TTT (NOR)	4709	4707	0	No Queue
	TTT (RES)	3918	4022	- 2.5	"
	TTT (UNR)	702	669	+ 4.9	"
	TTT (RES + UNR)	4620	4691	- 1.5	"
	Saving TTT	88	16	D = +72	--
1-4	TTT (NOR)	4709	4707	0	No Queue
	TTT (RES)	3797	3924	- 3.2	"
	TTT (UNR)	824	786	+ 4.7	"
	TTT (RES + UNR)	4621	4711	- 1.9	"
	Saving TTT	86	- 4	D = +90	
1-5	TTT (NOR)	4709	4707	0	No Queue
	TTT (RES)	3667	3823	- 4.0	"
	TTT (UNR)	1023	992	+ 3.1	"
	TTT (RES + UNR)	4690	4816	- 2.6	"
	Saving TTT	+ 17	- 109	D = +126	

* 1-3 MEANS PRIORITY OPERATIONS WITH ONE RESERVED LANE FOR AUTOS AND BUSES WITH THREE OR MORE PASSENGERS IN THE RESERVED LANE

total travel time differences increase from 72 pass.-hrs. to 126 pass.-hrs i.e., 1.5% to 2.6%. Differences in the unreserved lane decreased, while differences in the reserved lane increased. This would seem to indicate that as volumes decrease in the priority section, the differences between PRIFRE and EXCBUS increase.

2. Comparison under Queueing Conditions

Table 9 summarizes all the results from runs involving priority strategies in queueing situations. Large differences occur between the two programs when queueing occurs in the unreserved lanes. As demand increased in the unreserved lanes, and therefore increased the length and duration of queue, differences grew larger, ranging from 12% for 1-3 to almost 30% for 2-2. Input parameters for these runs were exactly the same as for the non-queueing situations described above, except that capacity of the road was decreased from 9000 to 7200.

The reason for such large differences between the two models in queueing situations lies in the two different queueing theories used in subroutine calculations. Another important difference is that PRIFRE will demote any excess demand for the reserved lanes into the unreserved lanes, no queueing being allowed in the reserved lane. EXCBUS allows queueing in the reserved lane.

Differences in overall trip travel time (Reserved + Unreserved) for both priority and normal operations are much smaller. PRIFRE and EXCBUS differ by only 1.9% under normal operations and by about 5-7% under priority operations. EXCBUS has higher travel time savings than PRIFRE in every case since it found much lower travel

TABLE 9 SUMMARY RESULTS COMPARISON OF PRIFRE AND EXCBUS MODEL (QUEUEING)

CASE	PARAMETER	EXCBUS	PRIFRE	% DIFFER.	QUEUEING SITUATION
1-2	TTT (NOR)	QUEUE IN	5629	--	Queue
	TTT (RES)	RESERVED LANE	4253	--	"
	TTT (UNR)	PAST T_{MAX} =	838	--	No Queue
	TTT (RES + UNR)	9.50.	5091	--	--
		THEREFORE			
		STRATEGY			
	SAVING TTT	ABANDONED	538		--
1-3	TTT (NOR)	5737	5629	+ 1.9	Queue
	TTT (RES)	4040	4146	- 2.5	No Queue
	TTT (UNR)	957	1087	- 11.8	Queue
	TTT (RES + UNR)	4997	5233	- 4.5	--
	SAVING TTT	740	396		--
1-4	TTT (NOR)	5737	5629	+ 1.9	Queue
	TTT (RES)	3809	3938	- 3.2	No Queue
	TTT (UNR)	1180	1344	- 12.1	Queue
	TTT (RES + UNR)	4989	5282	- 5.5	--
	SAVING TTT	748	347		--
1-5	TTT (NOR)	5737	5629	+ 1.9	Queue
	TTT (RES)	3676	3834	- 4.0	No Queue
	TTT (UNR)	1422	1632	- 12.8	Queue
	TTT (RES + UNR)	5098	5467	- 6.7	--
	SAVING TTT	639	162		--
2-2	TTT (NOR)	5737	5629	+ 1.9	Queue
	TTT (RES)	4224	4279	- 1.2	No Queue
	TTT (UNR)	781	1108	- 29.4	Queue
	TTT (RES + UNR)	5005	5388	- 7.0	--
	SAVING TTT	732	241		--
2-3	TTT (NOR)	QUEUE IN	5629	--	Queue
	TTT (RES)	UNR LANE	3998	--	--
	TTT (UNR)	DURING PEAK	3188	--	Queue
	TTT (RES + UNR)	PERIOD.	7187	--	--
		QUEUEING EX-			
		TENDED PAST			
		9.50. THERE-			
		FORE STRATE-			
	SAVING TTT	GY ABANDONED	-1557	--	--

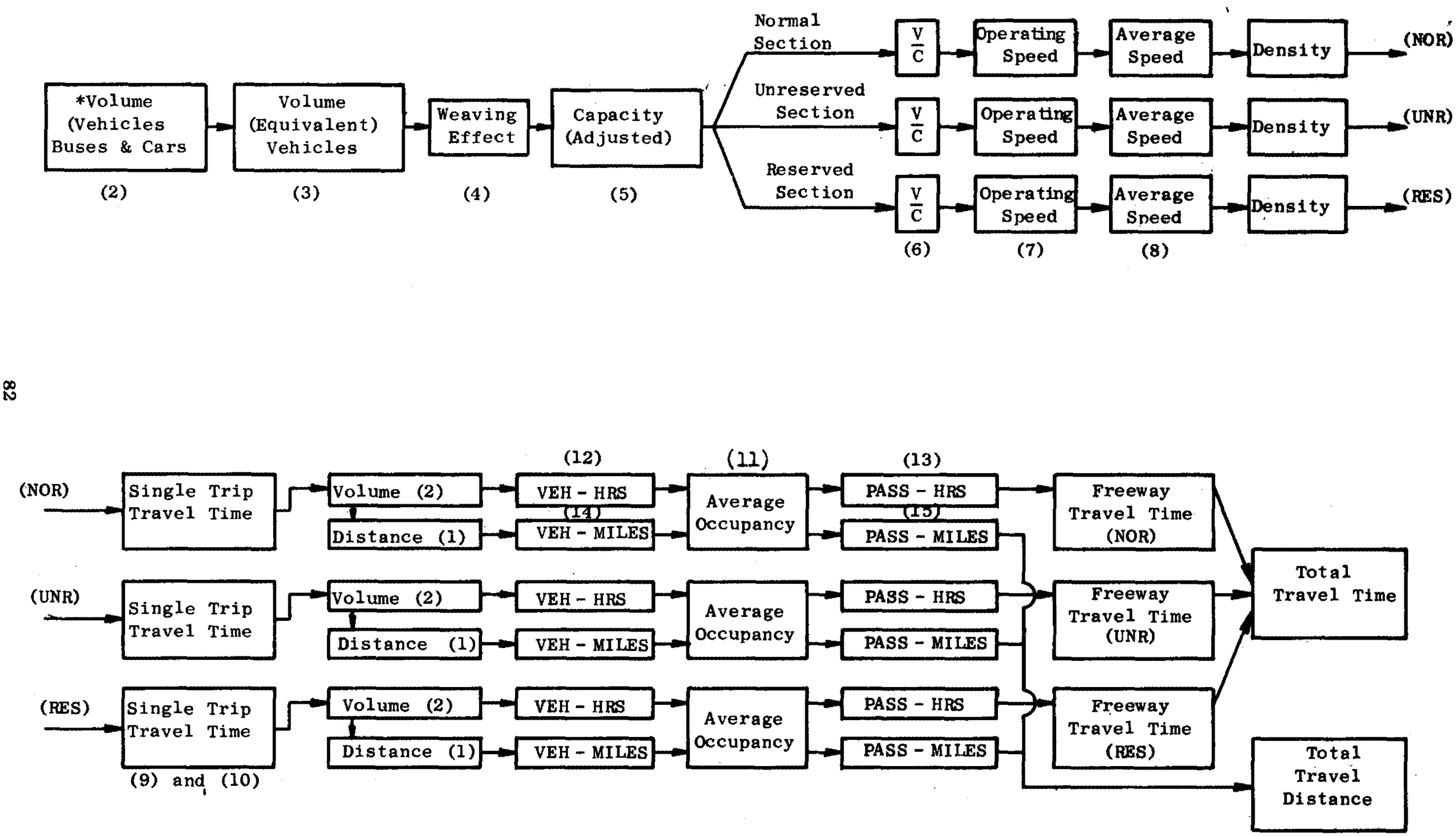
times for the unreserved lanes under queueing conditions. Manual checks, discussed extensively in the next section, seem to bear out PRIFRE's accuracy over EXCBUS'

D. Manual Checking of PRIFRE

Finally, to further illustrate and verify the computations made by the PRIFRE model, much effort was spent manually calculating freeway travel times and travel distances for three distinct cases and comparing them with the output obtained from PRIFRE. Three different time slices were analyzed, each depicting different elements of PRIFRE's subroutine calculations: 1) a non-queueing situation; 2) a queue increasing situation; and 3) a queue decreasing situation.

A flow chart of the manual calculation procedure is shown in Fig. 12. Example problems worked out for each time slice are contained in Appendix G, as are any special calculations for weaving or merging analysis. Basically the procedure is to calculate an input volume, modify and adjust it for bus equivalency factors, weaving effects, and merging constraints, calculate the adjusted capacity, and obtain a volume/capacity ratio. With this v/c ratio an operating speed can be found from Fig. 9.1 of the <u>HCM</u>, and an average speed calculated from this value by formula (3) in Chapter 2. This is done for all three possible sections - normal, reserved, and unreserved. Then single trip travel times can be found by dividing the length of the subsection by the average speed. Vehicle hours are then found by multiplying by the appropriate actual volume of vehicles flowing for that 15-min. time slice. Passenger hours are simply the product of vehicle-hours times the average occupancy of vehicles for that section

FIGURE 12 FLOW CHART OF CALCULATION PROCEDURE



* ADJUSTED VOLUME FOR ON RAMP AND MAINLINE QUEUEING SITUATIONS

NOTE: NUMBERS IN PARENTHESES REFER TO THE COLUMNS IN TABLES 11, 15, &19.

and situation. In a similar manner, vehicle-miles and passenger-miles are found. Finally, these values are summed up for total travel time and total travel distance.

Summary tables of these manual calculations are immediately followed by the actual PRIFRE computer results for the same time slice. The first computer table summarizes subroutine calculations while the second table summarizes travel times. Finally, a fourth table shows the final results of PRIFRE and manual calculations side by side. Close comparison of all the tables reveals remarkably similar results. All values are within a few percentage points of each other, while those in the final summary table are almost identical.

1. Results for Time Slice 1 - Non-queueing Situation

The freeway situation shown in Table 10 and illustrated in Figs. 13a and 13b was used for Time Slice 1. An 8-lane freeway (4 lanes each direction) containing seven subsections in 7½ miles was assigned an original capacity of 8000 vph. A 70 mph design speed was assigned to all sections and situations-normal, reserved, and unreserved. A three-mile reserved section consisting of one lane for buses and carpools with three or more occupants was the priority scheme evaluated. A free-flowing situation was maintained while inputting 45 buses and 2802 cars at the beginning of priority operations in subsection 3.

Manual results for Time Slice 1 are shown in Table 11 and can be compared with the results from PRIFRE in Tables 12 and 13. Examples 4.1 and 4.2 in Appendix G serve to illustrate the calculations made

TABLE 10 INPUT PARAMETERS

Sub-Sect. No.		1	2	RES. / 3 UNRES.	RES. / 4 UNRES.	5	6	7
No of lane		4	4	1 / 3	1 / 3	4	4	4
Length (feet)		5280	5280	7920 / 7920	7920 / 7920	5280	2640	5280
Capacity		8000	8000	1500 / 6000	1500 / 6000	8000	8000	8000
Volume	Buses	25	45	45 / 2802	45 / 2674	53	58	38
	Cars	2428	3035	233 / 0	233 / 0	3927	4713	4320
	Veh**	2453	3080	278 / 2802	278 / 2674	3980	4771	4367

Assume: Truck Factor = 1.00
Design Speed = 70 mph

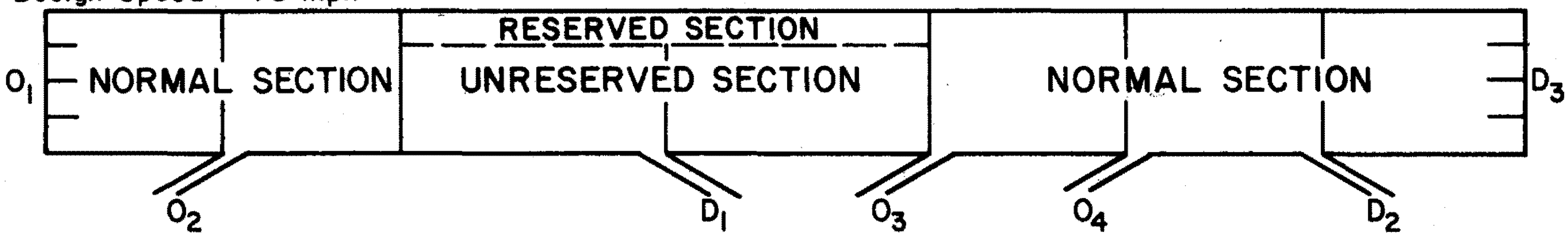


FIG. 13(a) FREEWAY CHARACTERISTICS

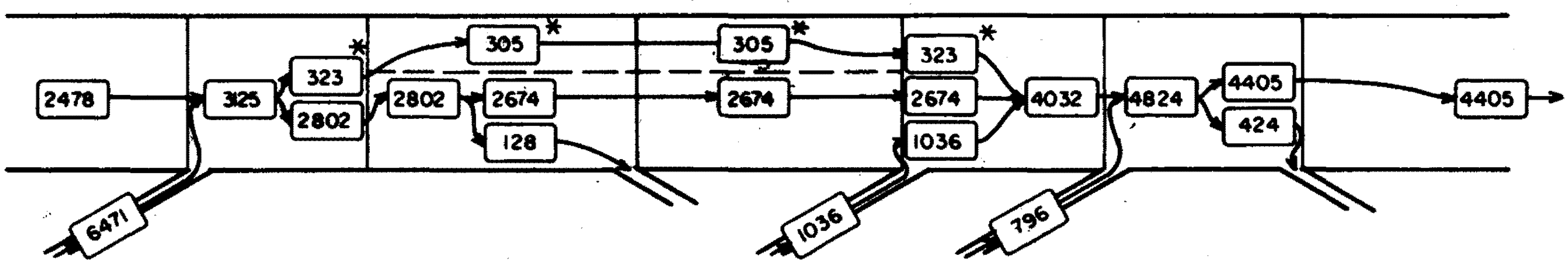


FIG. 13(b) FREEWAY VOLUMES (equivalent vehicles) FOR TIME SLICE 1
(See Figure 12 For Computer Output of Equivalent Vehicle Volumes)

** Veh = Buses + Cars = Total Vehicles in Subsection (NOT Equivalent Vehicles)

* Buses Aquire Different Equivalency Factors in Normal and Reserved Sections

TABLE 11 SUMMARY OF MANUALLY CALCULATED VALUES FOR TIME SLICE 1 - NO QUEUEING

	Sub-Section		(1) Subsection Length		(2) Volume	(3) Volume-Equiv. Vehicles	(4) Weaving	(5) Cap. C	(6) v/c (3)/(5)	(7) Oper. Speed	(8) Avg. Speed	(9) Individual Travel Time (1)/(8)	(10)	(11) Avg. Occ.	(12) Travel Time ¼(2)(9)	(13) (11)(12)	(14) Travel Dist. ¼(1)(2)	(15) (11)(14)
	No	Type	Feet	Miles	(vph)	(vph)	(vph)	(vph)		(mph)	(mph)	(hrs)	(min)	pass/veh.	(veh-hr)	(pass-hr)	(veh-mi)	(pass-mi)
Normal	1	NOR	5280	1	2453	2478	0	8000	.31	63	58	.0172	1.03	1.89	10.53	19.9	613.3	1162.1
Normal	2	NOR	5280	1	3080	3125	0	8000	.39	61	57	.0172	1.05	2.11	13.50	28.5	770.0	1624.7
Priority Section	3	RES	7920	1.5	278	305	0	1500	.20	51	50	.0300	1.80	10.90	2.08	22.6	104.3	1136.3
		UNR			2802	2802	0	6000	.47	58	55	.0275	1.65	1.24	19.25	23.9	1051.8	1304.2
	4	RES	7920	1.5	278	304	0	1500	.20	51	50	.0300	1.80	10.90	2.08	22.6	104.3	1136.3
		UNR			2674	2674	0	6000	.45	58	55	.0274	1.64	1.23	18.20	22.5	1002.7	1233.4
Normal Sect.	5	NOR	5280	1	3980	4033	0	8000	.50	58	55	.0182	1.09	2.04	18.10	36.9	945.0	2029.8
	6	NOR	2640	½	4771	4829	424	7576	.64	55	52	.0095	.52	1.99	11.30	22.5	596.4	1187.0
	7	NOR	5280	1	4367	4405	0	8000	.55	57	54	.0185	1.11	1.82	20.20	36.7	1091.5	1987.0
	Totals		39600	7½											115.00	236.0	6329.0	12801.

TABLE 12 COMPUTER OUTPUT – TIME SLICE 1

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RESERVED PRIORITY OPERATIONS

SUB SEC	FIRST [illegible]	DMD. [illegible]	ORIG. TOTAL	PR	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME
1	2478.	.	2478							
2	[illegible]	[illegible]	3125							
3	[illegible]	12[illegible]	[illegible]	1	[illegible]	15[illegible]	.20	6.	5[illegible]	1.79
4	[illegible]	.	[illegible]	1	[illegible]	15[illegible]	.20	6.	5[illegible]	1.79
5	1[illegible]	.	[illegible]							
6	[illegible]	424.	[illegible]							
7	[illegible]	44[illegible]	[illegible]							
					(3)	(5)	(6)		(8)	(10)

UNRESERVED OR NORMAL OPERATIONS

UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
N	4	2478.	8000.	0.	.31	11.	58.	1.03		5280.	0	0.
N	4	3125.	8000.	0.	.39	14.	57.	1.05		5280.	0	0.
N	3	2802.	6000.	0.	.47	17.	55.	1.65		7920.	0	0.
N	3	2674.	6000.	0.	.45	16.	55.	1.64		7920.	0	0.
N	4	4033.	8000.	0.	.50	18.	55.	1.09		5280.	0	0.
N	4	4829.	7576.	424.	.64	23.	52.	.57		2640.	0	0.
N	4	4405.	8000.	0.	.55	20.	54.	1.11		5280.	0	0.
		(3)	(5)	(4)	(6)		(8)	(10)		(1)		

TABLE 13 COMPUTER OUTPUT – SUMMARY TABLE – TIME SLICE 1

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TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3
1	373.	704.	815.
2	270.	601.	712.
3	0.	167.	273.
4	0.	57.	169.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3
1	387.	733.	844.
2	284.	630.	741.
3	0.	167.	273.
4	0.	57.	169.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NPR)	74. VEH-HRS	145. PASS-HRS	74. VEH-HRS	145. PASS-HRS
FREEWAY TRAVEL TIME (UPR)	37. VEH-HRS	46. PASS-HRS	37. VEH-HRS	46. PASS-HRS
FREEWAY TRAVEL TIME (RES)	4. VEH-HRS	45. PASS-HRS	4. VEH-HRS	45. PASS-HRS
INPUT DELAY (NPR)	0. VEH-HRS	0. PASS-HRS	0. VEH-HRS	0. PASS-HRS
INPUT DELAY (PNR)	0. VEH-HRS	0. PASS-HRS	0. VEH-HRS	0. PASS-HRS
TOTAL TRAVEL DISTANCE	6328. VEH-MI. (14)	12800. PASS-MI. (15)	6328. VEH-MI.	12800. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	115. VEH-HRS (12)	236. PASS-HRS (13)	115. VEH-HRS	236. PASS-HRS

TABLE 14 COMPARISON OF MANUAL CALCULATIONS WITH COMPUTER CALCULATIONS
TIME SLICE I - NO QUEUEING

		VEH-HR.		PASS-HR.	
		Manual	Computer	Manual	Computer
FREEWAY TRAVEL TIME	Normal Sections	74.	74.	145.	145.
	Unreserved Section	37.	37.	46.	46.
	Reserved Section	4.	4.	45.	45.
TOTAL TRAVEL TIME		115.	115.	236.	236.

	VEH-MI.		PASS-MI.	
	Manual	Computer	Manual	Computer
TOTAL TRAVEL DISTANCE	6,329.	6,328.	12,801.	12,800.

for this time slice. As can be seen in Summary Table 14, final output results are essentially identical with those of the PRIFRE computer program.

2) Results from Time Slice 2 - Queue Increasing Situation

Essentially the same freeway parameters exist for Time Slice 2 as were shown for Time Slice 1. The only changes are input volumes, and these can be seen in Figs. 14a thru 14f. The original volume is modified first for bus equivalency factors, then for merging capacity constraints at on-ramp in subsection 5, and finally for capacity constraints queueing the entrance to subsection 6. Example problems 4.3, 4.4 and 4.6 in Appendix G illustrate the type of calculations made for Time Slice 2. Since volumes are now 95 buses and 7780 cars, queueing occurs in subsection 5 for a distance of about ¼ mile.

Manual results are summarized in Table 15 and can be directly compared with the values obtained from PRIFRE in Tables 16 and 17. Final outputs are compared in Table 18 for Time Slice 2 and are very similar.

3). Results from Time Slice 3 - Queue Decreasing Situation

Again the same basic freeway situation exists as that presented in Time Slice 1. Input volume and their modifications for merging and capacity constraints are shown in Figs. 15a thru 15e. Table G2 and Ex. 4.6 in Appendix G summarize specific calculations made for the queue decreasing situation occurring in subsection 5. The queue actually dissipates before the 15-min. time slice is up, but

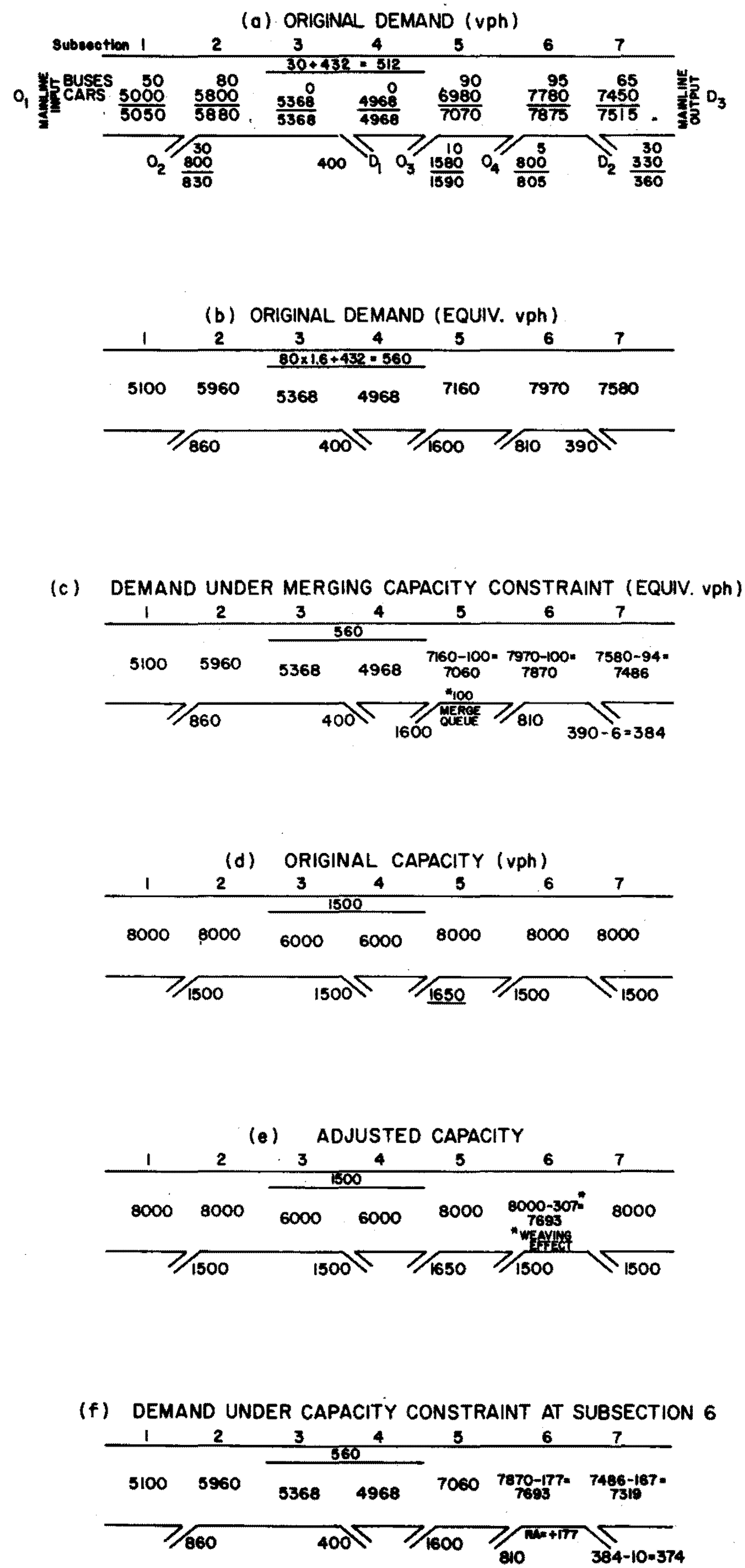

Figure 14 DEMAND AND VOLUME CALCULATIONS FOR TIME SLICE 2

TABLE 15 SUMMARY OF MANUALLY CALCULATED VALUES FOR TIME SLICE 2 - QUEUE INCREASING

			(1)		(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Sub-section		Length		Vol. Eq. veh	Weaving effect	Cap. C	v/c	Speed		Individual Travel Time (1)/(7)		Adjusted Volume	Avg. Occ.	Travel Time		Travel Dist.	
	No.	Type	(Feet)	(Mi)	(vph)	(vph)	(vph)		Op. (mph)	Avg. (mph)	(hrs)	(min.)	(vph)	pass/veh	(v-hrs)	(p-hrs)	(v-mi)	(p-mi)
Normal	7	NOR	5280	1	7319	0	8000	.92	45	44	.0228	1.37	$7319 \times \frac{7515}{7580} = 7256$	1.82	41.36	75.28	1814.	3301.
Normal	6	NOR	2640	$\frac{1}{2}$	7693	307	7693	1.00	36	36	.0139	.83	$7693 \times \frac{7875}{7970} = 7601$	1.99	26.41	52.56	950.	1890.
Normal	5*	NOR	5280	1	6883	0	8000	.88	40*	40	*	*	$6883 \times \frac{7070}{7160} = 6796$	2.03	44.10	89.08	1720.	3676.
Priority Sect.	4	RES	7920	$1\frac{1}{2}$	560	0	1500	.37	52	48	.0314	1.89	512	10.66	4.02	42.85	192.	2047.
Priority Sect.	4	UNR	7920	$1\frac{1}{2}$	4968	0	6000	.83	48	47	.0322	1.93	4968	1.23	39.90	49.08	1863.	2292.
Priority Sect.	3	RES	7920	$1\frac{1}{2}$	560	0	1500	.37	52	48	.0316	1.89	512	10.66	4.02	42.85	192.	2047.
Priority Sect.	3	UNR	7920	$1\frac{1}{2}$	5368	0	6000	.89	46	45	.0337	2.02	5368	1.24	45.10	55.92	2013.	2496.
Normal	2	NOR	5280	1	5960	0	8000	.74	52	50	.0200	1.20	5880	2.06	29.40	60.56	1470.	3028.
Normal	1	NOR	5280	1	5100	0	8000	.64	54	52	.0190	1.15	5050	1.88	23.90	44.93	1263.	2373.
	Totals		39600	$7\frac{1}{2}$											258.	518.	11477.	22949.

*See Table G1 in Appendix G for special calculations in Subsection 5.

TABLE 16 COMPUTER OUTPUT – TIME SLICE 2

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[illegible] PRIORITY OPERATIONS

S[illegible] SEC	[illegible]	[illegible]	[illegible] TOTAL	[illegible]	[illegible] VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME
1	[illegible]	[illegible]	[illegible]							
2	[illegible]	[illegible]	[illegible]							
3	[illegible]	4[illegible]	[illegible]	1	[illegible]	1500.	.37	12.	40.	1.80
4	[illegible]	[illegible]	[illegible]	1	[illegible]	1500.	.27	12.	40.	1.80
5	[illegible]	[illegible]	[illegible]							
6	[illegible]	374.	[illegible]							
7	[illegible]	7[illegible]	[illegible]							
					(2)	(4)	(5)		(7)	(9)

		[illegible] LENGTH VEHICLES	DELAY VEH-HRS
[illegible]	[illegible]	[illegible]	[illegible]
	[illegible]	25.61	3.20
	TOTAL	25.61	3.20

UNRESERVED OR NORMAL OPERATIONS

[illegible] NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
N	4	5100.	8000.	0.	.64	24.	52.	1.15		5280.	0	0.
N	4	5960.	8000.	0.	.74	30.	50.	1.20		5280.	0	0.
[illegible]	3	5368.	6000.	0.	.89	40.	45.	2.02		7920.	0	0.
[illegible]	3	4968.	6000.	0.	.83	36.	47.	1.93		7920.	0	0.
N	4	6883.	8000.	0.	.86	43.	40.	1.53	*	5280.	1396	173.
N	4	7693.	7693.	307.	1.00	54.	36.	.84		2640.	0	0.
N	4	7320.	8000.	0.	.91	41.	44.	1.36		5280.	0	0.
		(2)	(4)	(3)	(5)		(7)	(9)				

TABLE 17 COMPUTER OUTPUT – SUMMARY TABLE – TIME SLICE 2

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[illegible]

[illegible]	[illegible]	[illegible]	[illegible]
1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]

[illegible]

	1	2	3
1	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
4	[illegible]	[illegible]	[illegible]

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
[illegible]	[illegible] VEH-HRS	[illegible] PASS-HRS	239. VEH-HRS	467. PASS-HRS
[illegible]	[illegible] VEH-HRS	[illegible] PASS-HRS	123. VEH-HRS	151. PASS-HRS
[illegible]	[illegible] VEH-HRS	[illegible] PASS-HRS	12. VEH-HRS	131. PASS-HRS
[illegible]	[illegible] VEH-HRS	6. PASS-HRS	3. VEH-HRS	6. PASS-HRS
[illegible]	[illegible] VEH-HRS	[illegible] PASS-HRS	0. VEH-HRS	0. PASS-HRS
TOTAL TRAVEL [illegible]	[illegible] VEH-MI. (14)	[illegible] PASS-MI. (15)	17822. VEH-MI.	35754. PASS-MI.
TOTAL TRAVEL [illegible] [illegible]	[illegible] VEH-HRS (12)	[illegible] PASS-HRS (13)	377. VEH-HRS	755. PASS-HRS

TABLE 18 COMPARISON OF MANUAL CALCULATIONS WITH COMPUTER CALCULATIONS
TIME SLICE 2 – QUEUE INCREASING

		VEH-HR.		PASS-HR.	
		Manual Σ(12)	Computer	Manual Σ(13)	Computer
FREEWAY TRAVEL TIME	Normal Sections	165.	165.	322.	321.
	Unreserved Section	85.	85.	105.	105.
	Reserved Section	8.	8.	86.	86.
	Input Delay	3.	3.	6.	6.
TOTAL TRAVEL TIME		261.	261.	519.	518.

	VEH-MI.		PASS-MI.	
	Manual Σ(14)	Computer	Manual Σ(15)	Computer
TOTAL TRAVEL DISTANCE	11,477.	11,493.	22,949.	22,954.

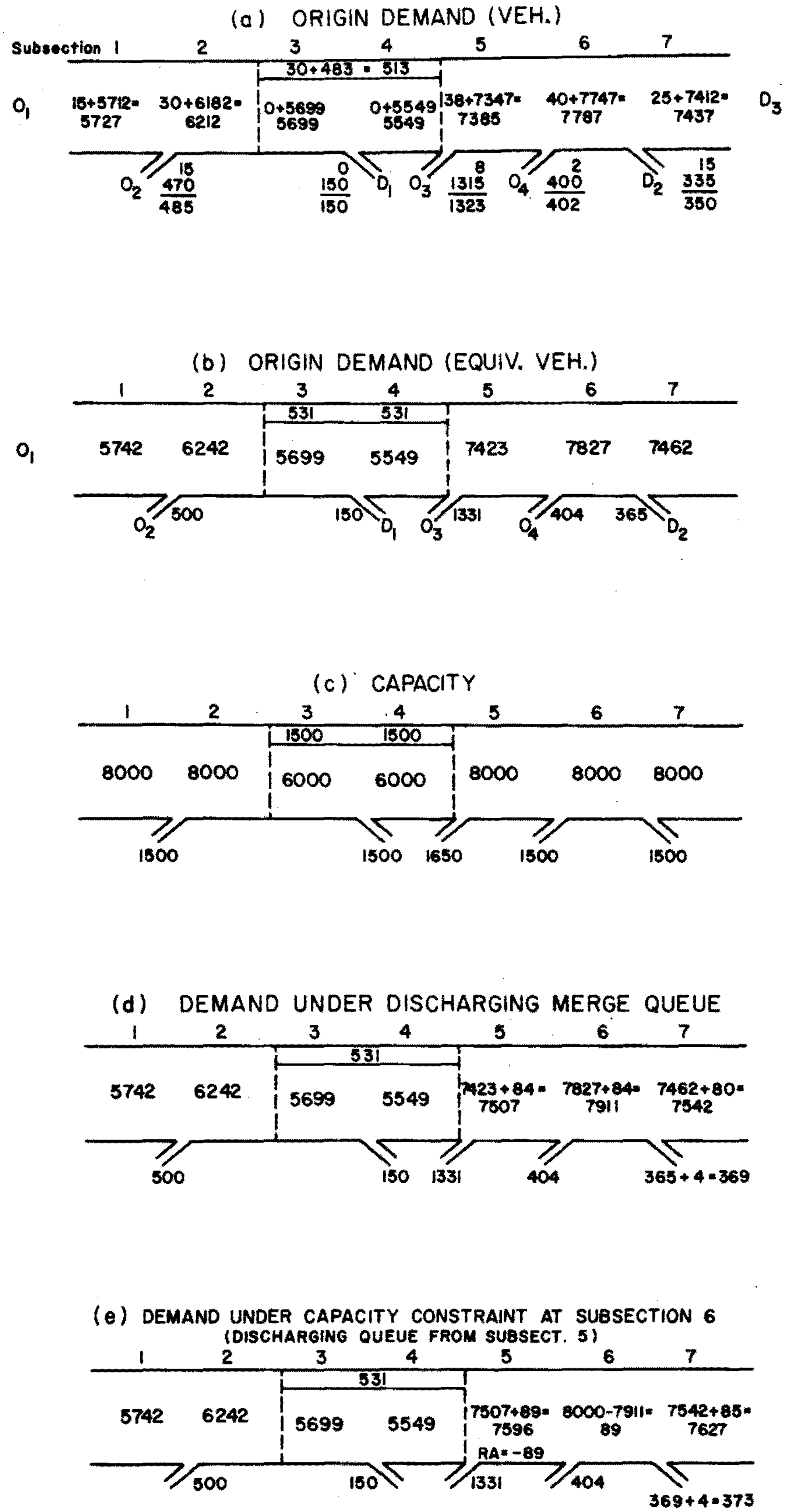

Figure 15 DEMAND AND VOLUME CALCULATIONS FOR TIME SLICE 3

PRIFRE recalculates the time of queue dissipation to coincide with .25 hrs, the end of time slice 3. This does not change the final values, but it does maintain PRIFRE's requirement for a constant demand over the 15-min. study period.

Manual results for Time Slice 3 are summarized in Table 19 and the corresponding computer values appear in Tables 20 and 21. PRIFRE again shows very close correlation with manually calculated values. Final outputs for Time Slice 3 are shown in Table 22 and are very close to the calculated final values.

E. Limitations and Summary

PRIFRE, the Priority Lane Model, was based on two other models, EXCBUS and FREEQ. Some of the limitations of these two models carry over into the existing PRIFRE model.

1. Limitations

The Priority Freeway Model (PRIFRE) represents a method for computing freeway travel times, and as such, only approximates the physical conditions found on real freeways. This method includes the idealization of physical queues. In the PRIFRE model, the ideal queues have properties which simplify the travel time calculations and at the same time may obscure the effect of some improvement plans and some priority lane schemes.

For example, much of the obscuring effect was found when investigating the possible improvement plan of adding an auxiliary lane. The error seems to be due to the method of handling queue collisions. Since there was no simple way of breaking the length of the fifteen-minute time interval when one queue collided with a second increasing

TABLE 19 SUMMARY OF MANUALLY CALCULATED VALUES FOR TIME SLICE 3 — QUEUE DECREASING

	Sub-Section		Length (1)		(2) Vol.-Equiv. Veh. (vph)	(3) Weaving Effect (vph)	(4) Cap. C (vph)	(5) V/C	(6) Speed	(7)	(8) Individual Travel Time (1)/(7)	(9)	(10) Adjusted Volume (vph)	(11) Avg. Occ. Pass./Veh.	(12) Travel Time	(13)	(14) Travel Dist.	(15)
	No.	Type	(Feet)	(Mi.)					OP. (mph)	AVG. (mph)	(hrs.)	(min.)			1/4(10)(8) (v-hrs)	(11)(12) (p-hrs)	1/4(10)(1) (v-mi)	(11)(14) (p-mi)
Normal	7	NOR	5280	1	7627	0	8000	.95	42	41	.0244	1.45	$7627 \times \frac{7437}{7462} = 7601$	1.56	46.36	72.46	1900	2970
Normal	6	NOR	2640	1/2	8000	0	8000	1.00	36	36	.0160	.84	$8000 \times \frac{7787}{7827} = 7959$	1.65	27.86	45.94	995	1641
Normal	5*	NOR	5280	1	7596	0	8000	*	*	*	.0260	1.56	$7596 \times \frac{7385}{7423} = 7557$	1.65	49.55	81.05	1889	3117
Priority Sect.	4	RES	7920	$1\frac{1}{2}$	531	0	1500	.35	49	48	.0312	1.87	513	6.10	4.00	24.40	192	1174
Priority Sect.	4	UNR	7920	$1\frac{1}{2}$	5549	0	6000	.92	44	43	.0350	2.10	5549	1.23	48.55	59.62	2081	2555
Priority Sect.	3	RES	7920	$1\frac{1}{2}$	531	0	1500	.35	49	48	.0312	1.87	513	6.10	4.00	24.40	192	1174
Priority Sect.	3	UNR	7920	$1\frac{1}{2}$	5699	0	6000	.95	42	41	.0367	2.20	5699	1.23	52.29	64.53	2137	2637
Normal	2	NOR	5280	1	6242	0	8000	.78	51	49	.0205	1.23	6212	1.64	31.84	52.06	1553	2539
Normal	1	NOR	5280	1	5742	0	8000	.72	53	51	.0198	1.19	5727	1.53	28.35	43.28	1432	2186
	TOTALS		39600	$7\frac{1}{2}$											296	468	12371	19993

*SEE TABLE G2 IN APPENDIX G FOR SPECIAL CALCULATIONS IN SUBSECTION 5

TABLE 20 COMPUTER OUTPUT – TIME SLICE 3

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SUB SECT	FIELD ORIG	DEMD, DEST	ORIG. TOTAL	RESERVED PRIORITY OPERATIONS: NL	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME
1	5742.	[illegible]	5742							
2	[illegible]	[illegible]	6242							
3	[illegible]	15[illegible]	6242	1	531	15[illegible]	.35	11.	48.	1.87
4	[illegible]	[illegible]	[illegible]	1	531.	1500.	.35	11.	48.	1.87
5	1331.	[illegible]	[illegible]							
6	404.	374.	[illegible]							
7	0.	7626.	[illegible]							
					(2)	(4)	(5)		(7)	(9)

		QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP [illegible]	INPUT POINT	[illegible]	0.
	MERGING POINT	4.75	3.32
	TOTAL	4.75	3.82

UNRESERVED OR NORMAL OPERATIONS

UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
N	4	5742.	8000.	0.	.72	28.	51.	1.19		5280.	0	0.
N	4	6242.	8000.	0.	.78	32.	49.	1.23		5280.	0	0.
U	3	5699.	6000.	0.	.95	46.	41.	2.20		7920.	0	0.
U	3	5549.	6000.	0.	.92	43.	43.	2.10		7920.	0	0.
N	4	7596.	8000.	0.	.95	50.	38.	1.56	*	5280.	423	-88.
N	4	8000.	8000.	0.	1.00	56.	36.	.84		2640.	0	0.
N	4	7626.	8000.	0.	.95	46.	41.	1.45		5280.	0	0.
		(2)	(4)	(3)	(5)		(7)	(9)				

TABLE 21 COMPUTER OUTPUT – SUMMARY – TIME SLICE 3

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TRAVEL TIME FOR NON-PRIORITY TRIP  .01 MINUTES

 0       1       2       3
 1    46[illegible].   [illegible]13.  1[illegible].
 2    343.    7[illegible]4.   [illegible]4[illegible].
 3      [illegible].    241.   3[illegible]7.
 4      [illegible].    [illegible]4.   23[illegible].

TRAVEL TIME FOR THE PRIORITY TRIP .01 MINUTES
 0       1       2       3
 1    42[illegible].   [illegible]3.  10[illegible]4.
 2    3[illegible].   7[illegible].   [illegible]5.
 3      0.    241.   3[illegible]7.
 4      0.    [illegible]4.   2[illegible].

                                         CURRENT TIME INTERVAL                 CUMULATIVE VALUES
FREEWAY TRAVEL TIME (T[illegible])        [illegible]. VEH-HRS    [illegible]4. PASS-HRS     422. VEH-HRS     761. PASS-HRS
FREEWAY TRAVEL TIME (T[illegible])        1[illegible]1. VEH-HRS    124. PASS-HRS     223. VEH-HRS     274. PASS-HRS
FREEWAY TRAVEL TIME ([illegible])          [illegible]. VEH-HRS     4[illegible]. PASS-HRS      2[illegible]. VEH-HRS     180. PASS-HRS
        INPUT DELAY ([illegible])          [illegible]. VEH-HRS      6. PASS-HRS       7. VEH-HRS      13. PASS-HRS
        INPUT DELAY ([illegible])          [illegible]. VEH-HRS      0. PASS-HRS       [illegible]. VEH-HRS       0. PASS-HRS

TOTAL TRAVEL DISTANCE              12[illegible]4. VEH-MI.   1[illegible]52. PASS-MI.    30175. VEH-MI.   55706. PASS-MI.
                                       (14)               (15)
TOTAL TRAVEL TIME UNDER
PRIORITY OPERATIONS                   [illegible]. VEH-HRS.    4[illegible]3. PASS-HRS     672. VEH-HRS    1223. PASS-HRS
                                       (12)               (13)
```

TABLE 22 COMPARISON OF MANUAL CALCULATIONS WITH COMPUTER CALCULATIONS
TIME SLICE 3 - QUEUE DECREASING

		VEH-HR.		PASS-HR.	
		Manual Σ(12)	Computer	Manual Σ(13)	Computer
FREEWAY TRAVEL TIME	Normal Sections	184.	183.	295.	294.
	Unreserved Section	101.	101.	124.	124.
	Reserved Section	8.	8.	49.	49.
	Input Delay	4.	4.	6.	6.
TOTAL TRAVEL TIME		297.	296.	474.	473.

	VEH-MI.		PASS-MI.	
	Manual Σ(14)	Computer	Manual Σ(15)	Computer
TOTAL TRAVEL DISTANCE	12,371.	12,354.	19,993.	19,952.

queue, an approximation had to be made which would have an effect on the length of the second queue equal to the effect made if the time interval could have ended at the time of queue collision, followed by a second time interval up to the fifteen minute point. However, in making this approximation, it was assumed that the velocity of the upstream boundary of the queue was a linear function of RA. In testing the program change, although improved over the previous method of neglecting the growth of the second queue until the time of queue collision, it was found that adding an auxiliary lane to the upstream queue bottleneck increased the resultant RA of the downstream bottleneck. This caused an earlier queue collision, a greater queue length, and an increased total travel time. This error was probably due to the linear relationship assumed between RA and shock wave velocity.

In addition to the anomaly found during queue collision, it is also possible to discharge more vehicles from a queue than were stored in it. This error, less serious than the first, is due to both the constant length of time interval and the method of calculating the number of vehicles in a queue, which has been previously discussed in Chapter III in the section dealing with a short queue. The conclusion to draw from the above is that the detailed behavior of individual subsections, especially during queue collisions, cannot be faithfully modeled by the PRIFRE model, largely because of important events which are somewhat obscured because they occur in the middle of a time interval.

An additional limit to the PRIFRE model is due to the instantaneous propagation of demand from upstream subsections to downstream subsections. Since a real freeway demand is propagated at the mean velocity of all individual vehicles, a study section length of approximately 10 miles is a functional maximum. The mean speed at which vehicles would have to travel in order to cross a 10-mile study section in 15 minutes is 40 miles per hour. Study sections longer than 10 miles will introduce errors in the demand of far downstream subsections.

Limitations of a not-so-fundamental nature are due to programming restrictions. Some examples of this are: 1) the requirement that subsection capacities remain constant over time slices; 2) the requirements that subsection demands remain constant over one time slice; and 3) if off-ramp demand exceeds the ramp capacity, no queueing calculations take place, and only a warning message occurs. These limitations can be corrected by making relatively minor changes in the program.

Finally, PRIFRE was not written to include diverge-point queues upstream of off-ramps. The only allowance made for heavy off-ramp traffic is that a message will be printed if off-ramp demand exceeds the off-ramp limits set by the user. No effort is made to compute the total volume in lane one upstream of off-ramps.

2. Summary (see Table 23)

This freeway model is built upon the four basic assumptions that (1) traffic demand is described by step functions of time; (2) traffic flow is treated as a compressible fluid; (3) subsection capacities are evaluated using the Highway Capacity Manual methods

TABLE 23 LIMITATIONS IN EXCBUS MODEL AND

COMMENTS ON EXTENDED PRIFRE MODEL

	LIMITATIONS IN EXCBUS MODEL	COMMENTS ON EXTENDED PRIFRE MODEL
A.	No on and off-ramps - demand does not change over length	15 minutes O-D demand tables include on and off-ramps.
B.	2 demand curves - triangular and trapezoidal demand variation over time.	15 minutes O-D demand table
C.	capacity is constant over time and distance	15 minute calc. of capacity for each subsection
D.	uniform bus demand or constant proportion bus demand	separate 15 minute O-D demand tables for buses
E.	distribution of which occupancies constant over time	15 minute bus occupancy and passenger car occupancy permitted
F.	same speed-flow-density relationship for normal, unreserved and reserved lane	each subsection of each special roadway may have any one of 9 curves
G.	trucks assumed to be the same as passenger cars	truck factors included in calculated capacity
H.	uniform distribution of volume over all lanes of multi-lane facility	special analysis made of right lanes in merge areas
I.	vehicles use lanes as assigned	still true, except when reserved lane exceeds capacity

(except for some bottleneck subsections); and (4) demand is instantaneously propagated downstream as opposed to propagation at the mean speed of the traffic. Upon this framework, ramp analysis and weaving analysis are superimposed to give more realistic results in weaving sections and at merge points.

Traffic demand is specified in the form of two origin-and-destination tables for every 15-minute time period. Formats for coding the O-D table and the other input data were discussed. Also, examples of possible output statements and rules for interpreting them were given.

As insurance against possible errors in programming, the results of manual calculations were compared to results of the computer model. All differences between these two sets of results were small and can be attributed to round-off errors of the manual calculations. These manual calculations confirmed that the operational computer program gave the results expected.

With this reliable program, schemes for obtaining model results which were close to actual conditions were discussed. This includes modification of bottleneck subsection capacities by using actual vehicle counts from the peak period, and changing the speed-volume relationship to one which more accurately describes the particular traffic being studied.

Although additional work and refinement could be made to expand and improve the PRIFRE model, nevertheless there are many areas of application in which the Model can be utilized. The Model can be applied to evaluating priority lane operations, reversible lane operations and other types of special operations. It is also felt the Model can be used in connection with planning future urban freeway systems, in evaluating existing freeway systems, and even possibly as part of on-line control.

5. PROCEDURE FOR APPLICATION OF THE PRIFRE MODEL

The procedure for the application of the PRIFRE model to Marin Route 101 for the afternoon peak period in the northbound direction is outlined and explained below. The existing base year freeway characteristics and the freeway characteristics after the first stage of lane addition from Spencer Avenue to the Richardson Bay Bridge (to be completed in late 1972) are summarized in Fig. 16.

The data needed to evaluate possible priority lane operations on Marin Route 101 was obtained primarily from the California Division of Highways and the Golden Gate Bridge, Highway and Transportation District. Much of the available data was collected at different times and roadway situations. When data was discrepant or lacking, engineering judgement was used and the assumptions and their model sensitivities are included in the following discussions.

This example application is intended only to show the procedures that one must go through in an evaluation process of possible freeways improvement schemes using the PRIFRE model. It is not intended that the numerical results in any way suggest the course of action to be taken by the transport agencies who must weigh multiple objectives and consider all possible alternatives related to the improvement of traffic operations. The following application of the PRIFRE model will not be used to evaluate the "wrong way" exclusive bus lane operation although the data set used in the following examples can be readily converted to include such an analysis in addition to or in combination with other freeway improvement schemes such as ramp control or preferential bus entry.

Subsection Number		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Length (feet)		200	400	5400	600	300	600	600	3000	1050	1600	2320	2500	550	4850	1300	1000	1400	3000	800	3600
No. of Lanes	Existing Design	4	4	4	4	4	4	4	4	4	4	4	3	3	3	3	3	3	3	3	3
	New Design	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3
Lane Width (feet)		11	11	11	11	11	11	11	11	10	11	11	11	11	11	11	11	11	12	12	12
Lateral Clearance		No Shoulders – Turnouts Only												8'	8'	8'	8'	8'	2.5'	8'	8'
Width Factor		–	.90	.90	.87	.87	.87	.87	.87	.85	.87	.87	.87	.95	.95	.95	.95	.95	.92	1.00	1.00
% Grade		0	0	0	0	0	+3	+6	+6	+5	+6	+6	-6	-6	-6	-6	-6	-3	0	0	0
% Trucks (and Buses)		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Truck Factor		–	.97	.97	.97	.97	.97	.72	.72	.72	.72	.97	.97	.97	.97	.97	.97	.97	.97	.97	.97
Capacity (vph)	Existing	10,000	7200	7200	6890	6751	6751	6500	6500	6400	6500	6961	5470	5470	5470	5470	7470	5470	5470	5820	5820
	After Improvement	10,000	7200	7200	6890	6751	6751	6500	6500	6400	6500	6961	7294	7294	7294	7294	7294	7294	7294	5820	5820
Capacity of One Reserved Lane			← BEGINNING OF PRIORITY LANE 1500 vph/LANE END OF PRIORITY LANE →																		
Speed-Flow/ Capacity Curve Number	NOR	3	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	UNR	3	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
	RES	3	4	1	1	1	2	3	3	3	2	2	2	4	4	1	1	1	5	5	5

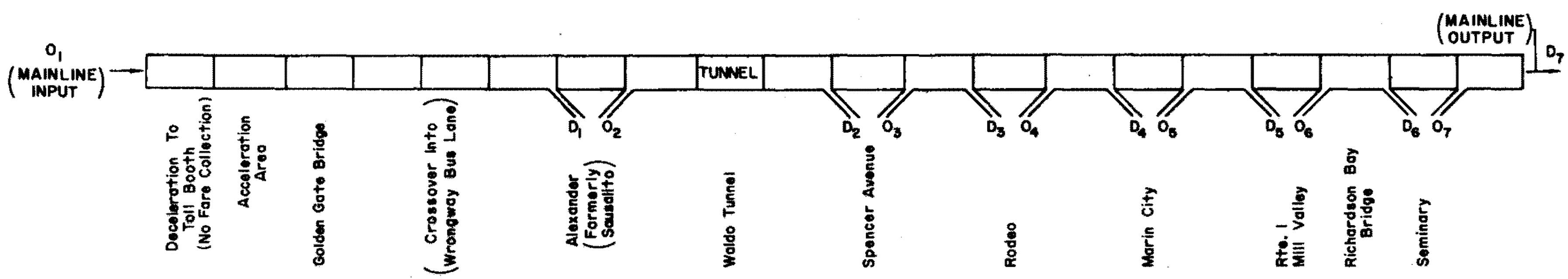

FIGURE 16 MARIN ROUTE 101 FREEWAY CHARACTERISTICS – NORTHBOUND DIRECTION – AFTERNOON PEAK PERIOD

A. Description of Site

The selected site is located in the San Francisco Bay Area. The freeway section to be studied on Route 101 extends approximately 5 miles north from the south end of the Golden Gate Bridge to the Richardson Bay Bridge in Marin County. The per capita income in Marin County is among the highest in the nation and there is a tendency for families to depend on the automobiles.

Several freeway improvements have been studied to alleviate the peak period and weekend congestion on this main facility which connects San Francisco with Marin County. As a first measure, a "wrong way" exclusive bus lane will be operated in late 1972 during the afternoon peak period in the northbound direction following a widening of a section of Route 101 to a full four lanes. The travel time during the peak hours over this section of the roadway for buses has often been 10% greater than the travel time by cars.* The sustained grades have limited the average speeds of buses to less than 30 miles per hour on the upgrade.

As noted in the California Division of Highways Project Report #3052 (Reference 18), the operation of the exclusive bus lane is not expected to result in significant travel time savings but rather it is hoped that the effort will affect modal split and better coordination of local agency activity. In fact, the bus operation taken over by the Golden Gate Bridge, Highway and Transportation District has attracted over 1000 commuters at least 9 months before the exclusive

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*Arthur Jenkins, Prospective Participation in a Public Transit Bus System by the Golden Gate Bridge and Highway District, 1968. p. 70.

bus lane is to be in operation.

A major factor in the sudden increase in bus ridership is that of the 154 buses operated by the agency, 132 are brand new air-conditioned with either reclining seats for long haul runs or non-reclining high-backed seats for local service. Bus interiors are brightly colored and have wide aisles and ample legroom. Service has been extended both in frequency and scope. The more convenient new downtown San Francisco routing is accepted by both commuters and drivers.

B. Demand Characteristics

1. Origin-Destination Tables for Buses and Non Buses.

In order to develop an adequate data base for analysis of improvement to freeway operations on the PRIFRE model, new data collection activities may be required if the local transport agencies cannot supply the necessary information. Three kinds of traffic data help in preparing a complete set of O-D tables for the input data to the PRIFRE model : (1) volume counts, (2) aerial photographs, and (3) O-D surveys.

Volume counts for this purpose should be quite extensive and should include counts at all on- and off- ramps within the study section as well as the freeway volume counts near the beginning and near the end of the study section, during the peak demand hours. The volume counts are to be entered as buses per hour in the O-D table for buses and car passengers per hour in the O-D table for non-buses for each 15 minute time slice interval during the peak period.

Storage of vehicles upstream of the beginning of the study section and at the on-ramps can be estimated from aerial photographs. The actual volume count plus the excess storage gives the demand which should be inputted to the PRIFRE model. Details of the method of computing excess demand from aerial photography are described in the Eighth Interim Report of the Bay Area Freeway Operations Study.*

The destination pattern for each on-ramp demand can be determined from the results of an O-D survey. The demand at each on-ramp is distributed among all downstream off-ramps (including the mainline exit of the study section, according to the destination pattern for each on-ramp.)

It would be desirable to conduct an O-D survey so that the destination pattern of each on-ramp vehicle is known. However, if this survey is not available and cannot be undertaken, it is possible to make up an O-D table with knowledge of the on- and off-ramp counts and some mainline freeway counts. In this case, the construction of the O-D table may be simplified by assuming that no vehicle that enters the freeway from an on-ramp will desire to exit at the next possible off-ramp. The on-ramp demands are distributed downstream in proportion to the off-ramp demands. Finally, the freeway input demand is distributed among all off-ramps in such a way that each vertical sum and horizontal sum in the O-D table becomes equal to the corresponding off-

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*Gillfillan, Walter E.,"Bay Area Freeway Operations Study, Eighth Interim Report." Berkeley: University of California, Institute of Transportation and Traffic Engineering, March 1969. (Special Report).

ramp and on-ramp demand. This method of determining the input demand destination pattern is expedient because in practice it may be very difficult to obtain dependable O-D information. The following example applies the procedure just described.

2. Bus and Auto Occupancy Data

The success of a priority lane operation will necessarily depend on the initial vehicle occupancies. Adequate samples of auto occupancy data must be collected thru field surveys or obtained from the local transport agencies. Commuter bus occupancy data can be best obtained from the transit agencies. For each time slice during the peak period, it will be necessary to enter the average bus occupancy and the distribution of cars according to their passenger occupancies after the time slice identification card as shown in Fig. 17.

Occupancy distributions are sensitive to many factors such as weather, socio-economic conditions, or changes in transit or freeway operations. It is therefore necessary to note these varying conditions when evaluating priority lane schemes.

C. Freeway Characteristics

The freeway parameters that are necessary to evaluate freeway operations on the PRIFRE model are shown in Fig. 16. The following descriptions will help determine the parameters to be inputted into the simulation model.

1. Freeway Capacity

The following description that is adapted from the FREEQ manual is helpful in determining the capacities of the freeway subsections.

```
E2296,1,100,50000,400. LEW BEFORE 2 OLD DESIGN NORMAL OPERATIONS
REQUEST,PRIFRE.0025
CLDR,I=PRIFRE.(UNLOAD).

MODEL APPLICATION TO MARIN 101  BEFORE LANE IMPROVEMENTS FEB 72 DATA
 20   4.   2.   2. 0
  1  410000      200  3        .97   O   TOLL BOOTH
  2  4 7200      400  4        .97       ACCELERATION  AREA
  3  4 7200     5400  5        .97       GOLDEN GATE BRIDGE
  4  4 6890      600  5        .97
  5  4 6751      300  5        .97       WRONG WAY BUS CROSSOVER
  6  4 6752      600  5        .97    D  NEGLECT VISTA POINT ON-OFF RAMP,SMALL V
  7  4 6500      600  5        .72       ALEXANDER (FORMERELY SAUSALITO)
  8  4 6500     3000  5        .72   O
  9  4 6400     1050  5        .72       WALDO TUNNEL
 10  4 6500     1600  5        .72    D
 11  4 6961     2320  5        .97       SPENCER
 12  3 5470     2500  5        .97   OD
 13  3 5470      550  5        .97       RODEO
 14  3 5470     4850  5        .97   OD
 15  3 5470     1300  5        .97       MARIN CITY
 16  3 7470     1000  5        .97   OD  CAPACITY  ADJUSTED  LARGE WEAVE EFFECT
 17  3 5470     1400  5        .97       BUS CROSSOVER
 18  3 5470     3000  5        .97   OD  MAILINE-RICHARDSON BAY BRIDGE
 19  3 5820      800  5        .97
 20  3 5820     3600  5        .97   OD  MAINLINE SOUTH OF TIBURON OFF
  1500
   3  0.0    25.    .65   24.   .85   24.   .95   23.    1.00  22.
   3 -1.00   22.   -0.0    0.
   4  0.0    49.    .65   37.   .85   33.   .95   26.    1.00  22.
   4 -1.00   22.   -0.0    0.
   5  0.0    55.    .90   46.   .95   44.   1.00  30.   -1.00  30.
   5  -.95   26.   -.90   23.   -.50   10.  -0.0    0.
```

***IMPORTANT! INSERT A BLANK CARD HERE WHEN INPUTTING SPEED-FLOW/CAPACITY CURVES.**

```
TIME SLICE 1  330-345
 40. 73.4 23.2  2.0  1.0  .4
                              1



 165 132     106 686 3003677
              13  13  10  26
              13  13  10  26

                  52  40 597
                         290
                         157
TIME SLICE 2, 345-400
 40. 73.4 23.2  2.0  1.0  .4
       1

               1
```

Figure 17 : Data Listing for Existing Design

a. H.C.M. Method. It is desirable to undertake a capacity analysis using the Highway Capacity Manual to make a first estimation of freeway capacities for the PRIFRE Model. The reasons for doing so are: (1) it is practically impossible to conduct all the necessary traffic surveys to obtain capacities for all the subsections; (2) even if enough data is available, capacities of subsections which are influenced from near upstream or downstream bottleneck sections can never be determined by actual traffic surveys; and (3) the Highway Capacity Model gives fairly good results for freeway subsections with normal design features.

The capacity analysis method is described in Chapter II. All the design and traffic elements which affect the freeway capacity should be prepared as shown in Fig. 16. If a subsection has a short auxiliary lane less than 4,000 feet, the Highway Capacity Manual does not provide a direct method for estimating the freeway capacity. Judgment on the part of the user will be required in such cases. It may be possible to approach the problem by using a modification of the Highway Capacity Manual. Other possibilities are described in the following two sections.

b. Actual Volume Measurement. If results of actual traffic data analysis indicate the existence of certain bottlenecks, and the actual capacity rates of flow are known for those bottleneck subsections, these actual capacities should be used as input to the model instead of the capacities calculated using the Highway Capacity Manual. Following are additional comments for adapting actual traffic data to the capacity input data:

(1) Even an actual capacity varies, depending upon several factors, such as the composition of traffic, weaving volumes, merging volumes, and the severity of congestion. Among the record of traffic counts for capacity flow conditions, an appropriate value of capacity should be selected, so that the model will simulate actual traffic conditions best.

(2) If a bottleneck subsection is in a weaving section, the weaving effect should be added to the actual capacity, because capacities are modified by subtracting the weaving effect from the freeway capacity in the model computation process.

2. Reserved Lane Capacity

Traffic flow data is currently not available to determine the capacity of a reserved lane on a freeway section under priority operations. It was assumed that the capacity of the reserved lane as modeled by PRIFRE approximates the conditions of tunnel traffic flow behavior. The large samples of speed, concentration and traffic flow data obtained in the Lincoln and Holland Tunnels, New York City indicate that on a level section, with 30% bus composition, alternate bus-car flow can be expected to achieve about 1300 vehicles per hour at about 23 mph. The value assumed for the capacity of a single reserved lane was 1500 (equivalent) vehicles per hour. The PRIFRE model assumes that the capacity of two reserved lanes is twice the one reserved lane capacity that is entered on the subsection capacity cards shown in Fig. 29 using the format given in Fig. 7A. If the user feels that the capacity of a two lane section is not exactly equal to twice the capacity of a single lane, he can insert any determined value on the capacity card and run the one and two lane priority operation schemes separately.

3. Speed-Flow/Capacity Curves

For each subsection of the freeway to be studied speed-flow/ capacity curves are necessary to specify the relationships in the normal, unreserved, and reserved lanes. If the design speed of the freeway subsection is known, the Highway Capacity Manual speed-flow/capacity curves which are stored in the PRIFRE program can be utilized by specifying curve numbers 50, 60, and 70 (corresponding to design speeds of 50 mph, 60 mph, and 70 mph) on the subsection capacity card in the field columns for normal, unreserved and reserved lanes.

The user may desire to input different sets of average speed-flow/ capacity curves to simulate the freeway traffic characteristics peculiar to the site, location and traffic behavior. If extensive speed measurements have been made at the same time as the volume counts, and aerial photographs have been taken of the study section, it is relatively easy to calculate the average speed for each subsection at each time interval. Using actual volume counts and estimated subsection capacities, the actual measured speeds can be plotted on the average speed- v/c ratio graph. In plotting actual average speeds, the average speeds for queueing traffic conditions should be clearly distinguished from those of non-queueing traffic conditions. These user supplied curves can then be numbered 1,2,3,4, or 5 and coded to be inputted into the PRIFRE model following the format described in Chapter 3.

D. Evaluation Strategy

The first step in the evaluation of freeway improvement schemes using the PRIFRE model involves calibrating the output of the simulation model to approximate the existing freeway conditions. The possible freeway improvement strategies can then be formulated and analyzed to determine the effect of measures taken to meet the stated objectives.

The one- and two-reserved lane concept will be analyzed for a section of Marin Route 101 for the afternoon direction following the addition of a lane from Spencer Avenue on-ramp (subsection 12) to the Richardson Bay Bridge (subsection 18). This new freeway design is the first of a series of scheduled lane additions and will be completed by late 1972. The existing design consists of four lanes extending from the Golden Gate Bridge (subsection 2) narrowing to three lanes at the beginning of subsection 12.

The first computer simulation run of normal freeway operations on Route 101 with the existing design using the data collected or assumed indicated that the PRIFRE model gave longer congestion time periods for major bottlenecks and did not indicate the minor bottlenecks that were observed on the speed and density contour maps supplied by the Division of Highways. The speed and density contour maps which were plotted from the computer output made it apparent that the modeling should not be used without modification of the input data.

1. Model Calibration

Previous experience with the FREEQ model indicated that the modeling tends to estimate greater travel times and longer congestion periods. It was assumed that during evening peak hours drivers travel on the study section with higher speeds for a given flow level than the speed level estimated from Fig. 9-1 of the Highway Capacity Manual, and that the actual capacities of the study section may be a little different from the capacities calculated strictly following the Highway Capacity Manual method, particularly for short weaving sections.

a. Speed-flow/capacity relationships

It was suggested by the freeway operations engineers of the California Division of Highways that the assumed 55 mph speed-flow/capacity relation developed from data collected on the Oakland Bay Bridge was more representative of the traffic characteristics on Route 101. No further attempt was made to change the speed-flow/capacity relationships for the normal operations of the existing freeway design. The assumed 55 mph speed-flow/capacity relation that is shown in Fig. 18 remains linear until about v/c = .9. The user can utilize the 65 mph speed-flow/capacity relation developed for the Eastshore Freeway by specifying the number 65 in the appropriate fields for speed curves on the capacity card.

b. Capacity Adjustments

Capacity adjustments at the bottleneck subsections were estimated both from the actual freeway volume counts and the relationship between bottleneck subsection demands and the length of the congestion periods. To compensate for the large decrease in the capacity due to the weaving volumes, the weaving effect volume was added to the original capacity of subsection 16.

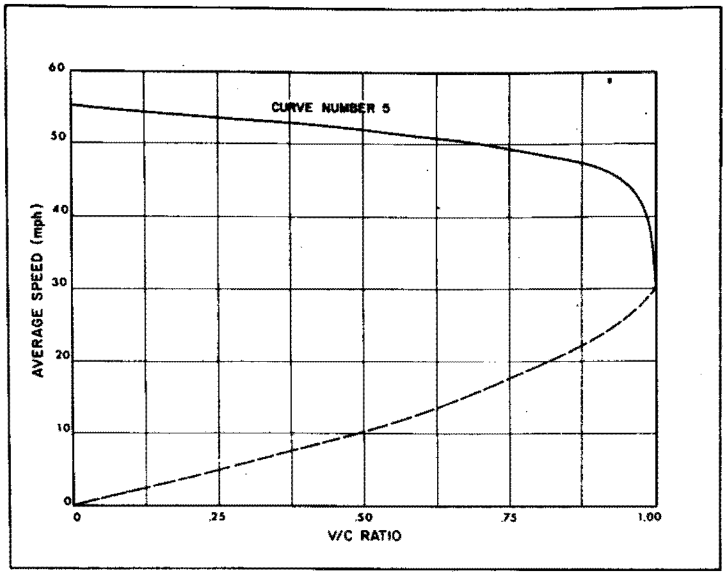

FIGURE 18: 55 mph SPEED-FLOW/CAPACITY RELATIONSHIP FOR OAKLAND BAY BRIDGE

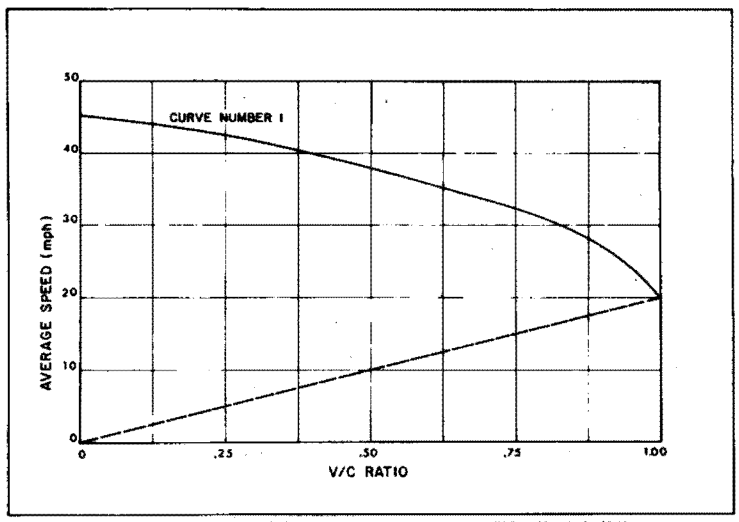

FIGURE 19: SPEED-FLOW / CAPACITY RELATIONSHIP IN ONE RESERVED LANE (DATA TAKEN FROM HOLLAND TUNNEL TRAFFIC FLOW STUDIES)

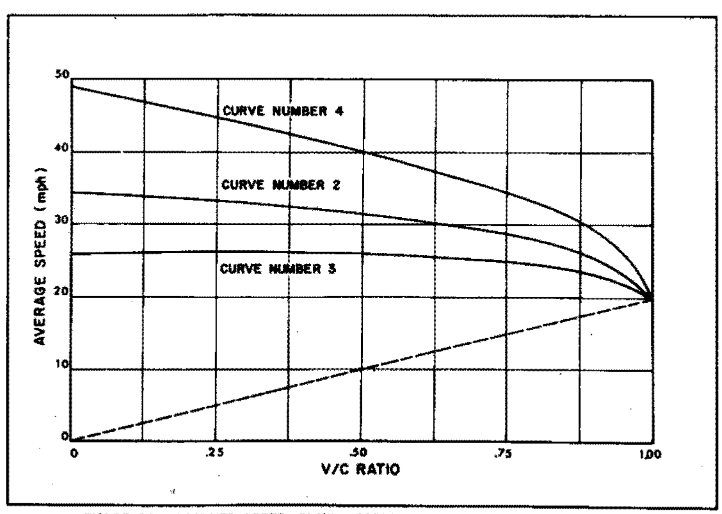

FIGURE 20: ASSUMED SPEED-FLOW / CAPACITY RELATIONSHIPS FOR ONE RESERVED LANE ON SUSTAINED GRADES ON MARIN ROUTE 101

c. Reevaluation

The model was retested with the adjusted capacities, new speed and density contours maps replotted, and again compared to the contour maps supplied by the Division of Highways. It was evident that the model was creating queues extending too far back from the bottleneck subsections. The possibility of incorrect ramp and mainline volume counts due to field measurements or changing traffic conditions caused by the recent shift into the newer buses was investigated. After consultation with the Division of Highways and the Golden Gate Bridge, Highway and Transportation District, adjustments were made to decrease the critical volumes that affect the queueing and bottleneck situations. The final adjustments made to the original data that best simulate existing traffic operations are shown in the data listing in Fig. 17.

2. Simulation of Existing Freeway Under Normal Operations

The output results from the calibrated model of the existing freeway under normal operations can be summarized and plotted in many ways. Figure 21 shows the single trip travel time for each 15 minute time interval during the peak period. Figure 22 relates the total travel time (passenger hours) expended during each time slice interval. These values shown and the summary tables from the computer output indicate that the simulation of the existing freeway characteristics can be used as a basis for comparing possible freeway improvement schemes.

3. Evaluation of New Design Under Normal Operations

The first stage of planned improvements to the operation of Route

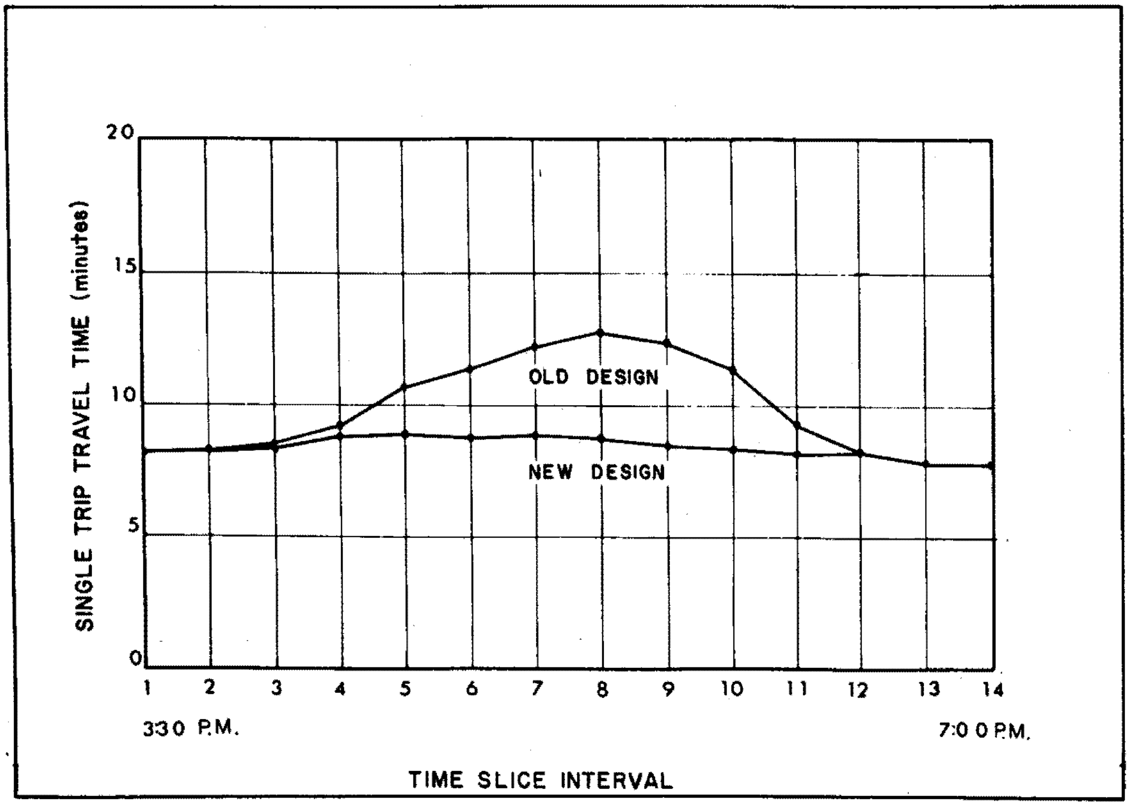

FIGURE 21: COMPARISON OF SINGLE TRIP TRAVEL TIME

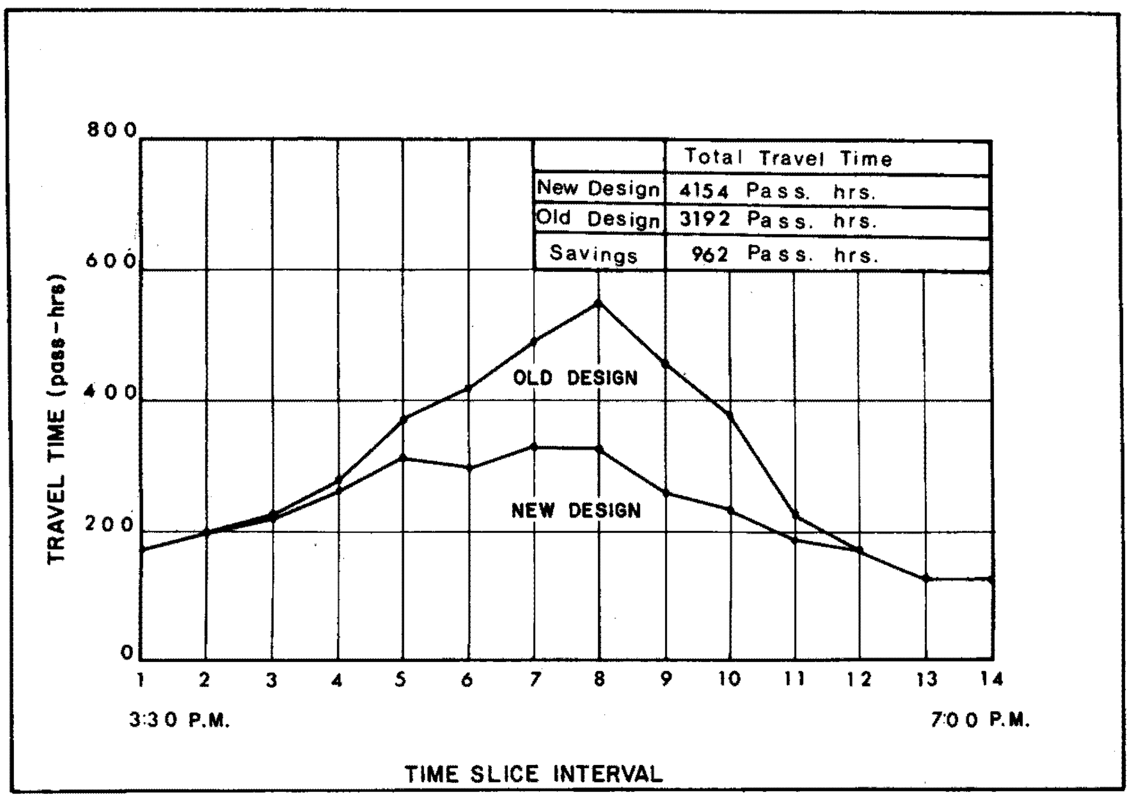

FIGURE 22: COMPARISON OF TRAVEL TIME BETWEEN OLD AND NEW DESIGN

101 involves the addition of a lane in the northbound direction in subsections 12 thru 18 (Richardson Bay Bridge) to be completed in late 1972 prior to the operation of the "wrong way" exclusive bus lane. The capacity cards that were coded to evaluate the old existing design were revised to reflect the lane addition and the resulting new freeway capacities (shown in Fig. 23). Demand patterns were assumed to be the same. The new data deck was rerun to evaluate the effect of this change in design on the operation of the freeway.

Results from the computer simulation of the freeway improvement scheme are compared to the freeway travel time on the existing freeway in Figs. 21 and 22. The summary of the freeway travel conditions shown in the computer output indicated that with this lane addition the congestion experienced on the old design has been eliminated. The weaving effect in subsection 16 remains, but the effect on the subsection capacity is not as critical. The comparison of total travel times with the existing operations show a travel time savings of 962 passenger hours for the afternoon peak period. The single trip travel time for the section under study drops below 9 minutes for the entire peak period after the lane is added.

If it is desired, for example, to operate priority lanes on this section of roadway, it is evident that the travel time for priority vehicles must be below 9 minutes in order to justify operations. The excess capacity in each subsection of roadway for each time interval under the new design can be found from the output summary tables and drawn as shown in Figs. 24, 25, to aid in determining the effect of reserving one or two lanes for use by priority vehicles. The contour

```
E2296,1,200,40000,600. LEW AFTER 2  NEW ONE RESERVED LANE, WITH SHIFTS
REQUEST,PRIFRE.0025
CLDR,I=PRIFRE.(UNLOAD).
'
MODEL APPLICATION TO MARIN ROUTE 101 NEW DESIGN WITH ONE RESERVED LANE SCH. 1-2-
  20   4.   2.   2. 3              5  .
  1  410000.         200   3   3   3 .97    0    TOLL BOOTH
  2P 4 7200 1500  400   4   4   4 .97        ACCELERATION AREA,START RESERVED LANES
  3P 4 7200 1500 5400   5   5   1 .97         GOLDEN GATE BRIDGE
  4P 4 6890 1500  600   5   5   1 .97
  5P 4 6751 1500  300   5   5   1 .97         BUS CROSSOVER  VISTA POINT OFF
  6P 4 6752 1500  600   5   5   2 .97     D   NEGLECT VISTA POINT ON-OFF RAMP,SMALL V
  7P 4 6500 1500  600   5   5   3 .72         ALEXANDER (FORMERELY SAUSALITO)
  8P 4 6500 1500 3000   5   5   3 .72    0
  9P 4 6400 1500 1050   5   5   3 .72         WALDO TUNNEL
 10P 4 6500 1500 1600   5   5   2 .72     D
 11P 4 6961 1500 2320   5   5   2 .97         SPENCER
 12P 4 7294 1500 2500   5   5   2 .97    OD
 13P 4 7294 1500  550   5   5   4 .97         RODEO
 14P 4 7294 1500 4850   5   5   4 .97    OD
 15P 4 7294 1500 1300   5   5   1 .97         MARIN CITY
 16P 4 7294 1500 1000   5   5   1 .97    OD   CAPACITY  ADJUSTED  LARGE WEAVE EFFECT
 17P 4 7294 1500 1400   5   5   1 .97         BUS CROSSOVER
 18  4 7294      3000   5   5   5 .97    OD   MAILINE-RICHARDSON BAY BRIDGE
 19  3 5820       800   5   5   5 .97
 20  3 5820      3600   5   5   5 .97    OD   MAINLINE SOUTH OF TIBURON OFF
  1500
   1  0.0     45.      .65     35.     .85     29.     .95     24.     1.00   22.
   1 -1.00    22.    -0.0      0.
   2  0.0     34.      .65     32.     .85     26.     .95     24.     1.00   22.
   2 -1.00    22.    -0.0      0.
   3  0.0     25.      .65     24.     .85     24.     .95     23.     1.00   22.
   3 -1.00    22.    -0.0      0.
   4  0.0     49.      .65     37.     .85     33.     .95     26.     1.00   22.
   4 -1.00    22.    -0.0      0.
   5  0.0     55.      .90     46.     .95     44.    1.00     30.    -1.00   30.
   5  -.95    26.     -.90     23.    -.50     10.   -0.0      0.
```

***IMPORTANT! INSERT A BLANK CARD HERE WHEN INPUTTING SPEED-FLOW/CAPACITY CURVES.**

```
TIME SLICE 1  330-345
  40. 73.4 23.2  2.0  1.0   .4
  40.71.1625.1902.1801.0300.44
  40.68.8127.2402.3601.1100.48
  40.66.3729.3702.5401.2000.52
  40.63.8231.6002.7301.2900.56
                             1




 165 132       106 686 3003677
                13  13  10  26
                13  13  10  26

                   .52  40 597
                           290
                           157
```

Figure 23 : Data Listing for New Design, One Reserved Lane with Shifts.

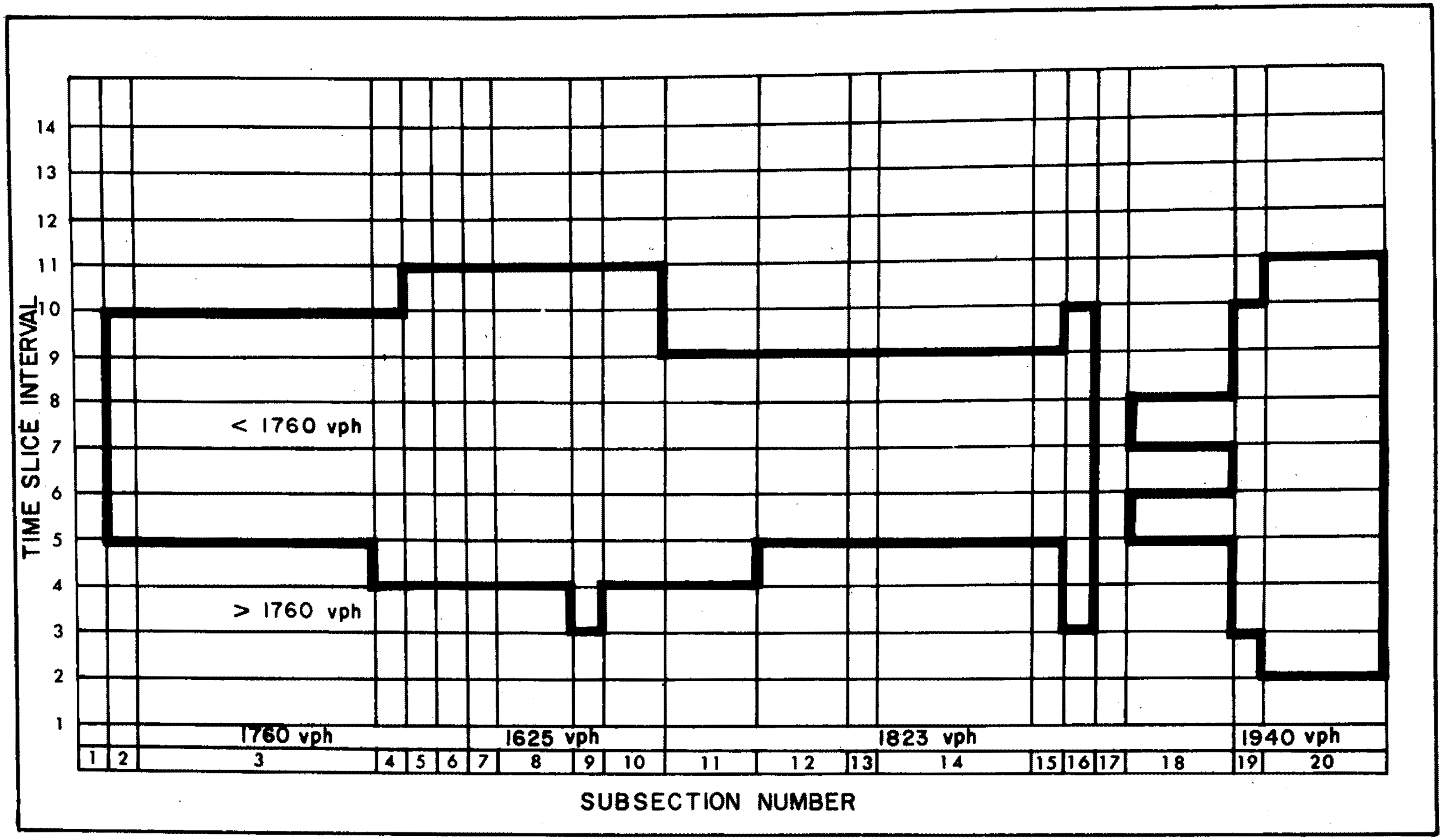

FIGURE 24: ONE LANE EXCESS CAPACITY CONTOUR MAP

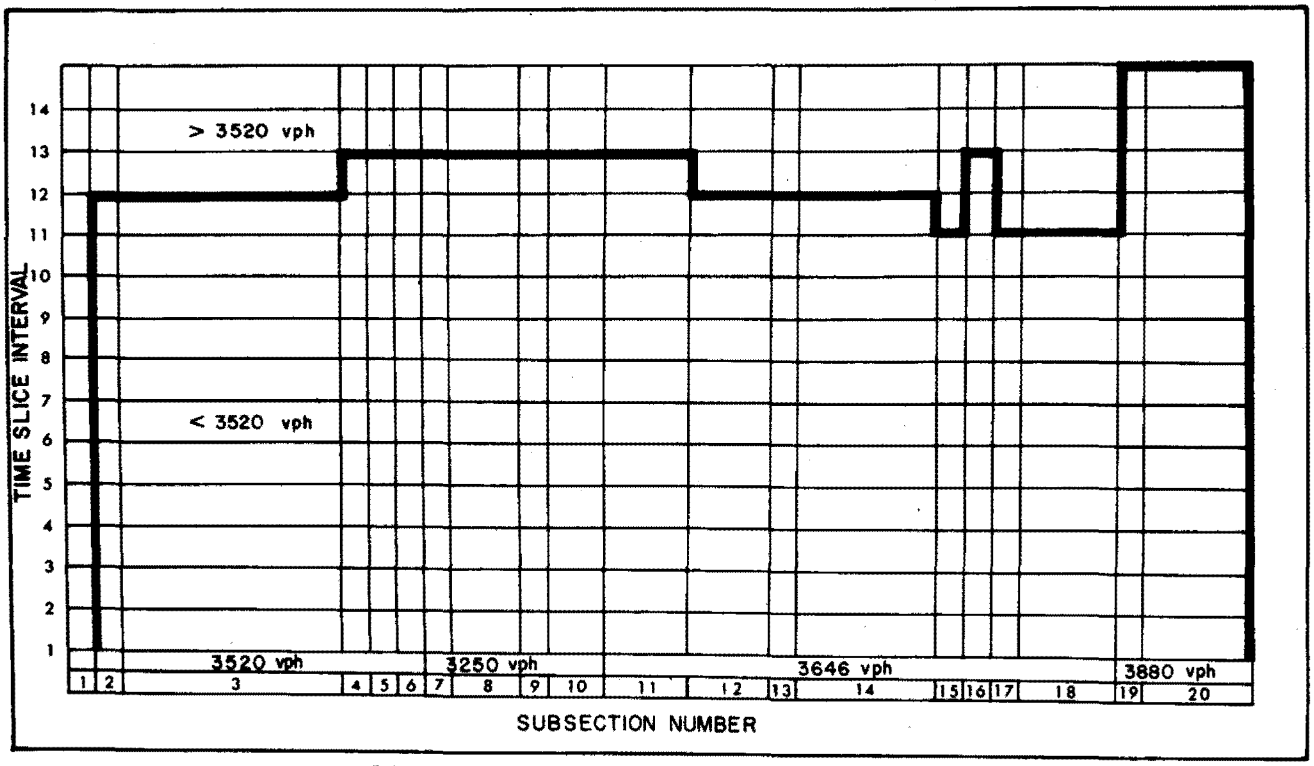

FIGURE 25: TWO LANE EXCESS CAPACITY CONTOUR MAP

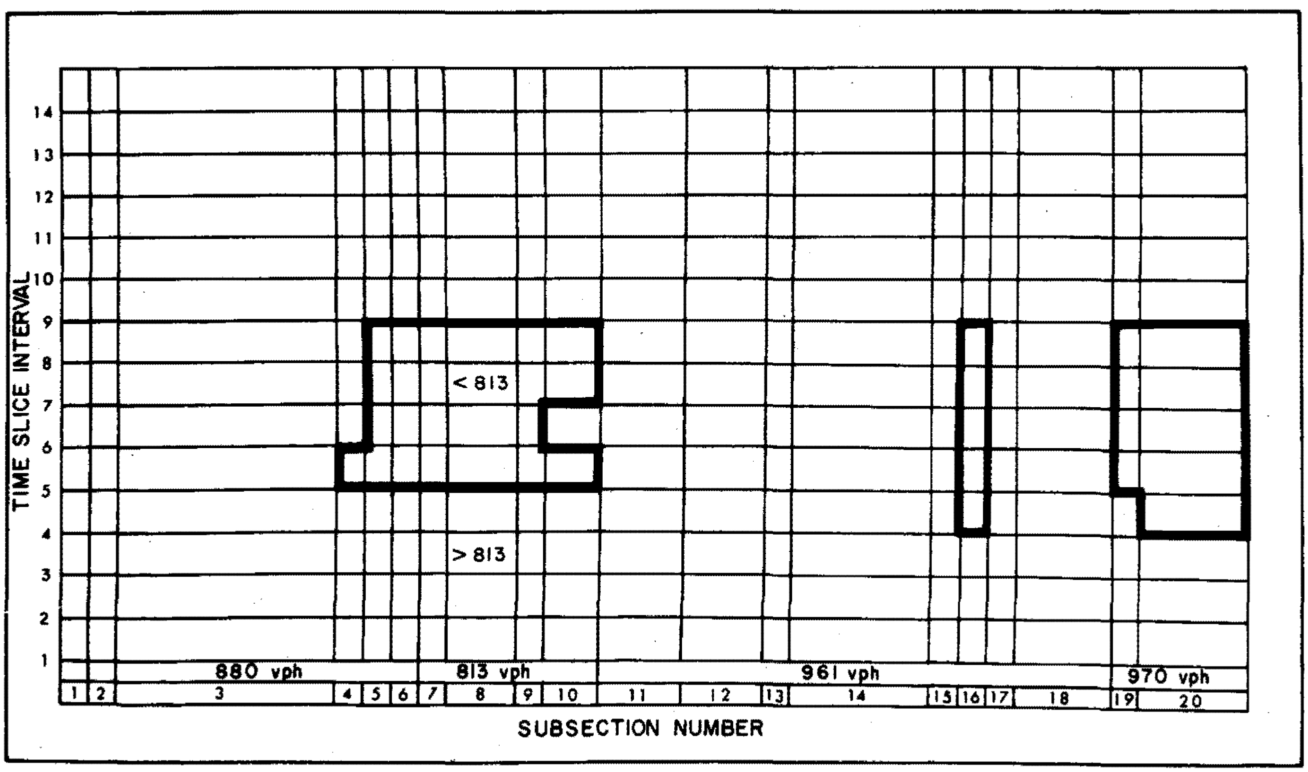

FIGURE 26: HALF LANE EXCESS CAPACITY CONTOUR MAP

lines shown in these figures separate the time and subsections which will be affected by the "removal" of a freeway lane(s) for use by priority vehicles. The half-lane excess capacity contour shown in Fig. 26 gives some idea of the degree that demand would exceed the reduced capacity if a lane were "removed".

Although the design speed of Marin Route 101 was 50 mph the California Division of Highways suggested that the 55 mph speed-flow/capacity relation developed for the Oakland Bay Bridge be used instead. Figure 18 shows this relationship (labeled curve number 5) that was used for evaluating the normal, existing freeway operations.

Because traffic flow data is currently not available to determine the speed-flow/capacity relations of reserved lanes, it was necessary to hypothesize that the speed-flow/capacity relationship of a reserved lane on a level roadway approximated that of tunnel traffic flow. Consequently, data from the Holland tunnel was used to develop speed-flow/capacity relationships to be used for a single reserved lane. This curve is labeled number 1 and is shown in Fig. 19.

Additional speed-flow/capacity curves (numbered 2, 3, and 4) were hypothesized and shown in Fig. 20. These relationships were used to simulate the effect of sustained 6% grades encountered by the buses on Marin Route 101. Even the new buses that will travel in the reserved lane can only negotiate the grades at approximately 30 mph. As later to be discussed, this limiting factor will critically affect the travel time savings when operating one reserved lane and therefore ultimately limit the alternatives available for priority lane operations.

4. Evaluation of Priority Lane Operations Using One and Two Reserved Lanes

The PRIFRE model has been programmed in such a way so as to facilitate the evaluation of priority lane operations on freeways. The following application and discussion of the reserved lane concept to Marin Route 101 will help clarify and show the flexibility of the model to aid in the feasibility analysis of proposed freeway improvement plans. PRIFRE is not an optimal-policy-seeking simulation program, but it can be used as an aid in the search for alternative traffic operation schemes. The numerical results of the following example application of the PRIFRE model are not intended to suggest courses of action for the transport agencies but rather to show how the PRIFRE model can be applied to aid in the analysis of possible freeway improvement schemes.

The hypothesized reserved lane operations would begin at 3:00 PM and last until 7:00 PM with the reserved lane starting immediately at the Golden Gate toll booths at the junction of subsections 1 and 2 and ending at the junction of subsections 17 and 18, south of the Richardson Bay Bridge as shown in Fig. 23.

The effect of weaving at the entrance to and exit from the reserved lane(s) will not be considered. Queueing inside the reserved lane will not be analyzed. Recall that the PRIFRE program will demote priority vehicles to the unreserved lanes when the demand for the reserved lane is exceeded. Non commute buses such as school buses, club buses, and trucks will not be allowed to use the reserved lane. Transit buses which must make stops at off-ramps or enter at on-ramps within the reserved lane section are assumed not to use the reserved lane. At least one vehicle must use the reserved lane in each time interval due to program limitations. Priority operations would be in effect for all the time slice intervals to be analyzed.

Definition: Passenger Shifts into Priority Status Vehicles

The user can define a reasonable shift into buses as follows: an x percent shift into buses occurs when x percent of persons originally occupying autos flowing past a point on the freeway shift into buses. As defined in Reference 15, page 28, the percent shift into buses is based upon person flow past a point on the freeway during the same time period. Person flow past a representative point on the freeway in autos is a smaller number than total person trips in autos using any portion of the freeway under consideration because not all trips traverse the entire length of the freeway. No effort was made to determine the effect of shifts into buses. The computer program shown in Appendix H was developed to help calculate the new auto occupancy distribution when passenger shifts are defined as shown in Table 24. (Note that a 5% passenger shift represents only a 1.9% shift in cars changing to priority status for the given occupancy distribution.)

Definition: Priority Operations Coding Scheme

1 - 2 - 0

- 0 → % shift into priority status cars
- 2 → buses and cars with 2 or more passengers allowed into the reserved lane
- 1 → number of reserved lanes

Definition:

N = Normal Operations
NP. = Non-priority vehicle
P = Priority vehicle

TABLE 24: EXAMPLE CALCULATION OF AUTO OCCUPANCY SHIFT

CAR OCCUPANCIES		BEFORE SHIFT			AFTER 5% PASSENGER SHIFT			Increase in Percent of Total Vehicles Using Facility Changing From Non-Priority To Priority Status
		%Distribution	Vehicles (Cars)	Passengers	Passengers	Vehicles (Cars)	% Distribution	
NON-PRIORITY	1	71.0	710	710	$710 - \frac{710}{1130}(56.5) = 674$	674	69.5	
NON-PRIORITY	2	21.0	210	420	$420 - \frac{420}{1130}(56.5) = 399$	200	20.6	
PRIORITY	3	6.0	60	180	$180 + \frac{180}{270}(56.5) = 218$	73	7.5	
PRIORITY	4	1.0	10	40	$40 + \frac{40}{270}(56.5) = 48$	12	1.2	
PRIORITY	5	1.0	10	50	$50 + \frac{50}{270}(56.5) = 60$	12	1.2	
SUB-TOTALS FOR PRIORITY CARS		8.0	80	270	326	97	9.9	1.9
TOTALS		100.0	1000	1400	1400	971	100.0	

a. One Reserved Lane with New Design

The boundaries of the priority lane as well as the times that priority lane operations should begin and end can be anticipated by analyzing the excess capacity diagrams plotted from the MODEL simulation of the new freeway design under normal operations. After deciding on the capacity of the priority lane, bus equivalency factors, speed-flow/capacity relationships in the normal, unreserved, and reserved lanes, minimum occupancy for priority status, and the type of output desired, the data deck can be recoded to begin analysis of reserving a freeway lane for the use of priority vehicles. Note: IOP can be set to 1,3,5, or 6 to evaluate a one reserved lane scheme.

Under the assumptions previously made, the results of operating one reserved lane on Marin Route 101 are summarized in Table 25. It is evident from Figs. 27b-e that the travel time for priority vehicles is always greater than the travel time under normal operations by about 2 minutes for all schemes considered. Clearly, priority vehicles are not receiving travel time benefits from priority operations. Allowing buses and vehicles with 2 or more passengers (scheme 1-2-0) into one reserved lane would exceed the capacity of the reserved lane during the peak hour even without a passenger shift.

Figure 28 shows the degree of shifts into priority status cars for schemes 1-2, 1-3, 1-4, and 1-5, to produce overall savings in freeway travel time with the one reserved lane concept in effect. The disbenefits in travel time to non-priority vehicles, even after a 20% passenger shift for all schemes considered, more than offsets any gains in travel time by the priority vehicles. Without additional

TABLE 25: SUMMARY OF FREEWAY TRAVEL TIME USING ONE RESERVED LANE (ALL VALUES EXPRESSED IN PASSENGER HOURS)

LEGEND FOR PRIORITY OPERATIONS SCHEMES: PLAN "1-2-0" (first figure: Number of Reserved Lanes; second figure: Buses and Cars with 2 or More Passengers in Reserved Lane; third figure: % Occupancy Shift into Cars)		PRIORITY OPERATIONS SCHEMES				
		Scheme 1-2-0	Scheme 1-3-0	Scheme 1-4-0	Scheme 1-5-0	Scheme 1-6-0 (Buses Only)
TRAVEL TIME UNDER NON-PRIORITY OPERATIONS	NORMAL OPERATIONS	3192	3192	3192	3192	3192
TRAVEL TIME UNDER PRIORITY OPERATIONS USING ONE RESERVED LANE	NORMAL SECTION	644	627	616	609	608
	UNRESERVED SECTION	1780	3804	4040	4239	4304
	RESERVED SECTION	1656	451	299	176	140
	INPUT DELAY IN NORMAL SECTION	0	5587	6161	6866	6997
	INPUT DELAY IN UNRESERVED SECTION	0	66	137	222	229
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS USING ONE RESERVED LANE		4080	10534	11254	12112	12278
TOTAL TRAVEL TIME SAVING OVER NON-PRIORITY OPERATIONS		-891	-7342	-8062	-8920	-9086

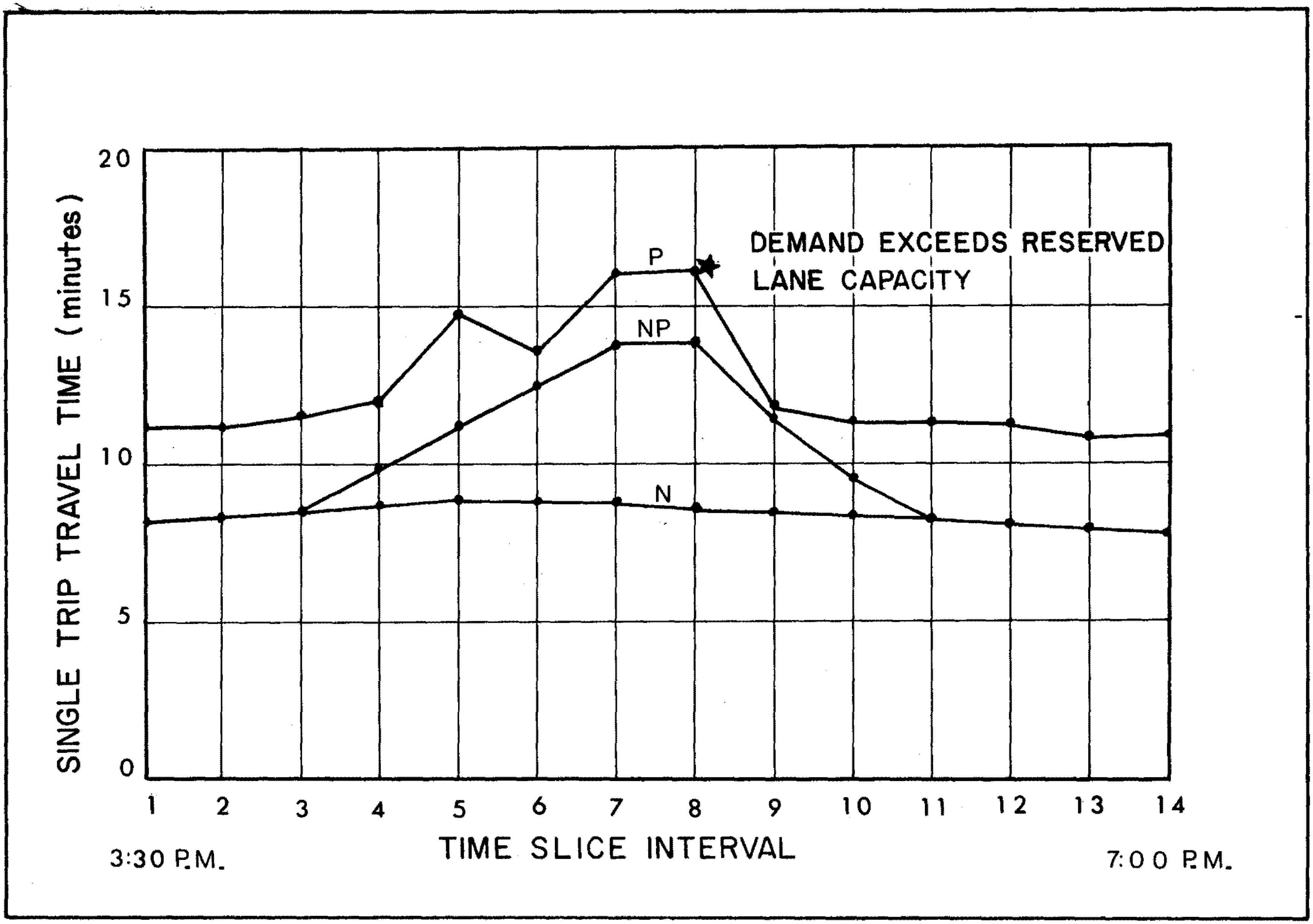

FIGURE 27(a): TRAVEL TIME UNDER PRIORITY OPERATIONS WITH ONE LANE RESERVED FOR BUSES AND CARS WITH 2 OR MORE PASSENGERS

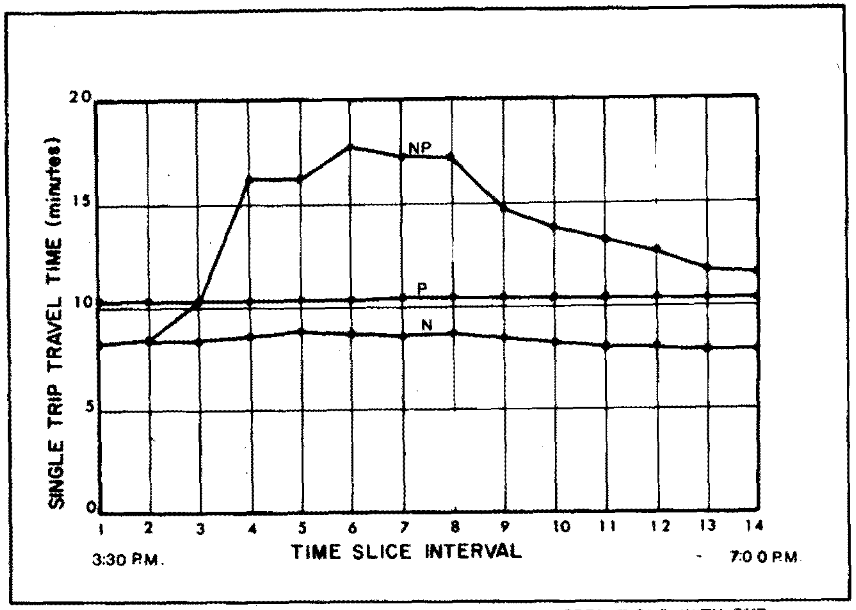

FIGURE 27(b): TRAVEL TIME UNDER PRIORITY OPERATIONS WITH ONE LANE RESERVED FOR BUSES AND CARS WITH 3 OR MORE PASSENGERS

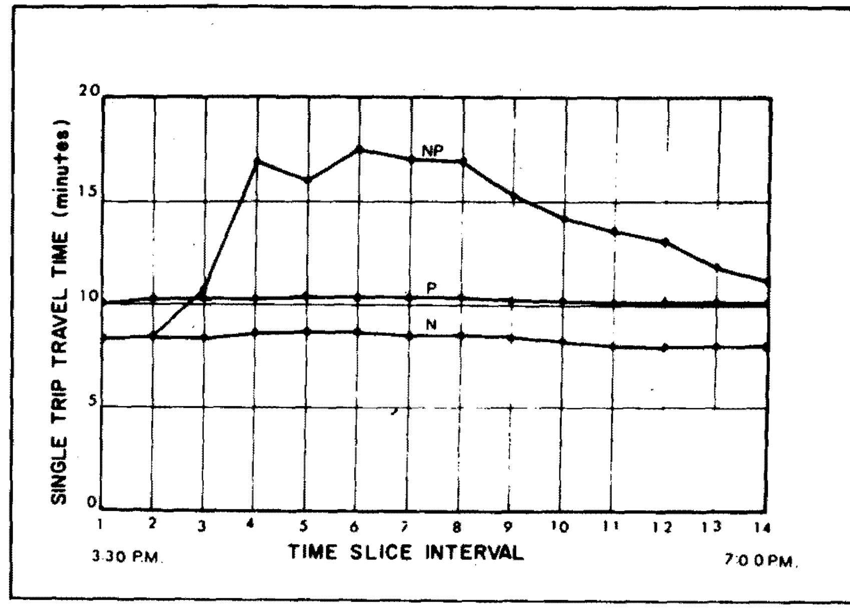

FIGURE 27(c): TRAVEL TIME UNDER PRIORITY OPERATIONS WITH ONE LANE RESERVED FOR BUSES AND CARS WITH 4 OR MORE PASSENGERS

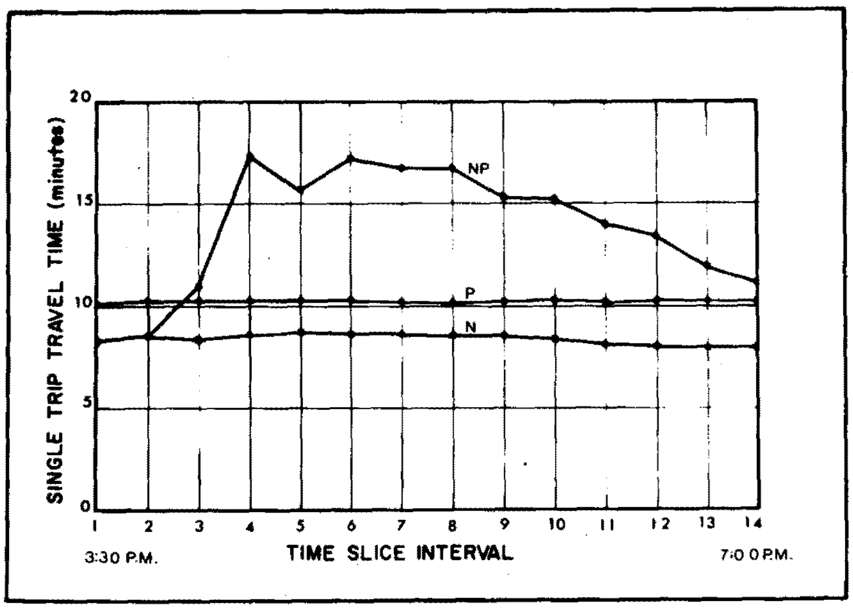

FIGURE 27(d): TRAVEL TIME UNDER PRIORITY OPERATIONS WITH ONE LANE RESERVED FOR BUSES AND CARS WITH 5 OR MORE PASSENGERS

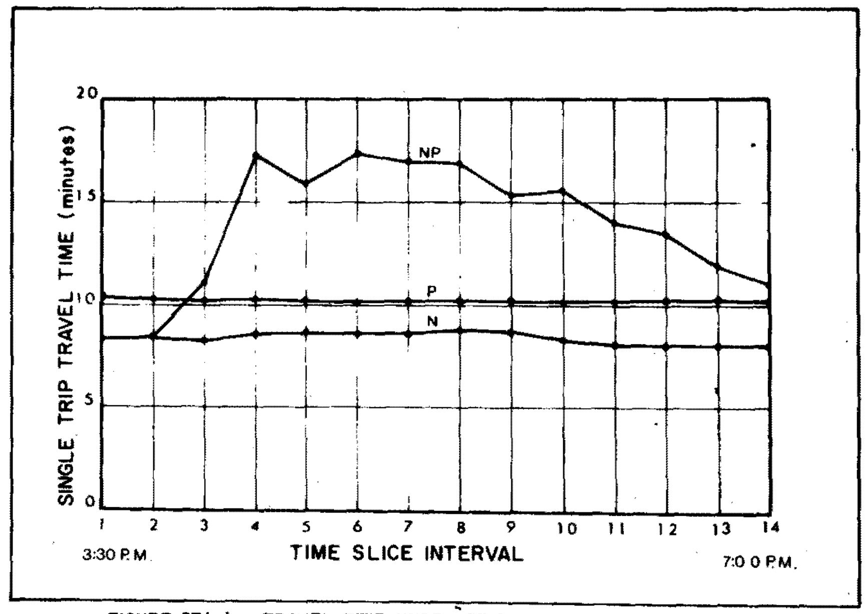

FIGURE 27(e): TRAVEL TIME UNDER PRIORITY OPERATIONS WITH ONE LANE RESERVED FOR BUSES ONLY

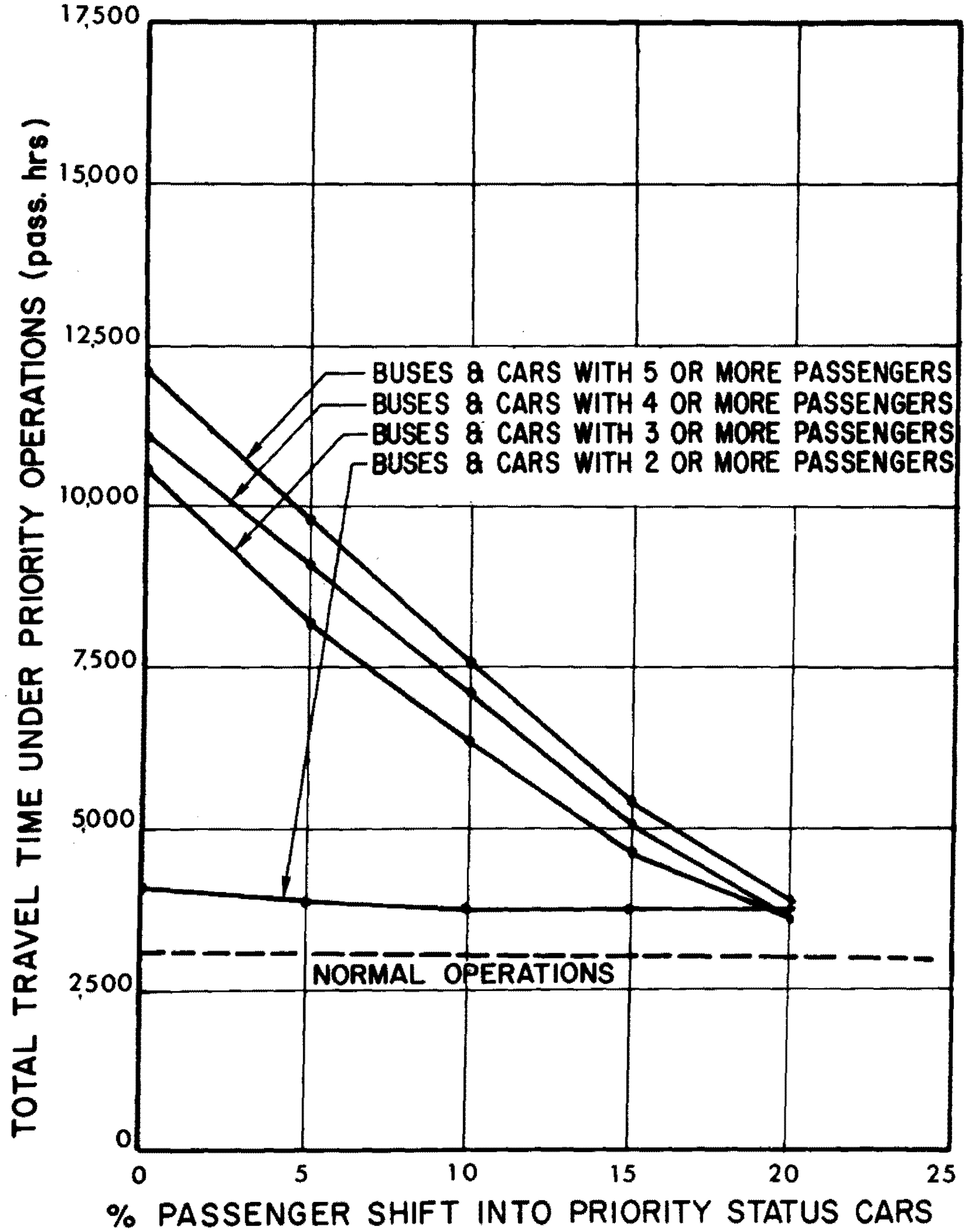

FIGURE 28 EFFECT OF PASSENGER SHIFT ON TOTAL TRAVEL TIME USING ONE RESERVED LANE

passenger shifts into buses, none of the schemes and conditions considered would equal or better the total freeway travel time under normal operations.

b. <u>Two Reserved Lanes with New Design</u>

The speed-flow/capacity relationships used in the data set for evaluating one reserved lane was changed so that the speed-flow/capacity relationships in the reserved lane were the same as those in the unreserved lanes. This measure was taken to compensate for the effect of the restrictive speed-flow/capacity curves used in the case of one reserved lane where passing was not allowed. The data listing and sample output for this evaluation is given in Appendices D and E. Note: IOP can be set to 2, 4, 5, or 6 to evaluate a two reserved lane scheme. A partial data listing is given in Fig. 29.

The results of the freeway travel time from the simulation of priority operations using two reserved lanes are given in Table 26. The single trip travel time for the priority vehicles is less than the travel time in normal operations by about 2 minutes as shown in Fig. 30 (for plan 2-2-0). Clearly, priority vehicles are now receiving the travel time benefits under priority operations.

An examination of the excess capacity in the reserved lanes for schemes 2-3-0, 2-4-0, 2-5-0 indicated that even if cars with 2 or more passengers were to be allowed into the reserved lanes, less than half of the reserved lane capacity would be utilized. It is possible that with a certain combination of shifts into buses and priority status cars that plans 2-3, 2-4, or 2-5 would be better

```
E2296,1,200,60000,600. LEW AFTER 25 NEW DESIGN, TWO RESERVED LANES  WITH SHIFTS
REQUEST,PRIFRE.0025
CLDR,I=PRIFRE..(UNLOAD).

MODEL APPLICATION TO MARIN ROUTE 101 NEW DESIGN WITH TWO RESERVED LANE,SHIFTS
  20    4.    2.    2. 2            5
   1  410000        200   3   3   3 .97    O    TOLL BOOTH
  2P 4 7200 1500   400   4   4   4 .97        ACCELERATION AREA,START RESERVED LANES
  3P 4 7200 1500  5400   5   5   5 .97          GOLDEN GATE BRIDGE
  4P 4 6890 1500   600   5   5   5 .97
  5P 4 6751 1500   300   5   5   5 .97          WRONG WAY BUS CROSSOVER
  6P 4 6752 1500   600   5   5   5 .97     D    NEGLECT VISTA POINT ON-OFF RAMP,SMALL V
  7P 4 6500 1500   600   5   5   5 .72          ALEXANDER (FORMERELY SAUSALITO)
  8P 4 6500 1500  3000   5   5   5 .72    O
  9P 4 6400 1500  1050   5   5   5 .72          WALDO TUNNEL
 10P 4 6500 1500  1600   5   5   5 .72     D
 11P 4 6961 1500  2320   5   5   5 .97          SPENCER
 12P 4 7294 1500  2500   5   5   5 .97    OD
 13P 4 7294 1500   550   5   5   5 .97          RODEO
 14P 4 7294 1500  4850   5   5   5 .97    OD
 15P 4 7294 1500  1300   5   5   5 .97          MARIN CITY
 16P 4 7470 1500  1000   5   5   5 .97    OD    CAPACITY  ADJUSTED  LARGE WEAVE EFFECT
 17P 4 7294 1500  1400   5   5   5 .97          BUS CROSSOVER
 18  4 7294       3000   5   5   5 .97    OD    MAILINE-RICHARDSON BAY BRIDGE
 19  3 5820        800   5   5   5 .97
 20  3 5820       3600   5   5   5 .97    OD    MAINLINE SOUTH OF TIBURON OFF
  1500
   3  0.0     25.     .65     24.     .85     24.     .95     23.     1.00   22.
   3 -1.00    22.    -0.0      0.
   4  0.0     49.     .65     37.     .85     33.     .95     26.     1.00   22.
   4 -1.00    22.    -0.0      0.
   5  0.0     55.     .90     46.     .95     44.   1.00      30.    -1.00   30.
   5  -.95    26.    -.90     23.    -.50     10.   -0.0       0.
```

***IMPORTANT! INSERT A BLANK CARD HERE WHEN INPUTTING SPEED-FLOW/CAPACITY CURVES.**

```
TIME SLICE 1   330-345
  40. 73.4 23.2  2.0  1.0   .4
  40.71.1625.1902.1801.0300.44
  40.68.8127.2402.3601.1100.48
  40.66.3729.3702.5401.2000.52
  40.63.8231.6002.7301.2900.56
                              1




 165 132       106  686 3003677
                13   13   10   26
                13   13   10   26

                     52   40  597
                              290
                              157
TIME SLICE 2   345-400
```

Figure 29 : Data Listing for New Design, Two Reserved Lanes with Shifts

TABLE 26: SUMMARY OF FREEWAY TRAVEL TIME USING TWO RESERVED LANES (ALL VALUES EXPRESSED IN PASSENGER HOURS)

LEGEND FOR PRIORITY OPERATIONS SCHEMES:
PLAN "2-2-0"
- First digit: Number of Reserved Lanes
- Second digit: Buses and Cars with 2 or More Passengers in Reserved Lane
- Third digit: % Occupancy Shift into Cars

		PRIORITY OPERATIONS SCHEMES				
		Scheme 2-2-0	Scheme 2-3-0	Scheme 2-4-0	Scheme 2-5-0	Scheme 2-6-0 (Buses Only)
TRAVEL TIME UNDER NON-PRIORITY OPERATIONS	NORMAL OPERATIONS	3192	3192	3192	3192	3192
TRAVEL TIME UNDER PRIORITY OPERATIONS USING TWO RESERVED LANES	NORMAL SECTIONS	524	373	353	340	337
	UNRESERVED SECTION	2316	2635	2702	2868	3094
	RESERVED SECTION	934	304	204	122	95
	INPUT DELAY IN NORMAL SECTION	9990	14415	15143	15658	15739
	INPUT DELAY IN UNRESERVED SECTION	2694	7748	8513	9018	9113
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS USING TWO RESERVED LANES		16458	25475	28337	28006	28378
TOTAL TRAVEL TIME SAVINGS OVER NON-PRIORITY OPERATIONS		-13266	-22283	-23725	-24814	-25186

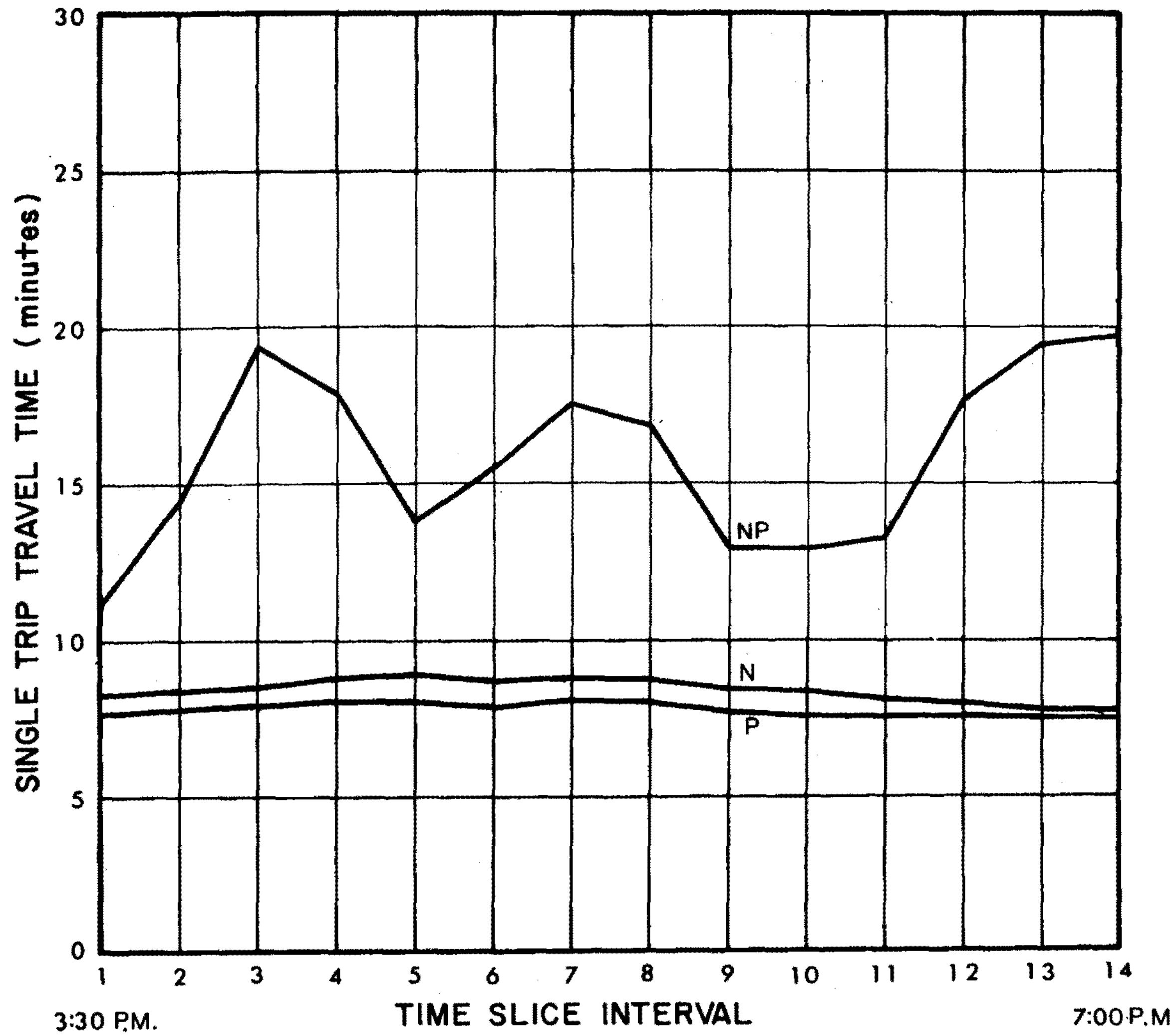

FIGURE 30 TRAVEL TIME UNDER PRIORITY OPERATIONS WITH TWO LANES RESERVED FOR BUSES AND CARS WITH 2 OR MORE PASSENGERS

strategies to operate, however plan 2-2-0 has a greater potential to utilize the excess capacity since it would be easier for people to form carpools with 2 passengers per car.

Figure 31 shows the effect of passenger shift into priority status cars on the total travel time for plan 2-2. If we were to assume, for example, that people will make an x percent shift into priority status cars for every x minutes saved by using the reserved lanes instead of the unreserved lanes, then Fig. 30 indicates that we could expect about 10% passenger shift to occur as a result of implementing strategy 2-2-0. Figure 31 shows, however, that the travel time loss to non-priority vehicles more than offsets the gain in travel time by priority vehicles even after as much as a 20% shift. Only 2/3 of the available reserved lane capacity is utilized by priority vehicles after a 20% shift. Unless additional shifting into buses occurs, or some other changes in operation strategy, it would be difficult for priority operations under plan 2-2 to equal or better the total travel time under normal operations.

With the aid of the excess capacity contour maps and the speed and density contour maps, it is possible to retest priority operations under plan 2-2 with different assumptions made as to the placement and length of the reserved lane. By starting the reserved lanes after the Golden Gate Bridge (at the beginning of subsection 5) and ending 3/4 of a mile earlier (at the end of subsection 14), reserved lane operations under plan 2-2 shows a marked improvement. However, the total travel time under priority operations is still greater than the travel time under normal operations even with a 20% shift into priority status cars, as shown in Fig. 32.

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*See Chapter 6 for determining adequate distance required for changing lanes to off-ramp 5.

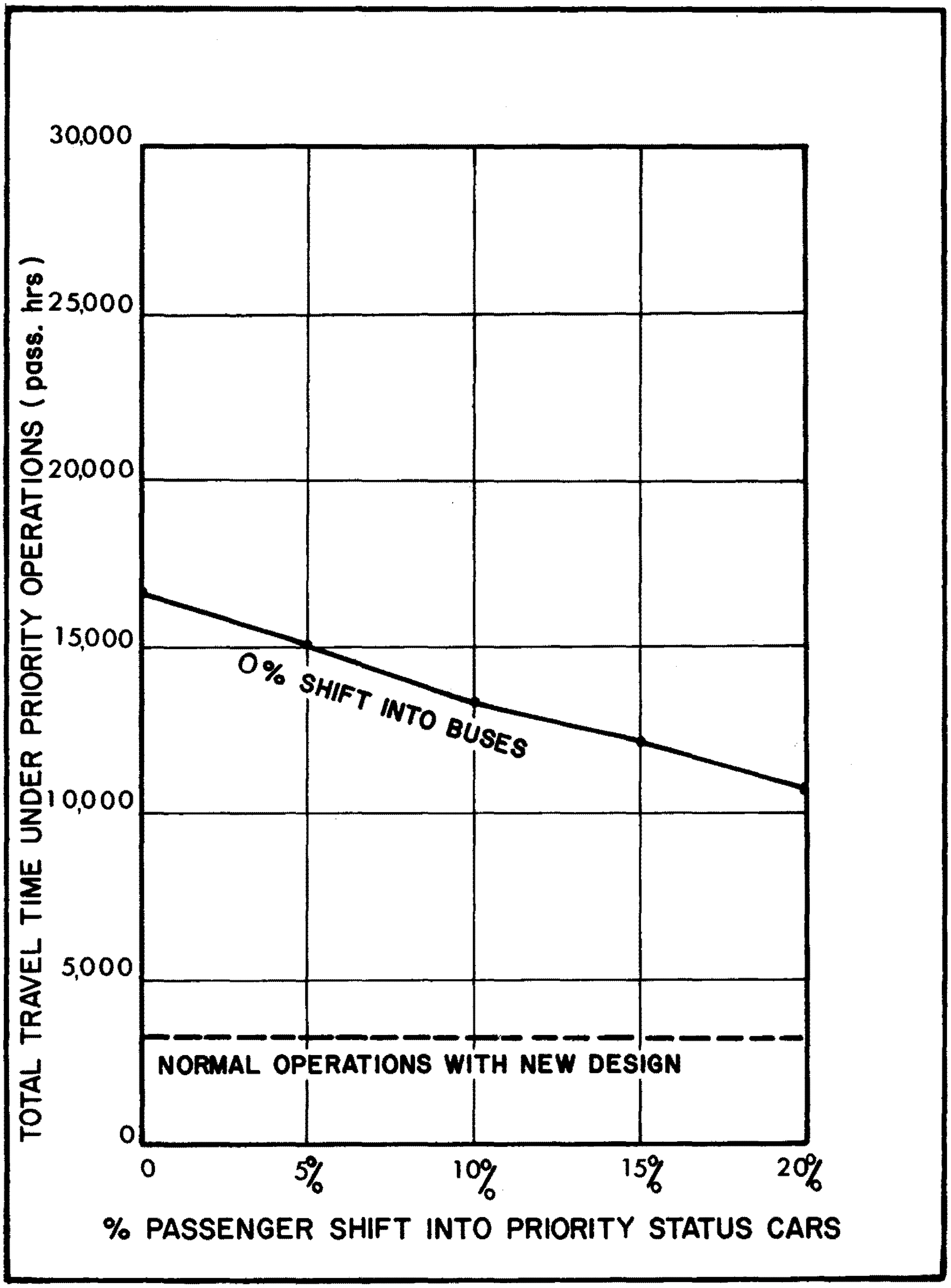

FIGURE 31 EFFECT OF PASSENGER SHIFT ON TOTAL TRAVEL TIME USING TWO RESERVED LANES

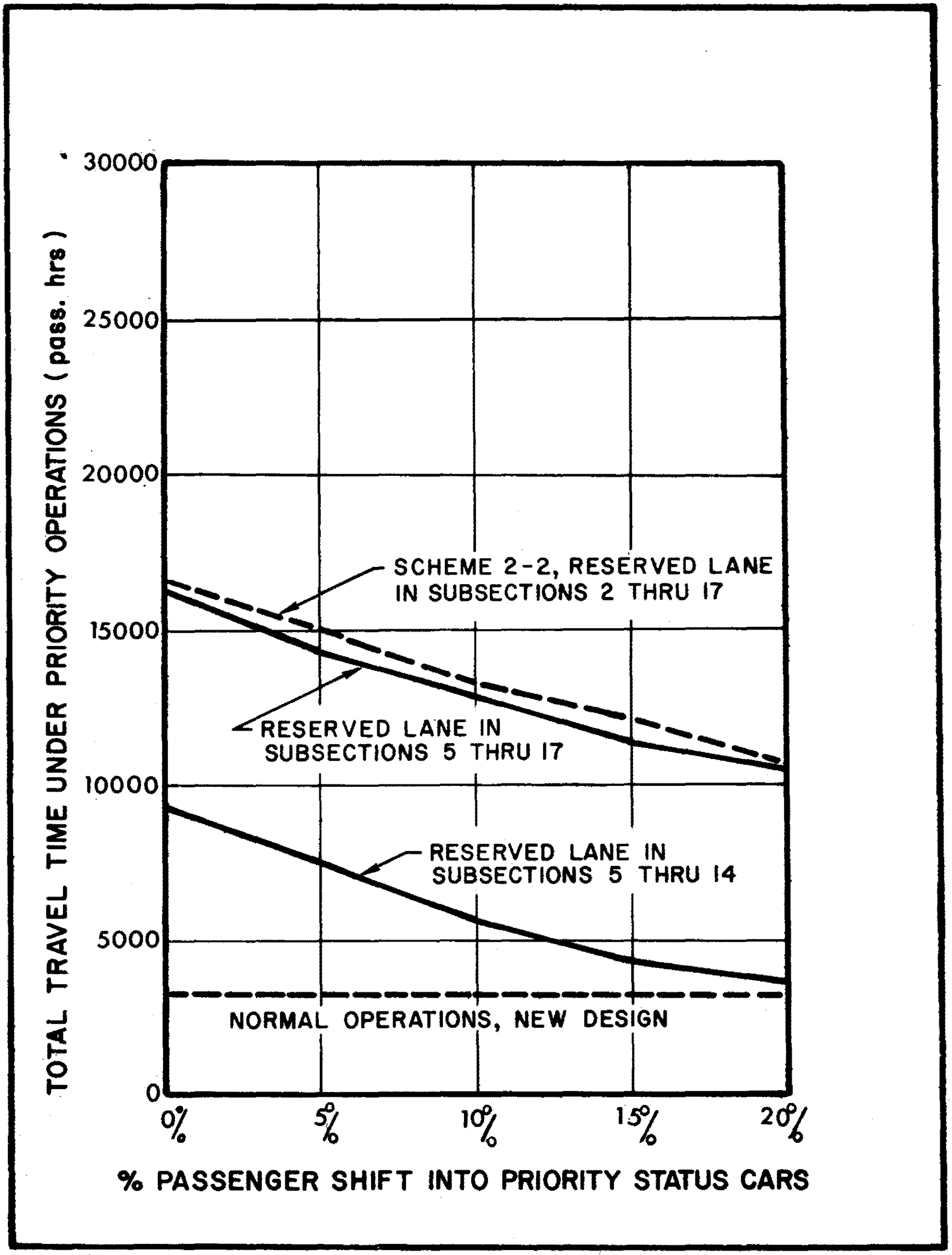

FIGURE 32 EFFECT OF CHANGES IN LENGTH AND PLACEMENT OF RESERVED LANE SCHEME 2-2.

5. Additional Analyses

Additional analyses can be made to determine the model sensitivity to changes in the various input parameters. The investigation can include such possibilities as:

a. Effect of shifts into buses - A family of lines can be plotted to represent the various levels of shifts into buses to determine the required combination of shifts into cars and buses to produce overall travel time savings over normal operations (see Reference 15).

b. Effect of changes or estimation errors in demand or modal split - The annual traffic growth rate can be specified on the parameter card (as described in Chapter 3) to project traffic volumes to determine the effectiveness of reserved lane operations in future years.

c. Effect of initial occupancies - The initial bus and car occupancies can be varied to determine the effect on travel time under priority operations.

d. Effect of assumed capacities - As noted earlier the capacities of the freeway subsections may need to be adjusted to simulate actual freeway conditions. The assumed reserved lane capacity can be varied to determine its effect on travel time.

e. Effect of speed-flow/capacity relationships - The effect of speed-flow/capacity relationships can be determined by varying the assumed speed-flow/capacity curves.

f. Effect of reserved lane length and placement - By making the appropriate changes in the coding of the capacity card, the effect of the length and placement of the reserved lane can be considered (as was demonstrated earlier).

g. Effect of shifts on average speed in the reserved and unreserved lanes - The effect of speed differentials can be examined by noting the speeds in each subsection under priority operations.

h. Effect of assumed bus equivalency factors - Bus equivalency factors may be velocity dependent. By varying the bus equivalency factors on the parameter card, the effect of the assumed values can be determined.

i. Effect of time - The optimum time for beginning and ending priority lane operations can be determined by analyzing different periods of time intervals. (Inspection of Fig. 27a would indicate that priority lane operations should start later and terminate earlier in time).

The possibility of other freeway operation schemes in addition to or in combination with design improvements or priority operations can be analyzed on the PRIFRE model.

1. Metered ramp control can be analyzed by changing specific on-ramp limits on the ramp limits card (and, if necessary, on the first occupancy card).
2. Preferential bus entry can be investigated by introducing a fictitious (bus) ramp next to a metered ramp.

3. "Wrong way" bus lanes can be analyzed by making appropriate changes to the parameter and capacity cards. Separate runs will be necessary to analyze the total travel time expended for both directions of freeway travel.

6. LANE-CHANGING MODIFICATIONS

One of the critical and previously unanswered questions about the reserved lane concept is how can vehicles move safely into and out of the reserved lane from the unreserved lanes. What minimum distance is required for an entering vehicle to cross all of the unreserved lanes and enter the reserved lane? Likewise, what is the minimum distance required for an exiting vehicle leaving the reserved lane and crossing the unreserved lanes to exit the freeway? If too great a distance is required, or speed differentials are too great for safe lane changing, the advantages of traveling in the reserved lane could be greatly reduced.

A. Problem Definition

Obviously there are many things influencing this complex lane changing situation. Some of the questions we must ask are:

1) What is an acceptable gap for changing lanes?

   a. Between the reserved lane and an unreserved lane;

   b. Between two unreserved lanes.

2) Having entered the freeway on the right side, how far downstream will a vehicle have to travel before reaching the left side reserved lane?

3) Knowing the location of right side on-ramps, where should the beginning of the reserved lane be?

4) Knowing the location of downstream right side off-ramps, where should the end of the reserved lane be?

5) If we opt for more than one reserved lane section, how far apart should these sections be, at a minimum?

6) What is the travel time delay caused by lane changing? To priority vehicles? To non-priority vehicles?

7) What effect do speeds and speed differentials play?

Which freeway lane should be proposed for priority vehicle use?

1) If the right lane is chosen, all vehicles entering or leaving the freeway would be required to cross the priority lane in front of fast moving buses. Where auto and truck traffic are in queue (the only places offering a possible time saving with buses in a priority lane), vehicles entering the freeway would block the priority lane until they forced their way into the queue in the adjacent lane.

2) If the median lane is chosen for a priority lane, an entering bus is required to accelerate, then weave across lanes used by autos and trucks. On a free flowing 8-lane freeway, this requires about 1-1/2 miles. If the bus enters a jammed freeway, the distance will be shorter. A bus weaving from the median lane to a right hand exit will require almost the same distance.

This long weaving distance would make priority lanes suitable only for the type of bus operations where loaded buses enter the freeway and proceed a long way to an exit near their destination. This is basically what they plan on doing in the Marin reversible bus lane project. Some of the local buses will not have access to the priority lane due to short weaving distance.

Use of the freeway as a bus route with stops at various interchanges would not be feasible.

3) In all cases where auto traffic is in queue, bus traffic in an adjacent lane should be traveling at a relatively slow speed as they pass the slower traffic for safety reasons. There is always a possibility for an auto in queue to unexpectedly cut out into the priority lane for passing or exiting.

B. Formulation of the Acceptable Gap

The distance required for lane changing is a function of traffic volume in the lane into which the vehicle is attempting to merge, (i.e., the "adjacent" lane), the average speed in the adjacent lane, the relative speed between the potential lane changer and the adjacent lane traffic, and the acceptable gap size for the lane change maneuver.

Consider the traffic situation depicted schematically in Fig. 33 . The vehicle labeled "potential lane changer" in lane 1 desires to change lanes into lane 2 within a distance d. In order to accomplish this, the lane changer must find a time gap in the adjacent lane which is of sufficient size to be acceptable.

The gap in the adjacent lane traffic presented to the lane changer when he is located at his initial position is indicated as g_1 . If g_1 is too small to be accepted, the potential lane changer must either slow down or speed up, in order to consider other gaps. (If traffic

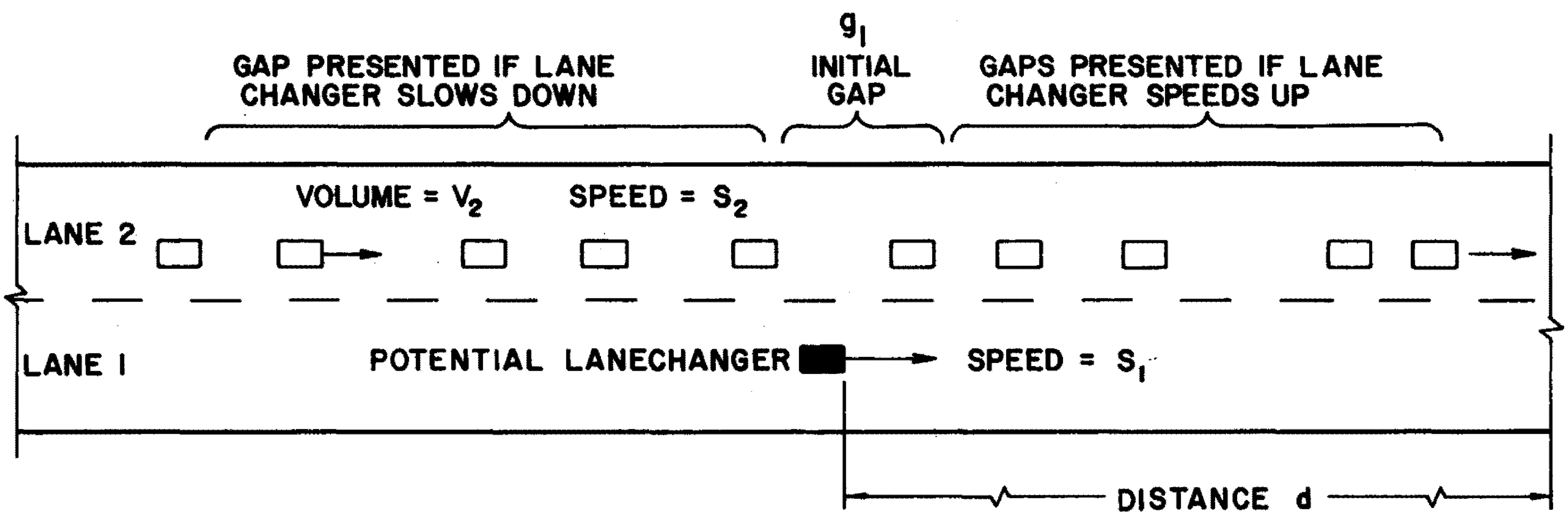

FIG. 3 3 SCHEMATIC DIAGRAM OF A LANE CHANGING SITUATION in lane 1 is dense, speeding up significantly may be impossible). The rate at which successive gaps are presented to the lane changer is equivalent to the relative volume rate in lane 2 (i.e., the volume rate measured relative to the moving lane change vehicle). In turn, the relative volume rate is a function of the absolute volume rate in lane 2 (i.e., measured from a stationary reference) and the relative speed between the lane changer and the traffic in the adjacent lane.

The relative lane 2 traffic volume, V_2', is linearly related to the absolute lane 2 traffic volume, V_2, as follows:

$$V_2' = |f_S V_2| \tag{1}$$

where

$$f_S = \frac{S_1 - S_2}{S_2}$$

S_1 = speed of potential lane changer

S_2 = average speed in adjacent lane

The factor, f_S, is termed the relative speed factor. The relationship between the relative speed factor and the relative volume in the adjacent lane given in Eq. (1) is illustrated in Fig. 34 .

If the lane changer slows down, the average number of adjacent lane vehicles, N that pass him in time, t , equals

$$N = V_2' t \tag{2}$$

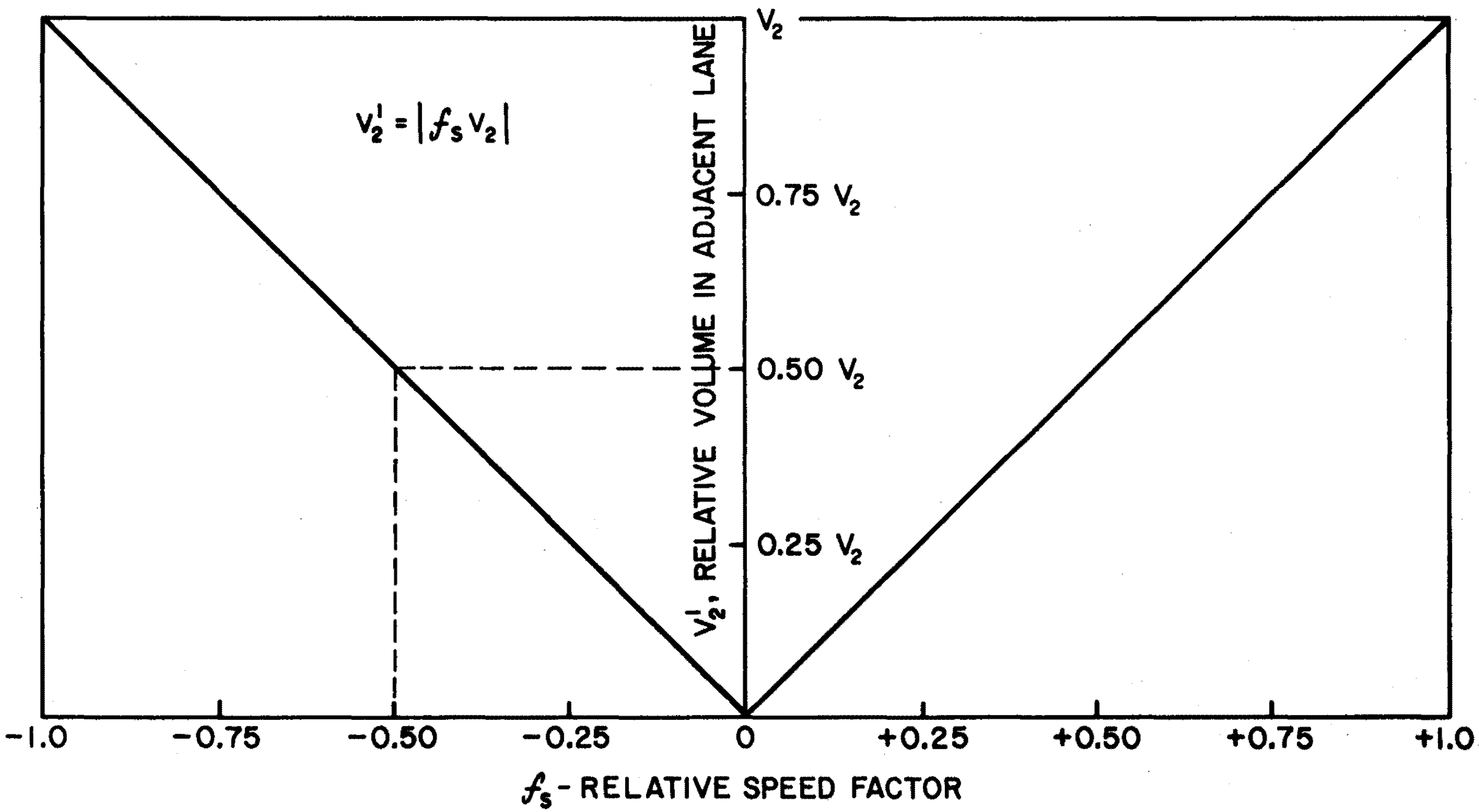

FIG. 34 RELATIVE VOLUME AS A FUNCTION OF RELATIVE SPEED

where

V_2' is in vehicles per second

t is in seconds.

Relating the above to distance, d, is possible by introducing the speed of the lane changer, S_1. The average number of vehicles that pass in distance, d, is given by:

$$N = \frac{V_2' d}{S_1} \qquad (3)$$

where

d is in feet

S_1 is in feet per second.

Equations (2) and (3) are also valid in the case where the lane changer speeds up.

It should be noted that we have dealt with average number, N, but N is Poisson distributed. Hence, the actual number of vehicles passing (or passed by) the lane changer during time, t, or distance, d, will vary considerably from one occasion to the next. The theoretical formulation, however, is based on the average N.

Next it can be stated that the number of gaps presented to the lane changer, n', is one greater than N because of the existence of the initial gap. In other words

$$n' = \frac{V_2' d}{S_1} + 1 = \frac{|f_S V_2| d}{S_1} + 1$$

where

n' = the average number of gaps in the adjacent lane presented to the potential lane changer.

The second phase of the analysis considers the question: "How many gaps are required to insure that at least one is acceptable?"

In order to answer this question, an associated probability must be selected. Then the number of gaps required can be formulated as a function of the adjacent lane traffic volume, V_2, and the acceptable gap size, g_a.

The cumulative distribution of gap sizes can be presented quite accurately using a shifted exponential distribution, as follows:

$$P(g \geq t) = \exp\left[-\frac{(t - \tau)}{(\bar{t} - \tau)}\right] \quad (5)$$

where

$P(g \geq t)$ = probability of a gap $\geq t$.

τ = minimum headway, sec.

$\bar{t}$ = average headway, sec. = $3600/V_1$

Or alternatively stated:

$$P(g \leq t) = 1 - \exp\left[-\frac{(t - \tau)}{(\bar{t} - \tau)}\right] \quad (6)$$

where

$P(g \leq t)$ = Probability of a gap $\leq t$.

Using probability theory it can be stated that the probability of n successive gaps in a row less than or equal to t is given by:

$$P(n \text{ successive gaps} \le t) = [P(g \le t)]^n \qquad (7)$$

and substituting from Eq. (6):

$$P(n \text{ successive gaps} \le t) = \left\{ 1 - \exp\left[- \frac{(t - \tau)}{(\bar{t} - \tau)} \right] \right\}^n . \qquad (8)$$

It follows that the probability of at least one of the n gaps being greater than t is given by:

$$P(\text{at least one gap} > t) = 1 - P(n \text{ successive gaps} \le t) \qquad (9)$$

Substituting:

$$P(\text{at least one gap} > t) = 1 - \left\{ 1 - \exp\left[- \frac{(t - \tau)}{(\bar{t} - \tau)} \right] \right\}^n . \qquad (10)$$

If design values are set for acceptable gap size, $t = g_a$, and for probability of a least one gap greater than g_a, one can solve for n using Eq. (10).

Now, the key to the analysis is to set:

$$\boxed{n = n'}$$

In other words, set the average number of gaps required to give probability P that at least one gap is acceptable equal to the average number of gaps in the adjacent lane presented to the potential lane changer.

Example: Required distance for changing lanes from an unreserved lane to a reserved lane.

Assume:

S_1 (speed in unreserved lane) = 24 mph

S_2 (speed in reserved lane) = 30 mph

V_2 (volume in reserved lane) = 1,200 vph

P(at least one gap > t) = .90

Ga = 3.5 sec

τ = .5 sec

Then

$$\bar{t} = \frac{3600}{1200} = 3.0 \text{ sec}$$

from Eq. (10) .

$$.90 = 1 - \left\{ 1 - \exp\left[- \frac{(3.5 - .5)}{(3.0 - .5)} \right] \right\}^n$$

$$\left\{ 1 - \exp\left[- \frac{3.0}{2.5} \right] \right\}^n = .10$$

$$\{ 1 - \exp[-1.2] \}^n = .10$$

$$[.699]^n = .10$$

$$n = 6.43$$

Then:

$$S_2 = 30 \text{ mph} = 44 \text{ fps}$$

$$f_s = \frac{24 - 30}{30} = - .20$$

$$S_1 = 24 \text{ mph} = 25.2 \text{ fps}$$

$$V_2 = 1200 \text{ vph} = .333 \text{ vps}$$

Substituting in Eq. (4),

$$6.43 = \frac{[- .20(0.333)]d}{35.2} + 1$$

d = 2870 feet = Required distance for changing lanes from an unreserved lane to a reserved lane.

C. Computer Program LCHANGE

A computer program was written for the computation of important lane changing parameters described already. The computer model, entitled "LCHANGE", is based on the theories described in section B, and outputs required distances for changing lanes from: (see Fig. 35)

DR.UR	- a reserved lane to an unreserved lane
DUR.R	- an unreserved lane to a reserved lane
DUR.UR	- an unreserved lane to an unreserved lane;
DNN	- a normal lane to an adjacent normal lane (i.e. before or after the priority section);
DON.P	- an on-ramp to the entrance of the priority lane;
DP.OFF	- the exit of the priority lane to a right-hand side off-ramp;
DP.OFF.M	- the middle of a priority lane section to a right-hand side off-ramp;
DON.P.M.	- an on-ramp to the middle of a priority lane section.

At present the PRIFRE Model does not allow the last two movements to take place. There is only one entrance and one exit to the priority lane(s), and that is at the beginning and end of the priority section, respectively. It would be a more flexible model if priority vehicles were allowed to enter and exit the priority lanes at specified intervals, so that more people could take advantage of the reserved lane.

Only one parameter card need be inputted to program LCHANGE to obtain the above outputs. The card format is shown in Fig. 36.

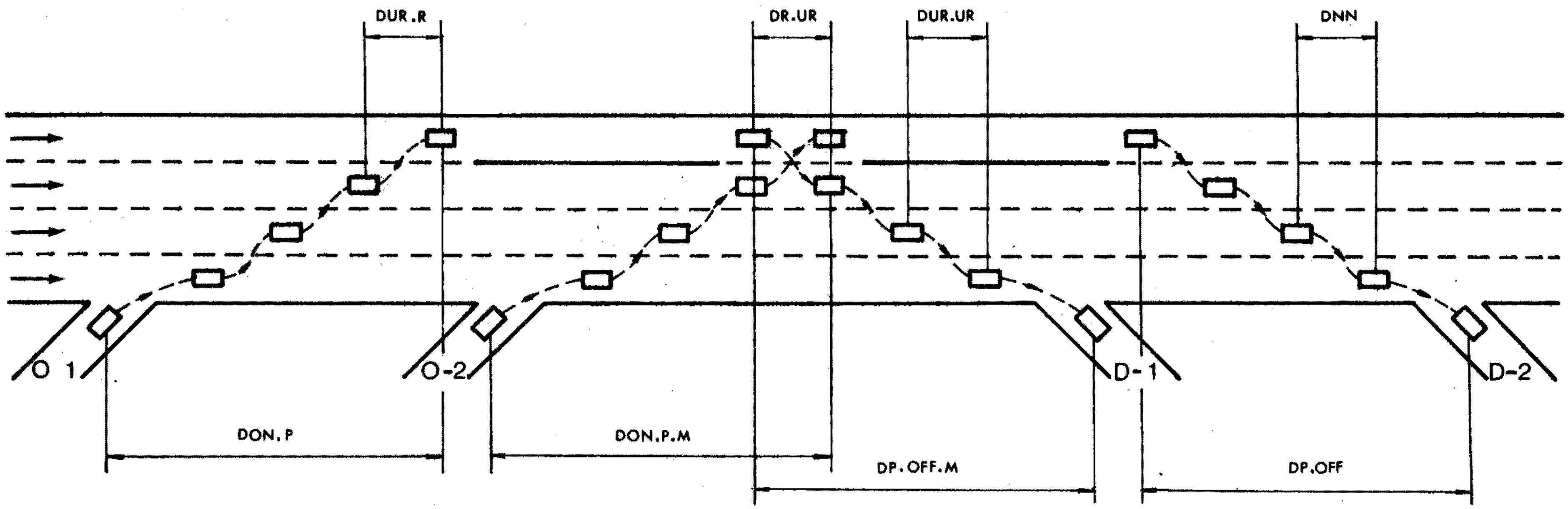

FIGURE 35. DISTANCES REQUIRED FOR LANE CHANGING

VN, VR, and VUNR are the volumes in vehicles/hour/lane in the normal, reserved, and unreserved lanes, respectively. SN, SR, and SUNR are the average speeds in miles/hour for the normal, reserved, and unreserved lanes. GAR and GAUNR are the acceptable gaps in the reserved and unreserved lanes. The acceptable gap in normal lanes is assumed equal to GAUNR for this simulation. HM is the minimum headway between vehicles for the whole freeway section under study, in seconds. XP represents the probability of successfully changing lanes in the computed distance output, and is expressed as a percentage. The value .95 would mean that there is a 95% assurance that the lane changing could take place in the distance outputted by the program. Finally, N is the number of freeway lanes (one side of the freeway only).

It is possible to make several different runs with different parameter cards at one time. All that is required is a new parameter card for each condition desired, and a blank card following the final parameter card to let the program know it is finished. Figure 37 show the data deck set-up acceptable to LCHANGE, and Appendix I contains a complete program listing an sample output.

It is felt that with more time and effort, this program could be worked into a subroutine for PRIFRE and become a valuable option to the user. PRIFRE would be a more flexible tool if it would permit the evaluation of allowing priority vehicles to enter and exit priority lanes at either random or specified intervals. Chapter 7 surveys areas of future research, and it is felt that this is one of the more valuable areas for improvement for a priority operations simulation model.

INPUT PARAMETERS:

VN	VR	VUNR	SN	SR	SUNR	GAR	GAUNR	HM	XP	N	
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31 32 33 34 35	36 37 38 39 40	41 42 43 44 45	46 47 48 49 50	51	52 53
1550.	800.	1800.	44.00	50.00	35.00	3.50	2.50	0.50	.950	4	
F5.0	F5.0	F5.0	F5.2	F5.2	F5.2	F5.2	F5.2	F5.2	F5.4	I1	

Figure 36 - PARAMETER CARD FOR LCHANGE

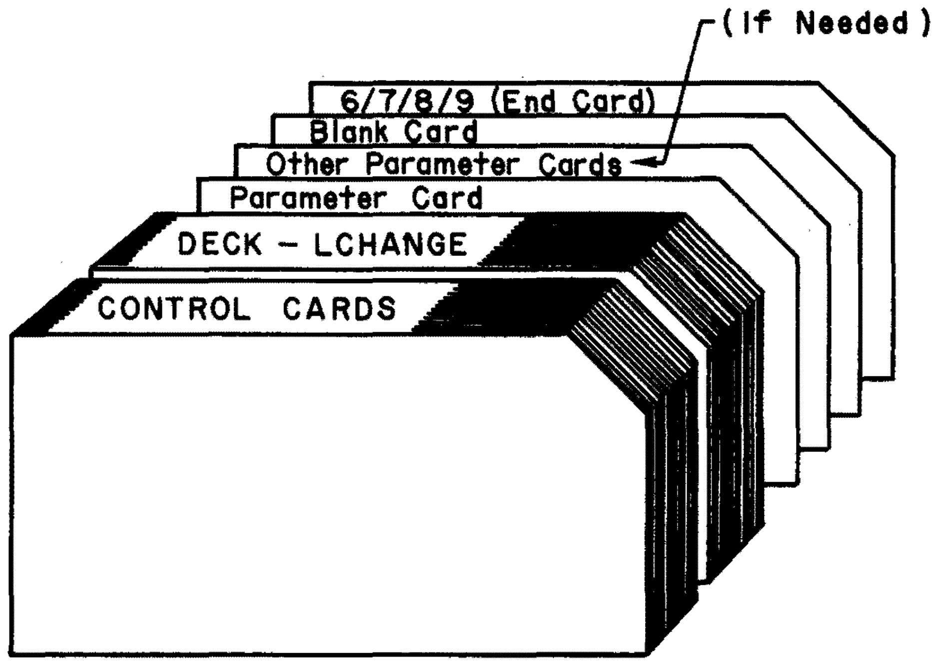

Figure 3.7 DATA DECK SET-UP FOR LCHANGE

D. Results of Lane Changing Studies

To answer the first five questions presented at the beginning of this chapter, and to find the required distances for changing lanes on freeways employing various priority strategies, the lane-changing theory described in section B was used. Specifically, Program LCHANGE was used to compute lane-changing distances for the following four basic types of lane-changing: (see Fig. 38)

Type A: A lane change from a reserved lane to an adjacent unreserved lane

Type B: A lane change from an unreserved lane to an adjacent reserved lane

Type C: A lane change from an unreserved lane to an adjacent unreserved lane

Type D: A lane change from a normal to an adjacent normal lane

Assume:

- volume in Normal lane (V_N) = 1550 veh/hr./Lane
- volume in Reserved lane (V_R) = 800 veh/hr./Lane
- volume in Unreserved lane (V_{UNR}) = 1800 veh/hr./Lane
- speed in Normal lane (S_N) = 44. mph
- speed in Reserved lane (S_R) = 50. mph
- speed in Unreserved lane (S_{UNR}) = 35. mph

The values of the variables used in LCHANGE - Eq. 10 - for each type of lane change were:

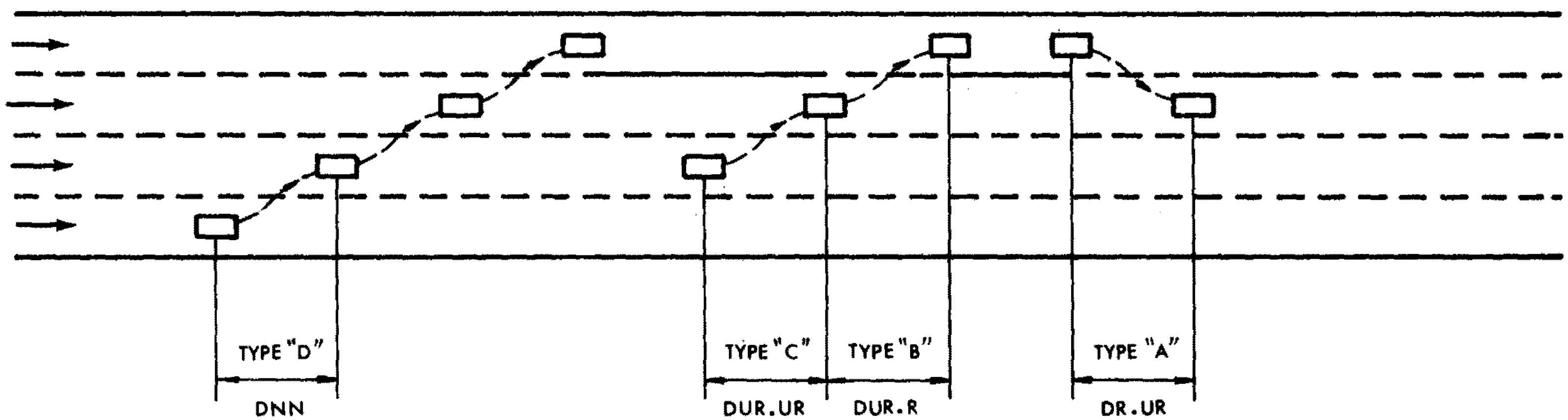

FIGURE 38 TYPES OF LANE CHANGING

Type A

S_1 (speed of lane changer) 50 mph

S_2 (speed in adjacent lane) = 35 mph

V_2 (Volume in adjacent lane) = 1800 veh./hr./lane

G_a (acceptable gap) = 2.5 seconds

Type B

S_1 = 35 mph

S_2 = 50 mph

V_2 = 800 veh./hr./lane

*G_a = 3.5 seconds

Type C

**S_1 = 28 mph

S_2 = 35 mph

V_2 = 1800 veh./hr./lane

*G_a = 2.5 seconds

Type D

S_1 = 35 mph(44×·8)

S_2 = 44 mph

V_2 = 1550 veh./hr./lane

G_a = 2.5 seconds

The required distances for changing lanes were calculated using the computer program for three different probabilities, and the summary of the results are given in the following Table 27 (See Appendix I for computer output).

*In this situation for changing lanes from a slow to a fast lane, we assume that an acceptable gap is 3.5 seconds; from a fast to a slow lane, an acceptable gap is 2.5 seconds. These values have been found to be reasonable from observed values in the field.

**In this situation we assume that the lane changer slowed down 20% - i.e., the speed of the lane changer = .80 x 35 = 28 mph. If the user wishes, he may substitute different % slow down values by changing cards no. 28 and 30.

TABLE 27

Distances Required for Changing Lanes

	P = .95 ft.	P = .90 ft.	P = .75 ft.
Type A	3008	2233	1208
Type B	2838	2003	900
Type C	3610	2680	1450
Type D	3823	2800	1447

For example, 2233 ft., is the required distance for changing lanes from a reserved lane to an unreserved lane with 90% assurance of success.

Suppose we have a freeway with the characteristics given in the Fig. 35. A car entering the freeway from on-ramp 0-1 destined for the reserved lane must make 3 lane changes of the type D, so the required distance will be (see Fig. 35):

DON.P = 2800 x 3 = 8,400 ft. with 90% assurance

DON.P = 1447 x 3 = 4,341 ft. with 75% assurance

The following table is the results of calculations for all the required distances shown in the Fig. 35 with different probabilities:

Situation	Required Distance	
	P = .90	P = .75
DON.P	8,400	4,341
DP.OFF	8,400	4,341
DON.P.M	7,363	3,799
DP.OFF.M	7,593	4,108
DR. UR	2,233	1,208
DUR. UR	2,003	900

7. FUTURE DIRECTIONS FOR PRIORITY OPERATIONS ON FREEWAYS

It might be helpful if we stated our objectives - i.e., What are we trying to accomplish with priority lanes?

- maximize the flow of people
- minimize total travel time
- improve environmental factors, such as air pollution
- minimize the number of vehicles entering downtown CBD's
- minimize total travel cost
- improve the quality of travel
- improve the safety of travel

Priority lane operations should strive to accomplish all of these objectives, particularly in maximizing the flow of people and in improving the environment. A significant aspect of priority lanes is that it could offer a real choice in travel modes that could compete on an equal travel time basis, something which our present transportation systems lack. This option, if exercised by a great enough number of people, could reduce traffic congestion, postpone or eliminate the need for additional freeways, and provide for an inexpensive mass transit alternative to a fixed guideway rapid transit system.

To make priority lanes most successful, the following conditions must be satisfied: 1) severe congestion must already exist in the corridor; and 2) buses and carpools must be able to encourage more people to forego use of their private cars in peak-hours. This last point is the critical one. This requires convenient services at both ends of the trip, and a positive savings in overall trip time from origin to destination as compared to private car travel. After all, time saved in a freeway priority lane may be insignificant when comparing it with the overall trip time.

To be really effective then, we must plan and design for the total trip, and not just for one link in it. A priority lane scheme may work beautifully, but if it is not part of a larger, total system improvement scheme, it may fail miserably. We must make plans to improve the whole system then. This means evaluating not only priority lane operations and the resulting potential time savings and occupancy shifts there, but evaluating the total home-to-work trip, travel times, modal choices and a revised occupancy shift based on the total trip time.

A. Survey of Current Priority Projects

There are several on-going projects involving priority lanes or priority entry for buses and carpools. Most of these have been in operation only a short while or are still in the planning stages, so that there is not much data to date to evaluate their success or failure. However, there are three different exclusive bus lanes that have been operating for over a year with considerable success. And there is one experiment involving reserved lanes for both carpools and buses that hopefully will provide us with much more information on the operation of such schemes and help other cities make decisions regarding their own proposed projects.

A brief survey of priority lane projects will be helpful in learning what various cities are trying to do, what kinds of schemes they are trying, and the problem areas encountered.

San Francisco-Oakland Bay Bridge[11,12,13,14,16]

In April of 1970, a morning peak period exclusive bus lane in the toll plaza area was implemented and the bus toll reduced, with the buses no longer having to stop to pay tolls (monthly bills were sent to bus companies). This saved the Alameda-Contra Costa Transit District $91,000 annually, while other commuter buses saved $19,000 annually. This one-half mile exclusive bus lane operation saved 5 minutes of travel time for approximately 15,000 patrons of the 500 buses using the bridge during the peak hours[12].

Based on information concerning an exclusive bus lane model developed by the University of California, Berkeley, in mid-1969, the FHWA Office of Highway Planning contracted with the University to expand the model to consider exclusive lanes for buses and carpools. This model was calibrated for the Oakland Bay Bridge conditions and was completed in late 1970[11]. As the result of this work, the University of California and the California Division of Bay Toll Crossings analyzed many different plans for bus and carpool lanes in the toll plaza area and on the bridge proper[13]. They developed a plan that was implemented December 8, 1971, in an effort to break the one-man, one-car habit on the world's third busiest toll bridge[14].

The priority scheme involves three 1-1/2 mile bypass lanes through the toll plaza, two of which are for passenger cars with three or more occupants and one which is for commute buses heading from the East Bay into San Francisco between 6 a.m. and 9 a.m. A series of signs alert commuters to the lanes which begin just beyond the conjunction of three freeways leading into the toll plaza area and extend for 700 feet onto the bridge proper[14] The priority carpool lanes are immediately adjacent to the exclusive bus lane and all three merge into the center lane of the five lane bridge. Initially the carpools moved toll free through the plaza; since May, 1972, they have been required to purchase a fee sticker at the reduced rate of $12 per year.

The California Highway Patrol is on hand to police those vehicles that pass through the reserved lanes with less than three occupants. The license numbers of the offending vehicles are jotted down, and warnings are mailed to their owners at their home addresses.

Although initially an experiment with only marginal benefits expected, the priority lane project has been extended through December 1972 in order to gather more valuable data and to see if more people will be encouraged to switch to carpools. Initially there were 1,262 carpools during the morning 3-hour peak-period while the figure is now over 2,000[16]

<u>Golden Gate Bridge - San Francisco[16,18]</u>.

Plans are underway to install a "wrong-way" exclusive bus lane in Marin County from the Golden Gate Bridge north to the Richardson Bay Bridge, a distance of 4 miles[18]. Two of the four southbound freeway lanes will be "borrowed" so that northbound commuter buses can speed by p.m. northbound rush hour traffic. The 150 peak-hour buses will travel on what is normally the fast southbound lane, next to the center barrier of the highway. The adjacent southbound lane will remain empty as a buffer zone, with a line of pylons down its center. Southbound traffic will be confined to the remaining two southbound lanes.

The project will affect only freeway US 101, and not the bridge proper. The plan will probably be effective by August for a six-month trial. Presumably if the experiment is successful, the plan would later include southbound commute buses in the morning after some widening presently under construction is completed.

Shirley Highway - Washington, D. C.[17,20,27]

The operation of exclusive bus lanes on the Shirley Highway (I-95) in northern Virginia began in September 1969, with the opening of a 5-mile section of completed reversible lanes in the freeway median. Since then an additional temporary 4-mile section has been constructed to the Potomac River and several slip ramps have also been built to enable more buses to gain entrance to the priority lanes[17].

Besides construction of the temporary lanes, an addition of 50 new buses during the peak period has improved service in the corridor. Ridership has increased remarkably from 1,900 to 6,700 at a survey point midway along the route, while total ridership is over the 14,000 mark as of spring 1972.

This demonstration project also includes improvements to the entire bus system -- not just one segment, such as the building of an exclusive lane. Work is proceeding on three main elements: 1) assistance in developing a plan for timely changes in bus routing during construction; 2) development of additional bus service; and 3) monitoring the vehicle and person flows to determine public response to the improved service[20]. Circulation of buses in downtown Washington, D. C. is being improved to take advantage of the exclusive lane across the 14th Street Bridge. The project also includes the provision of fringe parking lots and bus shelters.

New York - New Jersey Turnpike[17,19,28]

The first major reverse bus lane was established on I-495 in Northern New Jersey in December 1970. The lane extends 2-1/2 miles from the New Jersey Turnpike to the Lincoln Tunnel. During the morning peak hours, the outbound median lane is made available to inbound buses. No provision has been made for a similar process in the evening because of differing traffic conditions. Morning outbound traffic is alerted to the reverse flow by 80 directional signals placed directly over the outbound lanes, traffic posts placed every 40 feet to designate the reversed lane, and 50 changeable traffic signs. In addition, bus access ramps have been provided to the reserved lanes by the New Jersey Turnpike Authority. This project is being funded by a $500,000 grant under the Urban Corridor Demonstration Program[19].

Prior to opening the lanes, 30,000 printed notices were distributed to motorists using this particular highway facility to inform them about the reverse lane operation. Over 800 buses, carrying approximately 35,000 commuters, are now saving an average of 15 minutes each by completing the former 25-minute trip in 10 minutes. Thus, it is estimated that an annual savings of 2 million person-hours of commuter traveltime will be realized. Data obtained by the New Jersey Department of Transportation show that 82 percent of the people riding through the tunnel during the morning peak are being carried by bus. Arrangements are now being made to make this exclusive bus lane a permanent installation[17]

New York-New Jersey-Manhattan CBD Study[17,30]

Under agreement with the Tri-State Transportation Commission, consultant Edwards and Kelcey is assisting with an evaluation of how three complementary techniques involving the use of bus mass transit can be utilized to improve commuting in the New Jersey Route 3 and I-495 corridor from New Jersey to the Manhattan CBD[30]. The main thrust is to provide greater passenger-carrying capacity for the corridor than that afforded by the automobile alone.

The three techniques under consideration are:

A. Bus Priority and Traffic Control

B. Park-and-Ride Facilities

C. Bus Freeway Stops and Access

At present the number of buses operating on the study portion of Route 3 does not warrant allocation of an exclusive bus lane. As alternatives, two distinct systems are being considered:

A. A ramp metering system that will expedite and improve the flow of all traffic (buses included)

B. A priority access control system that will give preferential treatment to buses.

The study includes assessment of existing traffic and roadway conditions, a description of possible control systems and their tradeoffs, and recommendations of a preferred control system.

New York-Long Island Expressway[17]

On the Long Island Expressway in New York City a reverse direction exclusive bus lane for Manhattan-bound buses was set up on October 26, 1971, in the morning rush hours. The project on the two miles of expressway from the Brooklyn-Queens Expressway to the Queens-Midtown Tunnel is being monitored by the New York Department of Traffic to see if it can be made permanent. Over 160 private and Transit Authority buses originating in Queens are being directed through a cut in the median barrier onto the special lane. These buses, running at 80 percent capacity and carrying about 6500 people, are averaging three and a half minutes on the two miles to the tunnel. Traffic traveling the same distance in the three westbound regular lanes is averaging 18 minutes. Traffic in the remaining eastbound lanes is not being delayed despite the loss of a lane[17].

Boston-Southeast Expressway[17]

A reverse direction bus lane on the Southeast Expressway in Boston was put into operation from May to October 1971. The 8-1/2 mile bus lane was in operation from 7-9 a.m. and 4-7 p.m. It took two State maintenance crews 1-1/4 hours to place cones and change signing for the operation. There were 75 buses using the lane during the morning peak period and 77 buses during the afternoon peak period. Bus service was increased to handle the increase in demand. In the first month of operation, bus passengers increased 24 percent in the morning peak period. It is estimated that bus patrons were saving up to 1/2 hour in traveling time during the peak hour. The project received favorable press coverage, but was discontinued because decreasing hours of daylight and the onset of winter caused concern for the work crew's safety. It was subsequently resumed during the morning rush hours in April 1972.

Seattle - Blue Streak[17]

The Blue Streak Demonstration Project consists primarily of an express bus operation. Buses depart from a fringe parking lot (no parking charge) north of downtown Seattle and enter the reversible lanes of the Seattle freeway (I-5), where they mix with regular traffic. An exclusive bus ramp permits the buses to exit quickly from the reversible lanes and enter a special downtown circulation loop. During the afternoon the scheme is reversed.

The demonstration project, funded by a $1.3 million demonstration grant from UMTA, begun on September 9, 1970. The nine mile trip from the fringe parking lot to the heart of downtown takes approximately 16 minutes. The headway between buses is about 5 minutes and the fare is 35¢. Three weeks after the beginning of the project, the 500-car parking lot was filled to capacity. Efforts are presently underway to find additional parking facilities. A preliminary survey of Blue Streak patrons revealed that more than 70 percent formerly used an automobile to get to work.

Pittsburgh - PATways[17]

The final design and engineering of two exclusive bus highways (PATways) in Pittsburgh is nearing completion. The two facilities will be grade-separated and will total 12 miles in length. Ramps will be provided to permit intermediate trips as well as line-haul trips to the downtown. The facilities will be designed and constructed to permit adaptation to a future guideway system such as the Transit Expressway Revenue Line (TERL) which is also under development in the Pittsburgh area. The design and construction of these PATways is being funded by capital grants from UMTA. Extensions of this initial system are planned.

Atlanta - Rapid Busways[33]

Residents of Metropolitan Atlanta recently approved a $1.32 billion mass transit improvement program which includes 14 miles of exclusive bus roadways. They will interface with rail rapid transit stations running into downtown Atlanta. Two-thirds federal funding is expected from UMTA with construction to begin in 1973.

San Bernardino - Exclusive Busways[16,17]

This proposed exclusive bus highway will be located partly within the median of and partly adjacent to the San Bernardino Freeway (I-10). Construction is underway on the 11-mile $52 million grade-separated busway running between El Monte and downtown Los Angeles. The California Division of Highways hopes to have the first stage of this project completed by October 1972. This first stage will include a 6.6 mile bus roadway within the median of the San Bernardino Freeway and a fringe parking lot at El Monte. Connections will be made to city streets and the freeway at either end of the busway. No other access to or from the busway will be provided. This project is being coordinated with the widening of the freeway from 6 to 10 lanes. The estimated passenger volume will be 4,000 persons per hour in the peak direction. To handle the increased patronage, 100 new buses will be purchased. The average bus speed and travel time on the facility will be approximately 40 mph and 18 minutes respectively.

Chicago - Crosstown Expressway[17]

The FHWA has approved the participation of FAI funds in the additional right-of-way and construction costs for a highway mass transit facility within a portion of the new Crosstown Expressway presently being built. Several technical problems exist, however. There is an equal demand for transit services in each direction preventing the use of reversible bus lane operation. It has not been determined if buses on local routes will be given the use of access ramps to the facility or whether the facility will be used strictly as a line-haul operation.

Milwaukee - Bus Rapid Transit[17]

A study in Milwaukee has developed a transit plan which includes designs for a bus highway, a CBD distribution system, and fringe parking facilities. Buses will circulate in residential areas to pick up commuters and then enter an exclusive bus highway paralleling I-94 to downtown Milwaukee. In addition, a $300,000 UMTA demonstration grant was awarded to Milwaukee County to do system definition and cost analyses of a dual-mode bus system. The concept envisions buses being operated on suburban streets under their own power for collection of passengers and then being transferred to a guideway for automatic guidance and speed control of the line-haul portion of the trip. The possibility of distributing passengers in the downtown area while remaining on the guideway will also be investigated.

Twin Cities - Bus-Metered Freeway System[17,36]

A recent study recommends proceeding with the development of a Bus-Metered Freeway System in the I-35W Corridor. Analysis of the concept, the engineering detail, the operations, and the costs indicate the feasiblity of combining a freeway surveillance and control system (a proven concept) with a freeway express bus system (also a proven concept).

The major benefits of the Bus-Metered Freeway System include increased accessibility to the Minneapolis CBD, reduced parking requirements in the CBD, reduced accidents and high level of service on I-35W, lower travel costs for transit riders as compared to auto users, improved mobility for corridor residents, approximately equal travel times for express transit and auto users, and increased knowledge about the factors that influence modal choice.

The recommended freeway surveillance and control system is programmed to operate at lower volumes and higher speeds (40 mph) than systems currently in operation. Buses will be afforded priority entry at the ramps. A recommended transit service plan would add 12 new routes and revise existing express routes so that 50 new buses will be required to carry 6,000 passengers on a typical weekday. The complete plan includes exclusive bus ramps, new transit vehicles, bus shelters, bus signs, park-ride facilities, and a marketing and advertising campaign.

Los Angeles Area Freeway Surveillance and Control Project[16,17]

The Los Angeles Area Freeway Surveillance and Control Project is a 42-mile experimental project located on the Santa Monica, San Diego, and Harbor Freeways to determine the feasibility of operating freeways as an integrated system of transportation by means of a real-time surveillance and control system. The experimental project will involve techniques to provide traffic sensitive ramp control with priority entry for buses where possible, early detection and rapid removal of disabled vehicles and other hazards from freeways, an effective warning and information system for motorists, and services for the stranded motorist. Construction of the project began in 1970, and it is expected that the testing and evaluation of data obtained from the project will be completed by 1973.

Cleveland - Reserved Lanes for Buses and Carpools[15,17]

The final report of a feasibility study in Cleveland to evaluate the reservation of an exclusive lane on the I-90 Memorial Shoreway for buses and carpools was recently completed. The study was a general overview of the feasibility of priority lanes and was jointly funded by the FHWA, OST, and UMTA. The EXCBUS model developed at ITTE in Berkeley was used to evaluate various possible priority lane operations on freeways and in particular on I-90 in Cleveland. The investigation was a thorough one and included such items as modal choice analysis, safety implications, user cost analysis, legislation affecting such a traffic operations scheme, law enforcement required, and the needed public relations and information programs.

The concept of reserving one or more freeway lanes for buses and carpools was found feasible; however, the best scheme for any one particular freeway should be carefully evaluated, as each freeway has its own idiosyncrasies, and the optimum priority scheme may vary widely from one freeway to the next. Also considerable concern has been expressed by law enforcement agencies in Cleveland and surrounding communities regarding enforcement of such a freeway operation. Because of their concern, there will be no implementation of this project in Cleveland in the foreseeable future.

Miami, Florida - Reserved Lanes for Buses and Carpools[17]

A Florida DOT task force has been set up to look into the feasibility of this project in Miami on I-95. A 12-mile section of freeway running from Golden Glades south into downtown Miami has been selected for study. The DOT task force hopes to have a specific recommendation for an on-the-ground demonstration of reserving a lane for buses and carpools in a few months.

B. Survey of Future Research Areas

As was just seen, there are no less than 17 projects around the country involving freeway priority operations, either on-going or being planned. Five of these involve reverse direction exclusive bus lanes. PRIFRE can be used now to evaluate reverse direction priority lanes with a little extra work. Some preliminary work was done in the course of this project for setting up PRIFRE to evaluate such a reversible lane strategy for US 101 in Marin County. A problem arises from the fact that the existing program can handle only one side of the freeway at a time. So a reversible lane strategy would require at least three separate runs of PRIFRE to evaluate one reversible lane scheme - one run for the peak-direction traffic; one run for the priority vehicles in the reserved reversible lane; and one run for the non-peak direction, which is now minus the lanes, now assigned to priority traffic. This is somewhat cumbersome and requires more inputting parameters and O-D tables for both sides of the freeway and the special reserved lane. It is felt that with some effort the PRIFRE model could be expanded to handle these reversible lane evaluations all in one run. This would be a significant improvement since many cities now have or are considering these types of priority operations.

Three cities are considering freeway surveillance and control projects, with priority entry at on-ramps for buses and carpools. Los Angeles in particular has several miles on on-going freeway surveillance/control projects, and plans are being drawn up for similar control measures on several other heavily congested freeways. Chicago, Dallas, and Houston all have several freeway control strategies in operation. New York City and the Twin Cities are looking seriously at ramp metering and control strategies to improve freeway operation in heavily congested corridors during peak hours. Concurrent with the planning for all of these has been the investigation of the possibility of affording priority entry for high-occupancy vehicles at on-ramps. Indeed, many traffic engineers think that this strategy is the direction most priority operations will take, as it eliminates the many problems associated with removing a freeway lane from normal operations and converting it to priority operations.

PRIFRE is the logical starting point for constructing a model to evaluate such priority entry schemes. Together with on-going research work at ITTE for the California Division of Highways involving ramp control strategies and the FREEQ model, PRIFRE could be expanded to evaluate these coming new priority entry strategies. It could be a powerful tool for the traffic engineer and planner who is investigating possible ramp metering and priority strategies, and better enable him to make an optimum selection, since many more alternatives can be considered using high-speed computers and a PRIFRE-type program.

Another improvement to priority operations evaluation, and therefore to the PRIFRE model, would be to examine the objective functions desired - i.e., what is the desired output, or end result. Presently the primary objective function of PRIFRE is total travel time saved, in passenger-hours. A secondary objective is vehicle-hours saved, from which operating cost savings could be calculated. But there are many other meaningful objectives and factors to be considered when deciding upon a particular freeway operation strategy. One valuable consideration might be the total number and type of vehicles entering the downtown area from the freeway under study. This reflects on downtown street circulation, congestion, parking spaces, bus terminal facilities, and even air pollution. Another desirable output might be the amounts of various pollutants discharged by the vehicles under different operating strategies, as the amounts are known to vary with vehicle speeds, densities, accelerations, and numbers. A breakdown in free-flow causes a queue to form, and under stop-and-go operations, gasoline engines are very inefficient.

Perhaps an even larger objective that traffic engineers should be looking at is the whole home-to-work trip in its entirety, and not just some isolated segment of it, such as priority operation on a few miles of freeway. After all, the engineer can hardly expect people to switch modes or form carpools if all they save is a few insignificant minutes in passing through a priority lane while losing many more minutes in getting to and from the bus stop or carpool at either end of their trip. To be truly effective in instituting a priority operations scheme, the traffic planner needs to be able to predict occupancy shifts and changes of mode with some expectation of reasonable accuracy, and this means looking at the both ends of the trip and total trip travel time. It also requires an investigation into the effects of instituting new bus service, carpool incentives, and marketing campaigns.

PRIFRE could be expanded to look at the whole trip length, as well as the whole trip corridor. Parallel facilities, such as arterials, frontage roads, exclusive bus roadways, and rapid transit routes, could be examined in a corridor model. Only then can the many contingent effects of a potential priority operations scheme begin to be fully known to the traffic planner.

Another area in which the PRIFRE model can be significantly improved is in the field of lane-changing and weaving analyses for priority lane operations. Preliminary work in these areas has been investigated at ITTE and is discussed in Chapter 6 and Appendix I. Presently the PRIFRE model is not set up to handle weaving or lane-changing analyses at the entrance and exit of priority lane sections, nor is lane-changing allowed between the reserved lane and the unreserved lanes once the priority section has begun. This places a serious restriction on the use of the reserved lane by those persons who wish to exit before the priority lane ends. Likewise, those persons who enter the freeway downstream of the priority lane entrance will also not be allowed to crossover the unreserved lanes and enter the reserved lane. Whether or not this would be permitted in actual freeway operations or not is not yet certain, but it would be a flexible option to have in the PRIFRE model. Similarly, it would be beneficial to the user if the program could calculate weaving effects at the entrance and exit of the priority lane. With some further work on PRIFRE, it is felt the model could incorporate these important features.

Work is also being performed to improve the model FREEQ, one of the two basic models upon which PRIFRE is constructed. Queueing subroutines are being re-written in what is felt to be a more accurate representation of what actually occurs on a real freeway, and numerous other smaller changes have been made to refine and polish up the program and make it more valuable to the user. It is felt that some of these recent additions to FREEQ might be valuable to PRIFRE, and with a minimum of effort, could be incorporated into the present program.

To be sure, there are several areas of future research in which the PRIFRE model could be expanded and improved. A few of the more important ones have been discussed. One thing seems certain - there will be much emphasis placed on freeway priority operations in the next few years as one way to reduce growing congestion. Many new and different strategies will probably emerge. Traffic engineers and planners must meet this new challenge, and up-to-date accurate freeway models will play a valuable part in assisting these men in their decisions. With computer models many more strategies and alternatives can be evaluated than would be possible if done by manual calculations. This can only lead to sounder solutions, since more options can be considered and the optimum one selected.

TABLE 28

SUMMARY TABLE OF FUTURE RESEARCH DIRECTIONS:

A.	MODIFICATIONS TO PRIFRE	1. Lane changing between reserved and unreserved lanes in priority section
		2. Weaving analysis at beginning and at end of priority section
		3. Extend M.O.E. from travel time to safety, operational costs, pollution, etc.
		4. Auxiliary lane analysis - modify and improve
B.	EXTENSION OF PRIFRE MODEL	1. Priority operations with ramp control strategies
		2. Priority lanes with reversible lanes
		3. Bus lanes with reversible lanes
C.	RESEARCH STUDIES	1. Total trip considerations - whole trip length, whole corridor
		2. Occupancy shifts - how to predict, encourage
		3. Modal splits - how to predict, encourage
		4. Computer matching of carpool users
D.	DEMONSTRATION STUDIES- EDUCATION ENFORCEMENT	1. Exclusive bus lanes
		2. Priority lanes for buses and carpools
		3. Reversible lanes - priority operation
		4. Priority entry control with ramp metering
E.	FACTUAL EVALUATION OF EXISTING PRIORITY OPERATIONS	1. Exclusive bus lanes
		2. Reversible bus lanes
		3. Priority lanes for buses and carpools
F.	APPLICATION OF PRIFRE TO PROPOSED PRIORITY OBJECTIONS	1. Possible travel time losses for non-priority vehicles
		2. Safety - lane changing, etc.
		3. Law enforcement of violators
		4. Maintenance for priority lanes - coning, signing, etc.

GLOSSARY OF IMPORTANT PRIFRE PROGRAM VARIABLES

BV(50,2)	Bus volume percentages; 1 = normal lanes, 2 = priority lanes
CAPFP(50)	Capacity per priority lane in I-th subsection
CAPS(50)	Total capacity of I-th subsection
CARTRP(20,20)	Total number of car trips from I-th origin to J-th destination
CPM	Cumulative passenger-miles in nonpriority lanes
CPMP	Cumulative passenger-miles in priority lanes
CVM	Cumulative vehicle-miles in nonpriority lanes
CVMP	Cumulative vehicle-miles in priority lanes
EBL	Bus equivalency factor in priority lanes
EBN	Bus equivalency factor in nonpriority lanes
EFF(5)	Weaving effect in I-th subsection in vehicles
FAC(20)	Mixed storage array for simulation and performance variables
FRL(20)	Ramp limit for I-th off-ramp
GF	Growth factor
H(50)	Length of mainline queue in I-th subsection in miles
ICT	Output line count variable
IFL(5)	Growth period, time slice, and simulation option counters
IFLAB	SPEED flag used to determine which speed flow curve to use
IFLAG	Logical control variable used by CONTROL to determine the variables to be initialized
IOCS	Number of input occupancy values
IOP	Priority lane selector

IP(50)	Priority lane indicator for I-th subsection
IPAG, IPAGE	Output page count variables
ITRIG	Merging analysis logical flag; 1 = there are influencing ramps, 2 = no merging analysis needed, 3 = there are no influencing ramps. Also, used as control flag to determine exit from QUEUP-DISQ pair
ITX	Equivalent to ITRIG
ITYP	In merging analysis; 1 = no auxiliary lane, 2 = auxiliary lane. In weaving analysis; 1 = simple ON...OFF, 2 = multiple ON...OFF...OFF, 3 = multiple ON...ON...OFF
IXX(9), VXX(9)	Ramp numbers and revised ramp limits
IXXX(5,5), REVON(5,5)	Ramp limit variables
LANE(50,2)	Number of lanes in I-th subsection; 1 = total, 2 = priority
LEFT(50)	Special ramp indicator for I-th subsection
LX(10)	Ramp numbers of ramps which influence an on-ramp for merging analysis
NCRV(5,2), XXSF(20,5), YYSF(20,5)	Storage arrays for user supplied speed flow curves
ND(20)	Subsection number of I-th destination
NDES	Total number of destinations
NDS(50,3)	Design speed flag for I-th subsection; 1 = normal lanes, 2 = nonpriority, 3 = priority lanes
NG1	Current growth period variable
NGP	Number of growth periods
NNN(10)	Mixed storage array for logical control variables and ramp and subsection indices

NO(20)	Subsection number of I-th origin
NORG	Total number of origins
NOTS	Total number of time slices
NPL	Number of priority lanes in current simulation
NTOTAL(50)	Original subsection demand
NSEC	Total number of subsections
PCTVEH(5,5), BUSOC(5), AVE	Occupancy variables
PLC	Minimum vehicle occupancy for priority status
POFF(20,2)	Used by PRILANE to calculate volume of priority vehicles
PRI(7)	Number of priority lanes in priority section, depending on IOP
QD(50)	Used by DISQ to determine the destination pattern of a queue
RA(50)	Rate of storage of vehicles in I-th subsection
RD(20)	Ramp queue delay at I-th on-ramp
RDIS(50)	Distance from beginning of study section to ramps in feet, special ramps having negative values
RLIM(20)	Ramp limit for I-th on-ramp
RQ(20,2)	Ramp queue at I-th on-ramp; 1 = buses, 2 = non-buses
RRR(10)	Mixed storage array for volume and time variables
RVOL(50)	Ramp volume of I-th ramp, off-ramps having negative values
RXX	A priori ramp limit
SUM(20,2,2)	Ramp volumes; 1 = on-ramps, 2 = off-ramps; 1 = buses, 2 = non-buses
TBF(50)	Truck factor in I-th subsection

TD(50)	Total travel distance for I-th subsection in vehicle-miles for nonpriority lanes
TDP(50)	Total travel distance for I-th subsection in vehicle-miles for priority lanes
TOSUM(20,20,2)	Total number of trips from I-th origin to J-th destination; 1 = buses, 2 = non-buses
TRPVEH(20,20)	Total number of vehicle trips from I-th origin to J-th destination
TT(50)	Total travel time for I-th subsection in vehicle-hours for non-priority lanes
TTP(50)	Total travel time for I-th subsection in vehicle-hours for priority lanes
VNPR(50)	Volume of I-th subsection in nonpriority lanes
VPR(50)	Volume of I-th subsection in priority lanes
VPRIN(50)	Volume of I-th subsection of priority vehicles in nonpriority lanes
XLENGF(50)	Length of I-th subsection in feet
XLENGM(50)	Length of I-th subsection in miles
XMD(20)	Merge queue delay at I-th on-ramp
XMQ(20)	Merge queue length at I-th on-ramp

APPENDIX A

Some Definitions

Normal Operations	Existing mixed traffic operations in all freeway lanes.
Priority Lane Operations	Operation of a freeway facility on which one or more lanes have been reserved for the use by vehicles carrying more than a specified number of occupants. Under priority operations, the two classes of lanes will be referred to as reserved and unreserved. A priority lane operation in which only buses are allowed in the reserved lane (historically known as an exclusive bus lane operation) is a special case of the more general priority lane operation definition.
Priority Lane	A freeway lane reserved for the exclusive use of high-occupancy vehicles, i.e., buses and carpools during peak traffic hours.
Exclusive Bus Lane	A freeway lane reserved for the exclusive use of buses to bypass congestion during peak traffic hours.
Reversible Lanes	One or more freeway lane(s) reserved for high-occupancy vehicles so that traffic can flow in one direction in the morning peak and then reversed for afternoon peak flows in the opposite direction. Sometimes traffic in the reversible lane runs counter to the traffic in the adjoining freeway lanes.
Rapid Busway	A separate roadway constructed exclusively for use of buses; busway can be in the median of the freeway or completely removed from it.
Priority Entry	Under freeway surveillance and control operations, priority entry is afforded buses and/or carpools from the entrance ramps. Traffic is metered onto the freeway proper at a rate that maintains free-flowing conditions.

Queue	A waiting line of cars operating under stop and go conditions.
Queue Evolution	Occurs when the demand for a freeway section exceeds its capacity flow; the excess demand RA(I) begins to back up behind the limiting bottleneck and a queue forms.
Queue Collision	A phenomenon which occurs when two separate distinct queues in adjoining sections grow together, or "collide". The two queues then form one combined queue which proceeds to grow at a new, combined rate.
Queue Split	A phenomenon which occurs when one queue splits into two separate and distinct queues. This happens in a queue decreasing situation as the queue is being discharged. The capacity of the upstream section cannot meet the flow rate capacity of the downstream section so that the downstream queue begins to be discharged at a faster rate, and splits off from the upstream queue.
Queue Clear	A programming instruction which tells the computer to clear out the remaining queue at the end of a time slice if the remaining queue is very small. This keeps the program from fictitiously generating queue flow rates in the next time slice. Remember that demand and flow rates must remain constant over one entire time slice.
Downstream	The direction in which traffic is moving.
Upstream	The direction from which traffic has just come.
Mode	The manner or means selected for travel: auto, bus, rail, airplane, walking.
Occupancy Shift	Occurs when people are induced to switch modes. In this program, occupancy shift is defined as the percentage of persons in a non-priority status (i.e., non-carpool) that switch or may switch to priority status (carpool).

Demoted	A programming instruction which occurs when there is an excess demand for a priority lane. The assumption is that no queueing will be allowed in the priority lane; the excess number of priority vehicles (buses and carpools) are forced to use the unreserved freeway lanes. These vehicles are still eligible for other priority sections that may occur further downstream if they can qualify.

APPENDIX B

CDC 6400 CONTROL CARDS

The 6400 system control cards provide information concerning job processing and file handling to the operating system. With control cards a programmer decides how his program will be executed. Control cards use files as their arguments. A file that has not been previously defined will be created as a temporary file on the disk storage system.

The following cards are needed to execute the program PRIFRE from a magnetic tape:

JOB CARD.

JXXXX,1,100,50000,400. YOUR NAME where XXXX is your job number.

REQUEST,APPLE,HI,U.0025 -	This requests a tape named APPLE which contains the binary version of PRIFRE.
COPY BF,APPLE,PRIFRE	This copies the binary version to a temporary file.
REWIND,PRIFRE.	This rewinds that temporary file.
LGO,PRIFRE or LGO,PRIFRE,OUT	This will load and execute the program.

The second version of the card is used if more than one copy of the output is desired. In that case, the following cards are needed:

REWIND,OUT COPY CF,OUT	For each set of output these 2 cards are necessary.

After these cards, a card with a 7, 8, and 9 punched in column 1 is placed, and then the data deck to PRIFRE will execute a RUN.

APPENDIX C

COMPUTER PROGRAM LISTING

OF PRIFRE

APPENDIX C

CDC 6400 PRIFRE LISTING

```
      PROGRAM PRIFRE(INPUT,OUTPUT,TAPE1,TAPE5=INPUT)
      COMMON/CURVE/NCRV(5,2),XXSF(20,5),YYSF(20,5),NDS(50,3)
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/INTEG/NNN(10)
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           TOSUM(20,2)
      COMMON/OUTS/CVM,CPM,NTOTAL(50),CVMP,CPMP
      COMMON/PAGG/ATM,FDAT,ICT,IPAG
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      COMMON/REALS/RRR(10)
      COMMON/SLIC/PCTVEH(5,5),BUSOC(5),AVE,IXXX(5,5),REVON(5,5),ITSLT(8)
      COMMON/TIME1RA(50),TT(50),TD(50),TTP(50),TDP(50)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
      CALL SECOND(ATM)
      FDAT=22.0
      ICT=0
      IPAG=1
   10 FAC(20)=0.0
      FAC(19)=0.0
      CALL READIT
  100 CALL CONTROL(I)
      IF(I.EQ.2) GO TO 10
      CALL SLICE
      CALL RAMPQ
      CALL PRILANE
      CALL RMSUM (J)
      DO 20 L=2,J
      CALL UDRAMP (L,ITRIG)
      GO TO (30,20,40),ITRIG
   30 CALL PVL (L)
   40 CALL IVP8 (L,ITRIG)
      CALL P823 (L)
      CALL MERGQ(ITRIG)
      IF(ITRIG.EQ.1) CALL DISQ
   20 CONTINUE
      CALL WEAVCON
      ITRIG=2
   60 CALL QUEUP (ITRIG)
      IF(ITRIG.NE.3) GO TO 50
      CALL DISQ
      GO TO 60
   50 CALL TRAVEL
      CALL OUTIT
      CALL TIMEOU3
      GO TO 100
      END
      SUBROUTINE READIT
```

```
      COMMON/CURVE/NCRV(5,2),XXSF(20,5),YYSF(20,5),NDS(50,3)
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           TOSUM(20,2)
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      COMMON/SLIC/PCTVEH(5,5),BUSOC(5),AVE,IXXX(5,5),REVON(5,5),ITSLT(8)
      DIMENSION MTITLE(8),SSTIT(4),TEMP(10),NOSS(50)
C ---
C --- READ MAIN TITLE (JOB TITLE)
      READ 1000,MTITLE
      IF(EOF,5) 2,3
    2 CALL DISPLAY
    3 CALL PAGE(0)
      IPAGE=1
      NORG=0
      NDES=0
      JC=0
      CALL PAGE(1)
      PRINT 1001,MTITLE
C --- READ PARAME3ER CARD
      READ 1002,NSEC,FAC(1),FAC(2),PLC,IOP,NGP,GF,IOCS,EBN,EBL,FAC(18)
      IF(EBN.EQ.0) EBN=2.0
      IF(EBL.EQ.0) EBL=1.6
      CALL PAGE(1)
      PRINT 1003,NSEC,FAC(1),FAC(2),PLC,IOP,NGP,GF,IOCS,EBN,EBL
      IF (IOCS.LE.0) IOCS=1
      IF (IOCS.GT.5) GO TO 290
      IF (IOP.LT.*.OR.IOP.GT.6) GO TO 295
C --- READ THE CAPACITY CARD
      DO 60 I=1,NSEC
      READ 1004,NOSS(I),IP(I), LANE(I),CAPS(I),CAPFP(I),XLENGF(I),
      PRINT 1005,NOSS(I),IP(I), LANE(I),CAPS(I),CAPFP(I),XLENGF(I),
     1    NDS(I,1),NDS(I,2),NDS(I,3),TBF(I),LOD,LOE,LEFT(I),SSTIT
     1    NDS(I,1),NDS(I,2),NDS(I,3),TBF(I),LOD,LOE,LEFT(I),SSTIT
      CALL PAGE(1)
      IF(IP(I).EQ.1HP.AND.LEFT(I).EQ.1) GO TO 315
      JS=3
      IF (IP(I).EQ.1H ) JS=1
      IF (IP(I).NE.1HP.AND.IP(I).NE.1H ) GO TO 300
C --- WHAT IS THE DESIGN SPEED
      DO 15 J=1,JS
      IF (NDS(I,J).EQ.50.OR.NDS(I,J).EQ.60.OR.NDS(I,J).EQ.70) GO TO 15
      IF(NDS(I,J).EQ.65) GO TO 15
      IF (NDS(I,J).LT.1.OR.NDS(I,J).GT.5) GO TO 305
      IF (JC.NE.0) GO TO 5
      JC=1
      NCRV(1,1)=NDS(I,J)
      GO TO 15
    5 DO 10 K=1,JC
      IF (NDS(I,J).EQ.NCRV(K,1)) GO TO 15
   10 CONTINUE
      JC=JC+1
```

```
      NCRV(JC,1)=NDS(I,J)
   15 CONTINUE
C --- WHAT IS THE SECTION LENGTH IN MILES
      XLENGM(I)=XLENGF(I)/5280.
C --- IF THIS IS A PRIORITY SECTION WHAT IS THE FIRST LANE CAPACITY
      IF (IP(I).EQ.1H ) GO TO 30
      IF (CAPFP(I).LE.0.0) CAPFP(I)=1500.
C --- DOES THIS SECTION HAVE AN ON-RAMP AND/OR OFF-RAMP
   30 IF (LOD.NE.1HO) GO TO 35
      NORG=NORG+1
      NO(NORG)=I
      GO TO 40
   35 IF (LOD.NE.1H ) GO TO 310
   40 IF (LOE.NE.1HD) GO TO 45
      NDES=NDES+1
      ND(NDES)=I
      GO TO 60
   45 IF (LOE.NE.1H ) GO TO 310
   60 CONTINUE
      NO(NORG+1)=9999
      ND(NDES+1)=9999
C --- THIS IS THE END OF THE CAP CARDS  RAMP CARDS ARE NEXT
      READ 1006,RXX,(IXX(I),VXX(I),I=1,9)
      CALL PAGE(1)
      PRINT 1007,RXX
      DO 80 I=4,9
      IF(IXX(I).EQ.0) GO TO 80
      CALL PAGE(1)
      PRINT 1008,IXX(I),VXX(I)
   80 CONTINUE
      DO 85 I=1,3
      IF(IXX(I).EQ.0) GO TO 85
      CALL PAGE(1)
      PRINT 1009,IXX(I),VXX(I)
   85 CONTINUE
C --- READ ANY SPEED-FLOW CURVES
      IF (JC.EQ.0) GO TO 150
      CALL PAGE(1)
      PRINT 1010,(NCRV(I,1),I=1,JC)
      DO 120 J=1,6
      READ 1011,NCRT,(TEMP(I),I=1,10)
      IF(NCRT.EQ.0) GO TO 150
      JT=0
      DO 110 K=1,JC
      IF (NCRT.NE.NCRV(K,1)) GO TO 110
   95 DO 100 I=1,10,2
      IF(TEMP(I).EQ.0.0.AND.TEMP(I+1).EQ.0.0) GO TO 121
      JT=JT+1
      XXSF(JT,K)=TEMP(I)
      YYSF(JT,K)=TEMP(I+1)
  100 CONTINUE
      READ 1011,NCRTT,(TEMP(I),I=1,10)
      IF (NCRTT.EQ.NCRT) GO TO 95
      NCRT=NCRTT
  121 NCRV(K,2)=JT
      JT=0
      IF(NCRT.EQ.0) GO TO 150
```

```
      GO TO 120
  110 CONTINUE
  120 CONTINUE
C --- THIS SECT HAS TO END WITH AN UNEVEN SET OR A BLANK CARD
C --- NOW IT IS TIME SLICE TIME
  150 NOTS=0
C --- READ  TIME SLICE' TITLE CARD
  160 READ 1000,ITSLT
      IF (ITSLT(1).EQ.10HEND OD      )  GO TO 350
C --- READ UP TO 5 OCCUPANCY CARD/SLICE  IOCS=1,5
      DO 170 I=1,IOCS
      READ 1013,BUSOC(I),(PCTVEH(J,I),J=1,5),(IXXX(J,I),REVON(J,I),J=1,
     1      5)
  170 CONTINUE
      DO 210 K=1,2
      DO 200 I=1,NORG
      READ 1014,(TRIPS(I,J,K),J=1,NDES)
  200 CONTINUE
  210 CONTINUE
C --- NOW WRITE  THE GUY  ON TAPE
      WRITE(1) ITSLT,IOCS,(((TRIPS(I,J,K),J=1,NDES),I=1,NORG),K=1,2)
      DO 220 K=1,IOCS
  220 WRITE (1) BUSOC(K),(PCTVEH(J,K),IXXX(J,K),REVON(J,K),J=1,5)
      NOTS=NOTS+1
      GO TO 160
C ---
C --- ERROR SECTION
C ---
  290 PRINT 1015,IOCS
      CALL DISPLAY
  295 PRINT 1016,IOP
      CALL DISPLAY
  300 PRINT 1017,IP(I)
      CALL DISPLAY
  305 PRINT 1018,NDS(I,J)
      CALL DISPLAY
  310 PRINT 1019,LOD,LOF
      CALL DISPLAY
  315 PRINT 1020,I
      CALL DISPLAY
C --- EVERYTHING IS OK IF IT GETS TO THIS POINT
  350 END FILE 1
      PRI(1)=0
      PRI(2)=1
      PRI(3)=2
      PRI(4)=0
      PRI(5)=0
      PRI(6)=1
      PRI(7)=0
      NG1=0
      IFL(1)=0
      IFL(2)=IOP/3+1
      NPL=IFIX(PRI(IOP+1))
      IFL(3)=1
      REWIND 1
      RETURN
C ---
```

```
C --- FORMAT SECTION
C ---
 1000 FORMAT (8A10)
 1001 FORMAT (1HX,8A10)
 1002 FORMAT (I4,3F5.0,I2,I5,F5.2,I3,2F5.2,F6.0,I1)
 1003 FORMAT (/11H INPUT DATA /1X,I2,12H SUBSECTIONS,3X,7HFAC(1)=,F3.0,3
     1X,7HFAC(2)=,F3.0,3X,17HPRIORITY CUT-OFF=F3.0,3X,7HOPTION=I2,3X,I2,
     223H GROWTH PERIODS AT RATE ,F5.2,3X,I2,17H OCCUPANCY SHIFTS  /
     X1X,*PASSENGER CAR EQUIVALENCY OF BUSES(NORMAL) = *,F5.2,5X,*PASSEN
     XGER CAR EQUIVALENCY OF BUSES(PRIORITY) = *,F5.2//
     3  90H SSEC  NO. CAP. CAP 1  LENG NOR UNR RES  TRK. ORG. LFT      SU
     4B SECTION LOCATION                                  /
     5 60H NO. P LN        P. LN.       SPD SPD SPD  FAC. DES. RMP
     6   //)
 1004 FORMAT (I3,A1,I2,3F5.0,3I3,F5.3,2X,2A1,I1,4A10)
 1005 FORMAT (I4,1X,A1,I2,F7.0,2F6.0,3I4,F5.3,3X,2A1,I4,7X,4A10)
 1006 FORMAT (F6.0,9(I3,F5.0))
 1007 FORMAT (//17H    RAMP LIMITS = ,F5.0)
 1008 FORMAT (20X,7HON-RAMP ,I3,7H LIMIT= ,F5.0)
 1009 FORMAT (20X,8HOFF-RAMP,I3,7H LIMIT= ,F5.0)
 1010 FORMAT(16X,63HTHE FOLLOWING NUMBERED SPEED-FLOW CURVES HAVE BEEN A
     1SKED FOR -     ,I2,4(1H,,I2))
 1011 FORMAT (I4,10F7.0)
 1013 FORMAT (F5.0,5F5.1,6(I3,F5.0))
 1014 FORMAT (20F4.0)
 1015 FORMAT (13H IOCS ERROR -        ,I3  ,13H EXIT-CALLED  )
 1016 FORMAT (12H IOP ERROR -         ,I3  ,13H EXIT-CALLED  )
 1017 FORMAT (11H IP ERROR -          ,A1  ,13H EXIT-CALLED  )
 1018 FORMAT (12H NDS ERROR -         ,I3  ,13H EXIT-CALLED  )
 1019 FORMAT (20H LOD OR LOE ERROR - ,2A1,13H EXIT-CALLED  )
 1020 FORMAT(* LEFT OFF RAMP WITH IN PRI LANE SUB SEC, * I5,13HEXIT CALL
     1ED  )
      END
      SUBROUTINE PAGE(N)
      COMMON/PAGG/ATM,FDAT,ICT,IPAG
      IF(N.EQ.0) GO TO 10
      ICT=ICT+N
      IF(ICT.LE.62) RETURN
   10 ICT=4+N
      PRINT 1000,FDAT,IPAG
      IPAG=IPAG+1
      RETURN
 1000 FORMAT(1H8,*INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING*,
     140X,*VERSION *,F8.1 /X,*UNIVERSITY OF CALIFORNIA*,67X,*PAGE NO. *,
     2I7/X,*BERKELEY, CALIFORNIA*/)
      END
      SUBROUTINE DISPLAY
      COMMON/PAGG/ATM,FDAT,ICT,IPAG
      CALL PAGE(0)
      CALL REMARK(1H  )
      CALL REMARK(23H FREEWAY PRIORITY MODEL )
      CALL REMARK(1H  )
      CALL SECOND (ATMM)
      ELAS=ATMM-ATM
      COST=7.0/60.0*ELAS
      PRINT 1001
      PRINT 1000,ELAS,COST
```

```
      CALL EXIT
1000  FORMAT(//31X,*ELAPSED CPU TIME = *F7.3,* SECONDS, COST (AT $420.00
     1 PER CPU HOUR) = $ *F8.3)
1001  FORMAT(////////////41X,40HPPPPPP  RRRRR   I  FFFFFF  RRRRR   EEEEE
     1 /2(41X,40HP    P  R    R  I  F       R    R  E       /),41X,40HPPP
     2PP   RRRRR   I  FFFFF   RRRRR   EEEE   /41X,40HP        R  R    I
     3F      R  R    E      /41X,40HP       R    R   I  F       R   R
     4E      /41X,40HP        R    R  I  F       R    R  EEEEE  ////46X,
     5*THE FREEWAY PRIORITY MODEL*//)
      END
      SUBROUTINE CONTROL(IFLAG)
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/OUTS1CVM,CPM,NTOTAL(50),CVMP,CPMP
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      IFLAG=1
      IF(IFL(1).NE.0) GO TO 100
    5 DO 10 I=4,5
   10 IFL(I)=1
   15 DO 20 I=4,17
   20 FAC(I)=0.0
      DO 35 I=1,NSEC
      H(I)=0.0
      IF(IP(I).NE.1HP.OR.NPL.EQ.0) GO TO 35
      CAPS(I)=FLOAT(LANE(I,1)-NPL)/FLOAT(LANE(I,1))*CAPS(I)
   35 CONTINUE
      H(NSEC+1)=0.0
      CVM=0.0
      CPM=0.0
      CVMP=0.0
      CPMP=0.0
      DO 30 I=1,20
      RLIM(I)=RXX
      XMQ(I)=0.0
      RQ(I,1)=0.0
      RQ(I,2)=0.0
   30 CONTINUE
      RLIM(1)=CAPS(1)
      DO 40 I=1,NDES
   40 FRL(I)=RXX
      DO 50 I=4,5
      IF(IXX(I).EQ.0) GO TO 50
      NX=IXX(I)
      RLIM(NX)=VXX(I)
   50 CONTINUE
      DO 55 I=1,3
      IF(IXX(I).EQ.0) GO TO 55
      NX=IXX(I)
      FRL(NX)=VXX(I)
   55 CONTINUE
      IO=1
      DO 60 I=1,NSEC
      IF(LEFT(I).NE.2) GO TO 60
```

```
   70 IF(NO(IO).GE.I) GO TO 65
      IO=IO+1
      GO TO 70
   65 RLIM(IO)=RLIM(IO)*2.0
   60 CONTINUE
  100 IFL(1)=IFL(1)+1
      DO 120 I=1,20
      XMD(I)=0.0
  120 RD(I)=0.0
      IF(IFL(1).LE.NOTS) RETURN
      PRINT 1000
      IF(NPL.EQ.0) GO TO 130
      DO 125 I=1,NSEC
      IF(IP(I).NE.1HP) GO TO 125
      CAPS(I)=FLOAT(LANE(I,1))/FLOAT(LANE(I,1)-NPL)*CAPS(I)
  125 CONTINUE
  130 IFL(1)=0
      REWIND 1
      IF(IFL(2).EQ.1) GO TO 210
      IFL(2)=IFL(2)-1
      NPL=NPL+1
      IF(IOP.EQ.4) NPL=2
      GO TO 5
  210 IFL(3)=IFL(3)+1
      IFL(2)=IOP/3+1
      NPL=IFIX(PRI(IOP+1))
      IF(IFL(3).LE.IOCS) GO TO 15
      IFL(3)=1
      NG1=NG1+1
      IF(NG1.LE.NGP) GO TO 5
      IFLAG=2
      RETURN
 1000 FORMAT(///,01X,*END OF SIMULATION FOR ABOVE CRITERION*)
      END
      SUBROUTINE SLICE
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           TOSUM(20,2)
      COMMON/OUTS/CVM,CPM,NTOTAL(50),CVMP,CPMP
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      COMMON/SLIC/PCTVEH(5,5),BUSOC(5),AVE,IXXX(5,5),REVON(5,5),ITSLT(8)
((((((((((((((((((((((((((((((((((((((((((((((,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,999999
 *************************  
    5 ROMB(K**K20        ***** SEE ERRATA AT THE END OF THE LISTING
C--- READ THIS TIME SLICE
      READ (1) IT2LT,IOCS,(((TRIPS(I,J,K),J=1,NDES),I=1,NORG),K=1,2)
      I=1
      IC=0
  100 READ (1) BUSOC(I),(PCTVEH(J,I),IXXX(J,I),REVON(J,I),J=1,5)
      IC=IC+1
C--- FIND THE CORRECT OCCUPANCY SHIFT
      IF(IC.NE.IFL(3).AND.I.EQ.1) GO TO 100
      IF(IC.EQ.IOCS) GO TO 30
      I=2
      GO TO 100
   30 CALL PAGE(0)
```

```
      PRINT 2000,ITSLT,NPL,NG1,IFL(3)
      CALL PAGE(3)
C--- REVISE THE ON RAMPS
      DO 10 I=1,5
      IF(IXXX(I,1).EQ.0) GO TO 10
      J=IXXX(I,1)
      RLIM(J)=REVON(I,1)
      CALL PAGE(2)
      PRINT 2001,J,REVON(I,1)
   10 CONTINUE
      IF(NG1.EQ.0) GO TO 40
      XMUL=GF**NG1
      DO 50 K=1,2
      DO 50 J=1,NDES
      DO 50 I=1,NORG
   50 TRIPS(I,J,K)=TRIPS(I,J,K)*XMUL
C--- CALL ODADD TO FIGURE THE INPUT-OUTPUT VOLUMES
   40 CALL ODADD(0)
      IO=ID=1
      NTOT=0
      DO 150 I=1,NSEC
      IF(NO(IO).NE.I) GO TO 160
      NTOT=NTOT+SUM(IO,1,2)+SUM(IO,1,1)*EBN
      IO=IO+1
  160 IF(ND(ID).NE.I-1) GO TO 150
      NTOT=NTOT-SUM(ID,2,2)-SUM(ID,2,1)*EBN
      ID=ID+1
  150 NTOTAL(I)=NTOT
C--- PRINT OUT THE INFORMATION
      IF(FAC(2).NE.2) GO TO 400
      CALL PAGE(10)
      PRINT 1000
      PRINT 1001,BUSOC(1)
      PRINT 1008,(NUMB(J),J=1,NDES)
      CALL PAGE(NORG)
      DO 200 I=1,NORG
  200 PRINT 1007,I,(TRIPS(I,J,1),J=1,NDES)
      CALL PAGE(6)
      PRINT 1003,(SUM(J,2,1),J=1,NDES)
      PRINT 1002,(SUM(I,1,1),I=1,NORG)
      CALL PAGE(11)
      PRINT 1004,(PCTVEH(I,1),I=1,5),AVE
      PRINT 1008,(NUMB(J),J=1,NDES)
      DO 300 I=1,NORG
      CALL PAGE(1)
  300 PRINT 1007,I,(CARTRP(I,J),J=1,NDES)
      CALL PAGE(6)
      PRINT 1003,(SUM(J,2,2),J=1,NDES)
      PRINT 1002,(SUM(I,1,2),I=1,NORG)
      CALL PAGE(6)
      PRINT 1006,(TOSUM(J,2),J=1,NDES)
      PRINT 1005,(TOSUM(I,1),I=1,NORG)
      CALL PAGE(0)
  400 CALL ODADD(1)
      RETURN
 1000 FORMAT( 1X,*ALL VALUES IN VEHICLES PER HOUR*)
 1001 FORMAT(49X,*BUS OCCUPANCY *F6.1//45X,*BUS ORIGIN - DESTINATION TAB
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```
   1LE*//* ORIGINS*15X,*DESTINATIONS ACROSS*/* DOWN*/)
1002 FORMAT(X,*ROW SUMS (INPUT VOLUMES)*/6X,15(F6.0,2X)/X,10(F6.0,2X)/)
1003 FORMAT(X,*COLUMN SUMS(OUTPUT VOLUMES)*/6X,15(F6.0,2X)/X,10(F6.0,
   12X)/)
1004 FORMAT(44X,*NON-BUS OCCUPANCY DISTRIBUTION*//6X,*OCC. ONE = *F4.0,
   1* PCT  OCC. TWO = *F4.0* PCT  OCC. THREE = *F4.0* PCT OCC. FOUR =
   2*F4.0* PCT  OCC. FIVE = *F4.0* PCT*/21X*AVE OCC. = *F6.2,
   3     * PERSONS/VEHICLE*//45X,*NON-BUS ORIGIN - DESTINATION TABLE*//
   4* ORIGINS*15X,*DESTINATIONS ACROSS */* DOWN*/)
1005 FORMAT(X,*ROW SUMS (TOTAL INPUT VOLUMES)*/6X,15(F6.0,2X)/X,10(F6.0
   1,2X)/)
1006 FORMAT(31X,*TOTAL VOLUMES IN VEHICLES*//X,*COLUMN SUMS(TOTAL OUTPU
   1T VOLUMES)*/6X,15(F6.0,2X)/X,10(F6.0,2X)/)
1007 FORMAT(X,I2,X,20F6.0)
1008 FORMAT(2X,*0*,1X,20I6)
2000 FORMAT(*                    */X,8A10/24X,*NO. OF PRIORITY LANES = *I1,
   110X,*GROWTH PERIOD *I2,10X,*OCCUPANCY SHIFT*,I3)
2001 FORMAT(11X,*REVISED ON RAMP LIMIT - RAMP NO. *I6* TO *F6.1,* VEHIC
   1LES PER HOUR*/)
2002 FORMAT(1H6///)
     END
     SUBROUTINE ODADD(III)
     COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
     COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
     COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
    1          TOSUM(20,2)
     COMMON/SLIC/PCTVEH(5,5),BUSOC(5),AVE,IXXX(5,5),REVON(5,5),ITSLT(8)
     EBNF=1.0
     IF(III.NE.0) EBNF=EBN
  50 DO 30 I=1,20
     DO 30 J=1,2
     DO 40 K=1,2
  40 SUM(I,J,K) =0.0
  30 TOSUM(I,J)=0.0
     AVE=0.0
     DO 10 I=1,5
  10 AVE=FLOAT(I)*PCTVEH(I,1)+AVE
     AVE=AVE/100.0
     DO 20 I=1,NORG
     DO 20 J=1,NDES
     CARTRP(I,J)=FLOAT(IFIX(TRIPS(I,J,2)/AVE+0.5))
     TRPVEH(I,J)=CARTRP(I,J)+TRIPS(I,J,1)*EBNF
     SUM(I,1,1)=SUM(I,1,1)+TRIPS(I,J,1)*EBNF
     SUM(I,1,2)=SUM(I,1,2)+CARTRP(I,J)
     SUM(J,2,1)=2UM(J,2,1)+TRIPS(I,J,1)*EBNF
     SUM(J,2,2)=SUM(J,2,2)+CARTRP(I,J)
     TOSUM(I,1)=TOSUM(I,1)+TRPVEH(I,J)
  20 TOSUM(J,2)=TOSUM(J,2)+TRPVEH(I,J)
     RETURN
     END
     SUBROUTINE RAMPQ
     COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
     COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
     COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
     COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
    1          TOSUM(20,2)
     COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
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      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      DO 100 I=1,NORG
      IF(TOSUM(I,1).EQ.0.0) GO TO 100
      TA=TOSUM(I,1)-RLIM(I)
      P=RLIM(I)/TOSUM(I,1)
      IF(TA.GT.0.*) GO TO 20
      IF(TA.EQ.0.0) GO TO 100
      IF(RQ(I,1).LE.0.0) GO TO 105
      IF(I.EQ.1.AND.(XLENGM (1)-H(1)).LE.0.0001) GO TO 110
      PE=(TOSUM(I=1)+RQ(I,1)*FAC(1))/TOSUM(I,1)
      IF(PE.GT.P) GO TO 130
      BUSN=RQ(I,1)*RQ(I,2)
      VECH=(RQ(I,1)-BUSN)*FAC(1)
      BUSN=BUSN*FAC(1)
      RD(I)=RD(I)+RQ(I,1)/(2.0*FAC(1))
      RQ(I,1)=0.0
  160 PEV=(SUM(I,1,2)+VECH)/SUM(I,1,2)
      IF(SUM(I,1,1).NE.0) GO TO 135
      PEB=1.0
      GO TO 140
  135 PEB=(SUM(I,1,1)+BUSN)/SUM(I,1,1)
  140 DO 150 J=1,NDES
      TRIPS(I,J,1)=TRIPS(I,J,1)*PEB
  150 TRIPS(I,J,2)=TRIPS(I,J,2)*PEV
      GO TO 100
  130 BUSN=-TA*RQ(I,2)
      VECH=-TA-BUSN
      RQ(I,1)=RQ(I,1)+TA/FAC(1)
      RD(I)=RD(I)+(RQ(I,1)-TA/(2.0*FAC(1)))/FAC(1)
      GO TO 160
   20 BPEN=SUM(I,1,1)/TOSUM(I,1)
      IF(RQ(I,1).GT.0.0) GO TO 50
      RQ(I,1)=TA/FAC(1)
      RQ(I,2)=BPEN
      RD(I)=RQ(I,1)/(2.0*FAC(1))
   25 DO 40 J=1,NDES
      DO 40 K=1,2
   40 TRIPS(I,J,K)=TRIPS(I,J,K)*P
      GO TO 100
   50 RD(I)=(RQ(I,1)+TA/(2.0*FAC(1)))/FAC(1)+RD(I)
      RQ(I,1)=RQ(I,1)+TA/FAC(1)
      RQ(I,2)=(RQ(I,2)+BPEN)/2.0
      GO TO 25
  105 RD(I)=0.0
      RQ(I,1)=0.0
      RQ(I,2)=0.0
      GO TO 100
  110 RD(1)=RQ(1,1)/FAC(1)+RD(1)
  100 CONTINUE
      RETURN
      END
      SUBROUTINE PRILANE
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
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      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           TOSUM(20,2)
      COMMON/SLIC/PCTVEH(5,5),BUSOC(5),AVE,IXXX(5,5),REVON(5,5),ITSLT(8)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C--- CALL ODADD TO FIGURE THE INPUT-OUTPUT VOLUMES WITH THE REVISED TABL
      CALL ODADD(1)
      DSTCN=FAC(18)
      EBFAC=EBL/EBN
      NPLC=IFIX(PLC)
      PRIPEN=0.0
      IF(NPL.EQ.0) GO TO 12
      IF(PLC.EQ.6.0) GO TO 12
C--- FIND THE PERCENTAGE OF NON-BUSES ALLOWED IN A PRI LANE
      DO 10 J=NPLC,5
   10 PRIPEN=PRIPEN+PCTVEH(J,1)/100.0
   12 PNPEN=1.0-PRIPEN
      VP=VNP=VN=0
      IF(NPL.EQ.0) GO TO 30
      ID=1
C-- FIND THE LAST OFF RAMP OF A PRI LANE SECTION
      DO 13 I=1,NSEC
      VAL(I)=-1.0
      IF(ND(ID).EQ.I) ID=ID+1
      IF(IP(I).EQ.1HP) VAL(I)=ID-1
   13 CONTINUE
      VAL (NSEC+1)=0.0
      L=1
      DO 20 I=1,NSEC
      IF(VAL(I).EQ.-1.0) GO TO 20
      POFF(L,1)=VAL(I)
      IF(VAL(I+1).EQ.-1.0) L=L+1
   20 CONTINUE
   30 K=1
      ID=IO=1
      BPNRI=0.0
      BPN=0.0
C--- CALCULATE THE VOLUMES OF A SECTION
      DO 105 I=1,NSEC
      IF(NO(IO).NE.I) GO TO 150
      BPN=BPN+SUM(IO,1,1)
      I5=IO
      VN=VN+SUM(IO,1,2)*PNPEN
      IF(NPL.NE.0) GO TO 130
C-- IF NO PRI LANES, THEN THE BUSES ARE INCLUDED
      VN=VN+SUM(IO,1,1)
      IO = IO+1
      IF(I.EQ.1) GO TO 100
      GO TO 160
  130 IF(IP(I).EQ.1HP) GO TO 110
      IF(IP(I+1).EQ.1HP.AND.XLENGF(I).LE.DSTCN) GO TO 110
C----- VOLUMES OF THE PRI VECHILES
      VP=VP+SUM(IO,1,2)*PRIPEN+SUM(IO,1,1)
      BPNRI=BPNRI+SUM(IO,1,1)
      IO=IO+1
      IF(I.EQ.1) GO TO 100
      GO TO 160
C--- IN A PRI SITUATION, NEW PRI VECHILES CANNOT ENTER THE LANE(S) AND M
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C--- BE STORED
  110 VNP=VNP+SUM(IO,1,2)*PRIPEN+SUM(IO,1,1)
      IO=IO+1
      GO TO 160
  150 IF(ND(ID).EQ.I-1) GO TO 165
  155 IF(NPL.EQ.0.OR.IP(I).NE.1H .OR.IP(I-1).NE.1HP) GO TO 190
C--- IF THERE WERE NO RAMPS  BUT A PRI LANE ENDED, THE STORED VECHILES
C---  ARE ADDED TO THE PRI VECHILES FROM THE LANE
      VP=VP+VNP
      VNP=0.0
      GO TO 100
  190 IF(NPL.EQ.0.OR.IP(I).NE.1HP.OR.IP(I-1).NE.1H ) GO TO 100
C--- IF A PRI LANE STARTED THEN CHECK FOR VECHILES TO BE DEMOTED.
      I4=ID
      GO TO 175
  160 IF(ND(ID).NE.I-1) GO TO 155
C--- SAME AS ABOVE, ONLY SUBTRACTING TRAFFIC
  165 VN=VN-SUM(ID,2,2)*PNPEN
      BPN=BPN-SUM(ID,2,1)
      I4=ID
      IF(NPL.NE.0) GO TO 180
      VN=VN-SUM(ID,2,1)
      ID=ID+1
      GO TO 100
  180 IF(IP(I).EQ.1HP) GO TO 170
      VP=VP-SUM(ID,2,2)*PRIPEN-SUM(ID,2,1)
      BPNRI=BPNRI-SUM(ID,2,1)
      ID=ID+1
      IF(IP(I-1).NE.1HP) GOTO 100
C---  A LANE ENDED LAST SECTION
      VP=VP+VNP
      VNP=0.0
      GO TO 100
C---- CHECK TO SEE IF THIS IS THE FIRST PRI LANE SECTION,
  170 IF(IP(I-1).EQ.1HP) GO TO 200
C--- IF SO ,THEN ALL PRI VECHILES WHICH WANT TO EXIT DURING THE SECTION
C---- REDUCED TO NON-PRIORITY STATUS
  175 J3=IFIX(POFF(K,1))
      IF(NO(I5).EQ.I-1.AND.XLENGF(I-1).LE.DSTCN) I5=I5-1
      IF(NO(I5).EQ.I) I5=I5-1
      PROFB=0.0
      PROF=0.0
      IF(I4.GT.J3) GO TO 215
      DO 210 J=1,I5
      DO 210 JJ=I4,J3
      PROFB=PROFB+TRIPS(J,JJ,1)*EBN
  210 PROF=PROF+CARTRP(J,JJ)*PRIPEN+TRIPS(J,JJ,1)*EBN
      VP=VP-PROF
      VN=VN+PROF
      BPNRI=BPNRI-PROFB
  215 K=K+1
      I2=IO
      IF(ND(ID).NE.I-1) GO TO 100
  200 VN=VN-SUM(ID,2,2)*PRIPEN-SUM(ID,2,1)
      ID=ID+1
  100 VPR(I)=VP
      VNPR(I)=VN
```

```
      VPRIN(I)=VNP
      LANE(I,2)=0
      IF(IP(I).EQ.1HP) GO TO 115
      BV(I,1)=BPN/(VN+VP+VNP)
      BV(I,2)=0.0
      GO TO 105
  115 BV(I,1)=(BPN-BPNRI)/(VN+VNP)
      BV(I,2)=0.0
      IF(VP.NE.0) BV(I,2)=BPNRI/VP
  105 CONTINUE
      DO 300 I=1,20
      POFF(I,1)=0.0
  300 POFF(I,2)=0.0
      IF(NPL.EQ.0) RETURN
      L=-1
C---  FIND ONE VOL. FOR SECTION 1
      VNPR(1)=VNPR(1)+VPR(1)
      VPR(1)=0.0
C--- DIVIDE THE NUMBER OF LANES INTO PRIORITY AND NON-PRIORTIY AND IN
C---- NON-PRIORITY SITUATIONS FIND ONE VOLUME.
C---  ALSO FOR THE L TH PRIORITY SITUATION, SET POFF(L,1) TO THE
C---- NEGATIVE OF THE VECHILES ENTERING THE PRI LANE AND POFF(L,2) TO
C--- THE SECTION NUMBER. THEN SET POFF(L+1,1) TO THE NUMBER OF VECHILES
C--- ENTERING THE FREEWAY FROM THE SECTION POFF(L+1,2), WHEN THE PRI
C---- LANE ENDED
      DO 500 I=2,NSEC
      IF(IP(I).EQ.1HP) GO TO 510
      VNPR(I)=VNPR(I)+VPR(I)+VPRIN(I)
      VPR(I)=0.0
      VPRIN(I)=0.0
      GO TO 500
  510 BUSN=VPR(I)*BV(I,2)
      VPR(I)=VPR(I)-BUSN*(1.0-EBFAC)
      BV(I,2)=BUSN*EBFAC/VPR(I)
      IF(IP(I-1).EQ.1HP) GO TO 520
C--- A PRI LANE I2 STARTING THIS SECTION
      L=L+2
      POFF(L,1)=-VPR(I)
      POFF(L,2)=FLOAT(I)-1.0
      IF(IP(I+1).NE.1HP) GO TO 540
  530 VNPR(I)=VNPR(I)+VPRIN(I)
      LANE(I,2)=NPL
      VPRIN(I)=0.0
      GO TO 500
  520 IF(IP(I+1).EQ.1HP) GO TO 530
C---- A PRI LANE IS ENDING NEXT SECTION
  540 POFF(L+1,1)=VPR(I)
      POFF(L+1,2)=FLOAT(I)+1.0
      GO TO 530
  500 CONTINUE
C---  IN THIS SECTION CHECK FOR EXCESS DEMAND FOR PRIORITY LANES, AND
C---  DEMOTE THE EXCESS VECHILES TO NON-PRIORITY FOR THIS SITUATION
C---  ONLY.
      DO 600 L=1,20,2
      IF(POFF(L,2).EQ.0) RETURN
      IS=IFIX(POFF(L,2))+1
      CAP=NPL*CAPFP(IS)
```

```
C---   IF NO EXCESS , NOTHING TO DO
       IF(-POFF(L,1).LE.CAP) GO TO 600
       IT=IFIX(POFF(L+1,2))-1
       POFF(L,1)=-CAP
       POFF(L+1,1) = CAP
       J=L/2+1
       CALL PAGE(2)
       DO 620 K=IS,IT
       OVER=VPR(K)-CAP
       BOVER=OVER*BV(K,2)
       OVER=OVER-BOVER
       VPR(K)=VPR(K)-OVER-BOVER
       BOVER=BOVER/EBFAC
  620  VNPR(K)=VNPR(K)+OVER+BOVER
       PRINT 1000,J,IS,CAP,OVER,BOVER
  600  CONTINUE
C--- ALL DONE HERE
 1000  FORMAT(10H *******   ,*WARNING, FOR PRIORITY SECTION*,I3,* STARTIN
      1G IN SECTION*,I3,* THE CAPACITY OF *F6.0,* VEHICLES WAS EXCEEDED*/
      2* BY *,F7.0,* CARS AND *,F7.0,* EQUIVALENT VEHICLE BUSES (EBN). TH
      3EY HAVE BEEN DEMOTED TO NON-PRIORITY STATUS.*)
       RETURN
       END
       SUBROUTINE RMSUM (J)
       COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
       COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
       COMMON/INTEG/ISEC,IO,ID,NRAMPS,ITYP,IRAMP,NNN(4)
       COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
       COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
      1           TOSUM(20,2)
       COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
       COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
       COMMON/REALS/VOL1,VOLSUM,TS,SS,RRR(6)
C ---    RDIS  IS AN ARRAY OF DISTANCES OF RAMP NOSES FROM THE
C ---       BEGINNING OF THE STUDY SECTION IN FEET. LEFT HAND RAMPS
C ---       HAVE NEGATIVE VALUES OF RDIS.
C ---    RVOL  IS AN ARRAY OF RAMP VOLUMES. OFF-RAMPS HAVE NEGATIVE
C ---       VALUES
C --- IO AND ID ARE ORIGIN AND DESTINATION COUNTERS
       IO=1
       ID=1
C --- J IS THE RAMP NUMBER COUNTING ON-RAMPS AND OFF-RAMPS
       J=1
C --- SL IS THE CUMULATIVE DISTANCE FROM THE BEGINNING
       SL=0.
       DO 25 I=1,N2EC
C --- IF THERE IS AN ORIGIN IN SECTION I, STORE THE DISTANCE FROM
C ---       BEGINNING OF THE STUDY SECTION IN RDIS
       IF(NO(IO).NE.I) GO TO 15
       RDIS(J)=SL
C --- IF IT IS A LEFT HAND RAMP, MAKE RDIS NEGATIVE,OR IF A TWO LANE
C --- ONRAMP ALSO NEEDS NO ANALYSIS
       IF(LEFT(I).GE.1) RDIS(J)=-RDIS(J)
C --- STORE THE RAMP VOLUME AND INCREMENT THE ORIGIN COUNTER AND THE
C ---       RAMP COUNTER
       RVOL(J)=TOSUM(IO,1)
       IO=IO+1
```

```
      J=J+1
C --- INCREMENT SL
   15 SL=SL+XLENGF(I)
C --- IF THERE IS A DESTINATION IN SECTION I, STORE THE DISTANCE IN
C ---       RDIS
      IF(ND(ID).NE.I) GO TO 25
      RDIS(J)=SL
C --- IF IT IS A LEFT HAND RAMP, MAKE RDIS NEGATIVE
      IF(LEFT(I).EQ.1) RDIS(J)=-RDIS(J)
C --- STORE THE RAMP VOLUME AS NEGATIVE AND INCREMENT THE
C ---       DESTINATION COUNTER AND THE RAMP COUNTER
      RVOL(J)=-TO2UM(ID,2)
      IF(RVOL(J).EQ.0) RVOL(J)=-1.0
C --- IF RVOL = 0 IT IS ASSUMED TO BE ON-RAMP.
      ID=ID+1
      J=J+1
   25 CONTINUE
C --- VOLSUM =RVOL(1) WILL INITIALZE DEMAND FOR RAMP ANLYSIS
      VOLSUM=RVOL(1)
C    J=J-2  WILL LIMIT DO LOOP IN FOLLOWING PROGRAM SO THAT THE LAST
C    RAMP WILL NOT BE CONSIDERED, SINCE THE LAST RAMP IS AN OFF-RAMP.
      J=J-2
      NRAMPS=J
      RETURN
      END
      SUBROUTINE UDRAMP (L,ITX)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INTEG/ISEC,IO,ID,NRAMPS,ITYP,IRAMP,NNN(4)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      COMMON/REALS/VOL1,VOLSUM,TS,SS,RRR(6)
      ITYP=1
      TS=VOLSUM
C -VOLSUM  IS THE SUM OF ON-RAMPS MINUS THE SUM OF OFF-RAMPS UP TO
C ---       RAMP J
      VOLSUM=VOLSUM+RVOL(L)
      IF(RVOL(L).GT.0) GO TO 10
   15 ITX=2
      RETURN
C ---IF RDIS(L) IS NEGATIVE, ON-RAMP IS SPECIAL AND DOES NOT
C ---       NEED RAMP ANALYSIS. ITX=2 CAUSES IT TO BE SKIPPED IN THE
C ---       MAIN CALLING ROUTINE
   10 IF(RDIS(L).LT.0) GO TO 15
C    STATEMENTS UP TO 20 WILL FIND THE ORIGIN NUMBER IO CORRESPONDING TO
C    ON RAMP RVOL(L)
      IO=1
      I=1
   20 I=I+1
      IF(RVOL(I).LT.0) GO TO 20
      IO=IO+1
      IF(I.LT.L) GO TO 20
C --- SET ITX = 1, MEANING OTHER RAMPS AFFECT RAMP L AND BEGIN
C ---       LOOKING FOR THE OTHER RAMPS
      ITX=1
C --- INITIALIZE I, THE NUMBER OF RAMPS WHICH INFLUENCE RAMP L
      I=1
C --- K = L - 1, BEGIN LOOKING UPSTREAM
```

```
      K=L-1
C --- WHEN K = FIRST ON-RAMP, BEGIN LOOKING DOWNSTREAM
   30 IF(K.EQ.1) GO TO 50
C --- IF RAMP K IS NOT AN ON-RAMP, SKIP IT
      IF(RVOL(K).LE.0) GO TO 25
C --- IF RAMP K I2 LEFT HAND, SKIP IT
      IF(RDIS(K).LE.0) GO TO 25
C --- IF RAMP K IS NOT WITHIN 4000 FT., SKIP IT AND BEGIN LOOKING
C ---      UPSTREAM
      IF(RDIS(L)-RDIS(K).GT.4000.0) GO TO 50
C --- IF ALL TEST2 ARE SATISFIED, STORE RAMP NUMBER K IN THE ARRAY
C ---      LX AND INCREMENT I BY ONE
      LX(I)=K
      I=I+1
   25 K=K-1
      GO TO 30
C --- K = L + 1, BEGIN LOOKING UPSTREAM FOR OFF-RAMPS
   50 K=L+1
C --- IF RAMP K IS THE LAST OFF-RAMP, SKIP IT AND TERMINATE
   45 IF(K.GT.NRAMPS) GO TO 100
C --- IF RAMP K IS AN ON-RAMP, SKIP IT
      IF(RVOL(K).GE.0) GO TO 55
C --- IF RAMP K IS LEFT HAND, SKIP IT
      IF(RDIS(K).LE.0) GO TO 55
C --- IF RAMP K IS NOT WITHIN 4000 FT., SKIP IT AND TERMINATE
      IF(RDIS(K)-RDIS(L).GT.4000.0) GO TO 100
      LX(I)=K
C --- STATEMENTS 70 THROUGH 85 CHECK FOR AN INCREASE IN THE NUMBER
C ---     OF LANES UP TO NEXT OFF-RAMP, FOLLOWED BY A DECREASE IN
C ---     THE NUMBER OF LANES
      IF(K.NE.L+1) GO TO 60
      ISEC=NO(IO)
      IF((LANE(ISEC,1)-LANE(ISEC-1,1)).LE.0) GO TO 60
      ID=1
   70 ID=ID+1
   85 IF(ISEC-ND(ID)) 80,75,70
   80 IF((LANE(ISEC,1)-LANE(ISEC+1,1)).NE.0) GO TO 60
      ISEC=ISEC+1
      GO TO 85
   75 ISS=ND(ID)
      IF((LANE(ISS,1)-LANE(ISS+1,1)).NE.1) GO TO 60
      ISEC=L+1
C --- ITYP=2 MEAN2 AUX. LANE CONDITION
      ITYP=2
C ---RVOL(K) MUST BE REMOVED FROM THROUGH TRAFFIC AT THIS TIME
C ---     BECAUSE IT IS NOT ENTERED INTO THE ARRAY LX
      TS=TS+RVOL(K)
      GO TO 55
   60 I=I+1
   55 K=K+1
      GO TO 45
C --- REDUCE I BY ONE TO OBTAIN PROPER LENGTH OF LX
  100 IRAMP=I-1
C    TS IS TEMPORARY SUM OF RAMP VOLUMES.  THIS VARIABLE REPRESENTS THE
C    THROUGH TRAFFIC.
      TS=VOLSUM-RVOL(L)
C --- INITIALIZE SS FOR FOLLOWING SUBPROGRAM
```

```
      SS=0.
C --- IF I = 0, NO RAMPS INFLUENCE RAMP L. ITX = 3
      IF(IRAMP.GT.0) RETURN
      ITX=3
      RETURN
      END
      SUBROUTINE PVL (L)
      COMMON/INTEG/ISEC,IO,ID,NRAMPS,ITYP,IRAMP,NNN(4)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      COMMON/REALS/VOL1,VOLSUM,TS,SS,RRR(6)
C --- DO FOR THE NUMBER OF RAMPS INFLUENCING RAMP L
      DO 100 I=1,IRAMP
      K=LX(I)
C    SS IS THE TOTAL RAMP TRAFFIC WITHIN 4000 FEET IN LANE ONE.
C    TS IS THE THROUGH TRAFFIC.
C ---       FIND THE DISTANCE BETWEEN RAMP NOSES
C ---       DISTANCE MUST BE POSITIVE
      DIS=ABS(RDIS(L)-RDIS(K))
      IF(RVOL(K).GT.0) GO TO 50
      DIS = DIS - 500.
C    STATEMENTS 201-205 FIND THE PERCENT OF TRAFFIC IN LANE ONE AT A
C    DISTANCE (DIS) FROM AN OFF-RAMP.
      IF(DIS-586.) 204,206,201
  201 IF(DIS-1280.) 206,207,202
  202 IF(DIS-3140.) 207,208,203
  203 IF(DIS-4000.) 208,208,209
  206 PV2=(-.25316E-6*DIS+.28078E-3)*DIS+.92238
      GO TO 205
  207 PV2=1.297-3.36E-4*DIS
      GO TO 205
  208 PV2=(.13178E-6*DIS-1.1083E-3)*DIS+2.4249
      GO TO 205
  209 PV2=.01
      GO TO 205
  204 PV2=1.
  205 CONTINUE
C --- SS IS INCREMENTED BY PERCENT OF RAMP TRAFFIC
      SS=SS-PV2*RVOL(K)
C ---  TS IS REDUCED BY ADDING NEGATIVE RAMP VOLUME
      TS=TS+RVOL(K)
      GO TO 100
   50 CONTINUE
      DIS = DIS + 500.
C    STATEMENTS 201-205 FIND THE PERCENT OF TRAFFIC IN LANE ONE AT A
C    DISTANCE (DIS) FROM AN  ON-RAMP.
      IF(DIS-500.)  104,106,101
  101 IF(DIS-710.) 106,107,102
  102 IF(DIS-1170.) 107,108,103
  103 IF(DIS-4000.) 108,108,109
  106 PV1=(-2.063E-6*DIS+1.971E-3)*DIS+.5302
      GO TO 105
  107 PV1=1.57-9.58E-4*DIS
      GO TO 105
  108 PV1=.4145*DIS/(DIS-600.6)-.3996
      GO TO 105
  109 PV1=.01
```

```
      GO TO 105
  104 PV1=1.
  105 CONTINUE
      SS=SS+PV1*RVOL(K)
      TS=TS-RVOL(K)
  100 CONTINUE
      RETURN
      END
      SUBROUTINE IVP8 (L,ITX)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INTEG/ISEC,IO,ID,NRAMPS,ITYP,IRAMP,NNN(4)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      COMMON/REALS/VOL1,VOLSUM,TS,SS,RRR(6)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(100)
      ITX=2
C --- STATEMENTS 57 THROUGH 39 FIND THE PERCENT OF THROUGH TRAFFIC
C ---      IN LANE ONE ACCORDING TO THE METHOD OF FIGURE 8,3 OF THE
C ---      HIGHWA8 CAPACITY MANUAL
   57 K=NO(IO)
C---- TAKING AWAY ASSIGNED PRI LANES AND THEIR VOLUMES
      N=LANE(K,1)-LANE(K,2)
      VTHRU=TS-VPR(K)
      IF(ITYP.EQ.2) N=N-1
      IF(N.GT.4) N=4
      GO TO (10,10,20,30),N
   10 P8=0.4
      IF(VTHRU.LE.3500) P8=0.05+1.0E-4*VTHRU
      IF(VTHRU.LE.1500) P8=0.2
      GO TO 39
   20 P8=0.18
      IF(VTHRU.LE.5000) P8=8.0E-5*VTHRU-0.22
      IF( VTHRU.LE.3500) P8=0.06
      GO TO 39
   30 P8=0.1
      IF(VTHRU.LE.6500) P8=0.035+1.0E-5*VTHRU
      IF(VTHRU.LE.4500) P8=0.08
   39 VOL1=P8*VTHRU+SS+RVOL(L)
      RETURN
      END
      SUBROUTINE P823 (L)
      COMMON/INTEG/ISEC,IO,ID,NRAMPS,ITYP,IRAMP,NNN(4)
      COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
      COMMON/REALS/VOL1,VOLSUM,TS,SS,RRR(6)
C --- ITYP=2 MEANS EXECUTE RAMP ANALYSIS FOR AUXILLARY LANE CASE.
      IF(ITYP.NE.2) RETURN
C --- L IS RAMP COUNTER FOR ON-RAMPS ONLY
C --ISEC = OFF-RAMP COUNTER
C --- YL IS DISTANCE BETWEEN RAMP L AND ISEC
      YL=RDIS(ISEC)-RDIS(L)
C ---   P5 GIVES THE PERCENT OF ON-RAMP TRAFFIC IN LANE ONE 500 FEET
C ---      DOWNSTREAM OF ON-RAMP NOSE(FROM FIG. 8.25 OF HCM)
      P5=0.8
      IF(YL.LE.1000.0) GO TO 60
      P5=0.8-0.0003*(YL-1000.0)
      IF(YL.LE.20*0.0) GO TO 60
      P5=0.5-0.00025*(YL-2000.0)
      IF(YL.LE.3000.0) GO TO 60
```

```
      P5=0.25-0.0001*(YL-3000.0)
   60 VOL1=VOL1-(1.0-P5)*RVOL(L)
      IF(YL-1000.) 1,10,10
   10 IF(YL-1500.) 11,20,20
   20 IF(YL-2000.) 21,30,30
   30 IF(YL-2500.) 31,40,40
   40 IF(YL-3000.) 41,50,50
C --- STATEMENTS 1 THROUGH 50 FIND  P3 , THE PERCENT OF OFF-RAMP
C ---     TRAFFIC STILL IN LANE ONE 500 FEET DOWNSTREAM FROM ON-RAMP
C ---     NOSE
    1 AYL=(YL-500.)*1000./YL
      IF(AYL-500.) 3,3,6
    3 P3  =.00048*AYL
      GO TO 100
    6 P3  =.00142*AYL-.47
      GO TO 100
   11 AYL=(YL-500.)*1000./YL
      P1=.00142*AYL-.47
      BYL=(YL-500.)*1500./YL
      IF(BYL-1000.) 13,13,16
   13 P2=.00048*B8L-.16
      GO TO 19
   16 P2=.00135*BYL-.97
   19 P3  =P1*(1.-(YL-1000.)/500.)+P2*(YL-1000.)/500.
      GO TO 100
   21 AYL=(YL-500.)*1500./YL
      P1=.00135*AYL-.97
      BYL=(YL-500.)*2000./YL
      IF(BYL-1500.) 23,23,26
   23 P2=.0004*BYL-.21
      GO TO 29
   26 P2=.00048*BYL-.33
   29 P3  =P1*(1.-(YL-1500.)/500.)+P2*(YL-1500.)/500.
      GO TO 100
   31 AYL=(YL-500.)*2000./YL
      P1=.00048*AYL-.33
      BYL=(YL-500.)*2500./YL
      IF(BYL-2000.)33,33,36
   33 P2=.00014*BYL-.02
      GO TO 39
   36 P2=.00036*B8L-.46
   39 P3  =P1*(1.-(YL-2000.)/500.)+P2*(YL-2000.)/500.
      GO TO 100
   41 AYL=(YL-500.)*2500./YL
      P1=.00036*AYL-.46
      BYL=(YL-500.)*3000./YL
      IF(BYL-2500.)43,43,46
   43 P2=.22
      GO TO 49
   46 P2=.25
   49 P3  =P1*(1.-(YL-2500.)/500.)+P2*(YL-2500.)/500.
      GO TO 100
   50 P3=0.23
C --- SOMETHING IS NEEDED TO CORRECT VOL1 BECAUSE OF AUX. LANE
C --- RVOL IS A NEGATIVE NUMBER
  100 VOL1=VOL1-(P3*RVOL(ISEC))
      RETURN
```

```
      END
      SUBROUTINE MERGQ (ITX)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/INTEG/ISEC,IO,ID,NRAMPS,ITYP,IRAMP,NNN(4)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/REALS/VOL1,VOLSUM,TS,SS,RRR(6)
C ---VOL1IS VOLUME IN LANE ONE AT FIRST, BUT IS REDUCED BY 2000, THE
C --- THE MERGE POINT CAPACITY
      VOL1=VOL1-2000
C --IF VOL1 IS PLUS, MERGE QUEUE XMQ(IO) MUST INCREASE ACCORDING TO
C ---      QUEUE THEORY
      IF(VOL1.EQ.0) RETURN
      IF(VOL1.GT.*) GO TO 20
C --IF VOL1 IS MINUS, AND IF A QUEUE EXISTS AT IO, QUEUE WILL BE
C ---      DISCHARGED
      IF(XMQ(IO).GT.0.0) GO TO 10
      XMQ(IO)=0.0
      XMD(IO)=0.0
      RETURN
   10 IF(XMQ(IO)+VOL1/FAC(1)) 15,20,20
   15 VOL1=-XMQ(IO)*FAC(1)
   20 XMD(IO)=(XMQ(IO)+VOL1/(2*FAC(1)))/FAC(1)
      XMQ(IO)=XMQ(IO)+VOL1/FAC(1)
      ID=1
      ISEC=NO(IO)
   25 ID=ID+1
C --- IF QUEUE WAS PRESENT, STATEMENTS 25 THROUGH 28 WILL FIND IO
C ---      AND ID VALUES TO BE USED BY DISQ TO DISTRIBUTE QUEUE
C ---      ACCORDING TO ITS DESTINATION PATTERN
      IF(ND(ID).LT.ISEC) GO TO 25
      IO=IO-1
      ITX=1
      RETURN
      END
      SUBROUTINE DISQ
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7),
      COMMON/INTEG/ISEC,IO,ID,NNN(7)
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           TOSUM(20,2)
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/REAL2/VOL1,RRR(9)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C --- VALUES OF IO AND ID ARE FOUND IN QUEUP OR MERGQ
C --- DO LOOP 35 INITIALIZES ARRAY  QD TO ZERO
      DO 35 MM=ID,NDES
   35 QD(MM)=0.0
C --- DO LOOP 50 WILL SUM OVER ROWS OF OD TABLE TO FIND FOR EACH
C ---       DESTINATION ID HOW MANY VEHICLES  QD(ID) WILL HAVE TO GO
C ---       THROUGH THE QUEUE.  THIS ESTABLISHES THE DESTINATION
C ---       PATTERN OF THE QUEUE.
   40 DO 50 NN=1,IO
      DO 50 MM=ID,NDES
   50 QD(MM)=QD(MM)+TRPVEH(NN,MM)
      BS=0.0
C --- SUM  QD SO PERCENTAGES MAY BE COMPUTED
```

```
      DO 60 MM=ID,NDES
   60 BS=BS+QD(MM)
C ---- VOL1 REPRESENTED  BY THE PERCENTAGE BN, THE TOTAL OVER QD
      BN=VOL1/BS
C --- DO LOOP 65 CHANGES  QD SO THAT IT WILL NOW TOTAL TO BN BUT SO
C ---       THAT THE RELATIVE DISTRIBUTION REMAINS THE SAME
      DO 65 MM=ID,NDES
   65 QD(MM)=QD(MM)*BN
      BS=0.0
      IDK=ID
C --- DO LOOP 75 DISTRIBUTES THE (+OR-) VOL1 VEHICLES FROM THE QUEUE
C ---       DOWNSTREAM ACCORDING TO THE DESTINATION PATTERN  QD
      DO 75 JT=ISEC,NSEC
C --- THE FIRST TIME THROUGH THE LOOP, BS=0.0 , SO VNPR IS
C ---       CHANGED BY THE FULL AMOUNT VOL1.
      VNPR(JT)=VNPR(JT)+BS-VOL1
C --- IS THERE A DESTINATION IN SECTION JT
C --- NO... GO TO 75
      IF(ND(IDK).NE.JT) GO TO 75
C --- YES... CHANGE  BS ACCORDING TO  RELATIVE VOLUME FOR OFF-RAMP
C ---       IDK
      BS=BS+QD(IDK)
      TOSUM(IDK,2)=TOSUM(IDK,2)-QD(IDK)
      IDK=IDK+1
   75 CONTINUE
      RETURN
      END
      SUBROUTINE WEAVCON
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INTEG/I,J,IL,ITX,ITY,IS,IST,ISS,NNN(2)
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/REALS/FL1,FL2,VX1,VX2,VW1,VW2,RRR(4)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C---  CLEARING EFF
      DO 10 I=1,50
   10 EFF(I)=0.0
      I=2
      J=IL=1
    5 CALL TYPEWV
      IF(ITX.NE.1) RETURN
      GO TO (30,30,40),ITY
   30 CALL WVOL
      GO TO 50
   40 CALL WVL3
   50 CALL WVEFF
      GO TO 5
      END
      SUBROUTINE TYPEWV
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7
      COMMON/INTEG/I,J,IL,ITX,ITY,IS,IST,ISS,NNN(2)
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/REALS/FL1,FL2,VX1,VX2,VW1,VW2,RRR(4)
C --- INITIALIZE
```

```
      ITX=1
      IEND=1
C--   IEND=1 MEANS THAT ON-RAMP I+1 IS NOT THE LAST ON-RAMP
      JEND=1
C--   JEND=1 MEANS THAT OFF-RAMP J+1 IS NOT THE LAST OFF-RAMP
    2 FL1=0.
      FL2=0.
C --- IS THE ON-RAMP I UPSTREAM OF OFF-RAMP J
      IF(NO(I).LE.ND(J)) GO TO 4
C --- NO... J = J + 1
    3 J=J+1
C --- HOW MANY MORE OFF-RAMPS ARE THERE
      IF(J+1-NDES) 2,201,12
C --- TWO OR MORE... TRANSFER TO 2
C --- NONE... ITX = 2   END OF WEAVING ANALYSIS
   12 ITX=2
      RETURN
C --- ONE... JEND = 2   EXACTLY ONE MORE OFF-RAMP
  201 JEND=2
C--   JEND=2 MEANS THAT OFF-RAMP J+1 IS MAINLINE END OF STUDY SECTION
      GO TO 2
C --- HOW MANY MORE ON-RAMPS ARE THERE
    4 IF(I+1.GT.NORG) GO TO 42
C --- TWO OR MORE... TRANSFER TO 401
C --- NONE... SIMPLE WEAVING POSSIBLE, TRANSFER TO 42
C --- ONE... IEND = 2
  402 IEND=2
C--   IEND=2 MEANS THAT ON-RAMP I+1 IS THE LAST ON-RAMP
C --- IS NEXT ON-RAMP UPSTREAM OF OFF-RAMP
  401 IF(NO(I+1)-ND(J)) 5,15,42
C --- NO... SIMPLE WEAVING POSSIBLE, TRANSFER TO 42
C --- YES... ITYP = 3 IF THERE IS NOT A THIRD ON-RAMP
    5 GO TO (501,15),IEND
C --- IS THIRD ON-RAMP UPSTREAM OF OFF-RAMP
  501 IF(NO(I+2).GT.ND(J)) GO TO 15
C --- NO... ITYP = 3
C --- YES... TRANSFER TO 8, LOOK FOR NEW WEAVING SECTION
    8 I=I+1
      IL=1
      GO TO 2
C--   15 THRU 33 HANDLES  ON...ON...OFF  ITYP=3
   15 IS=NO(I)
      ISS=NO(I+1)
      IST=ND(J)
C --- FIND FL1, LENGTH OF THE SIMPLE PART OF MULTIPLE WEAVING
C ---        SECTION
      DO 20 K=ISS,IST
   20 FL1=FL1+XLENGF(K)
C --- IF FL1 IS GREATER THAN 8000 FT., GO TO NEXT POSSIBLE WEAVING
C ---        SECTION
      IF(FL1.LE.8000.0) GO TO 25
   22 I=I+2
      GO TO 2
   25 IT=ISS-1
C --- FIND FL2, SECOND PART OF MULTIPLE WEAVING SECTION
      DO 28 K=IS,IT
   28 FL2=FL2+XLENGF(K)
```

```
C --- MAKE SURE TOTAL LENGTH IS LESS THAN 8000 FT.
      IF(FL1+FL2.GT.8000.0) GO TO 8
   33 ITY=3
      RETURN
C--   42 THRU 45 HANDLES  ON...OFF  ITYP=1  AND THE FIRST PART OF
C--                        ON...OFF...OFF  ITYP=2
   42 IS=NO(I)
      ISS=ND(J)
C --- FIND FL1, LENGTH OF SIMPLE PART OF EITHER SIMPLE WEAVING
C ---       SECTION OR OF MULTIPLE WEAVING SECTION
      DO 45 K=IS,ISS
   45 FL1=FL1+XLENGF(K)
      IF(FL1.GT.8*00.0) GO TO 8
C --- IF JEND = 2, SIMPLE WEAVING ONLY IS POSSIBLE
   47 GO TO (55,50),JEND
   50 ITY=1
      GO TO (65,8),IL
C--   IL IS A LOGIC CONTROL TO PREVENT WEAVING ANALYSIS OF ...ON...OFF
C--      IF IT IS PART OF MULTIPLE WEAVING SECTION  ON...ON...OFF
C --- IF ON-RAMP I IS THE LAST ONE,  THEN ITYP = 2
   55 GO TO (502,57),IEND
C --- IF THERE IS ANOTHER ON-RAMP, IT IS UPSTREAM OF THE SECOND
C ---       OFF-RAMP
  502 IF(NO(I+1).LE.ND(J+1)) GO TO 50
C --- YES... SIMPLE WEAVING, TRANSFER TO 50
C --- NO... ITYP = 2   MULTIPLE WEAVING POSSIBLE
C--   57 THRU 63 HANDLES SECOND PART OF  ON...OFF...OFF  ITYP=2
   57 IST=ND(J+1)
      IT=ISS+1
C --- FIND FL2 AND CHECK THAT TOTAL LENGTH OF WEAVING SECTION IS
C ---       LESS THAN 8000 FT.
      DO 60 K=IT,IST
   60 FL2=FL2+XLENGF(K)
      IF(FL1+FL2-8000.) 63,63,50
   63 ITY=2
   65 RETURN
      END
      SUBROUTINE WVOL
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INTEG/I,J,IL,ITX,ITY,IS,IST,ISS,NNN(2)
      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           TOSUM(20,2)
      COMMON/REALS/FL1,FL2,VX1,VX2,VW1,VW2,RRR(4)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C --- IS  IS FIRST SECTION NUMBER OF WEAVING SECTION
      IS=NO(I)
C --- IF MA IS +1, THEN ON-RAMP AND FIRST OFF-RAMP ARE BOTH RIGHT
C ---       HAND RAMPS OR BOTH LEFT HAND RAMPS
      MA=1
C --- IF MB IS +1, THEN ON-RAMP AND SECOND OFF-RAMP ARE ON THE SAME
C ---       SIDE OF THE FREEWAY
      MB=1
      IST=ND(J+1)
      ISS=ND(J)
      IF(LEFT(IS).NE.1) GO TO 15
      MA=-MA
      MB=-MB
```

```
   15 IF(LEFT(ISS).NE.1) GO TO 19
      MA=-MA
C ---  IF ITYP = 1, SKIP TO SIMPLE WEAVING MOVEMENT SECTION.  IF
C ---        ITYP = 2, DO MULTIPLE WEAVING FIRST
   19 GO TO (45,20),ITY
   20 IF(LEFT(IST).NE.1) GO TO 50
      MB=-MB
   50 IF(MB.EQ.-1) GO TO 55
C ---  VX1 AND VX2 ARE THE WEAVING MOVEMENTS WHICH MUST CROSS EACH OT
C ---        OTHER BETWEEN THE FIRST AND THE LAST  RAMPS
      VX1=TOSUM(I,1)-TRPVEH(I,J)-TRPVEH(I,J+1)
      VX2=TOSUM(J+1,2)-TRPVEH(I,J+1)
      GO TO 45
   55 VX1=VNPR(IST)-TOSUM(I,1)-TOSUM(J+1,2)+TRPVEH(I,J+1)+TRPVEH(I,J)
      VX1=VX1-VPR(IST)
      VX2=TRPVEH(I,J+1)
   45 IF(MA.EQ.1) GO TO 48
C ---  VW1 AND VW2 MUST CROSS EACH OTHER IN THE SIMPLE WEAVING PART
      VW1=VNPR(IS)-TOSUM(I,1)-TOSUM(J,2)+TRPVEH(I,J)-VPR(IS)
      VW2=TRPVEH(I,J)
      RETURN
   48 VW1=TOSUM(I,1)-TRPVEH(I,J)
      VW2=TOSUM(J,2)-TRPVEH(I,J)
      RETURN
      END
      SUBROUTINE WVL3
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INTEG/I,J,IL,ITX,ITY,IS,IST,ISS,NNN(2)
      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           3OSUM(20,2)
      COMMON/REALS/FL1,FL2,VX1,VX2,VW1,VW2,RRR(4)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
      IS=NO(I)
C ---  MA IS +1 IF FIRST AND LAST RAMPS ARE ON THE SAME SIDE, -1
C ---        OTHERWISE
      MA=1
C ---  MB HAS THE SAME ROLE FOR FIRST AND SECOND RAMPS
      MB=1
      ISS=NO(I+1)
      IST=ND(J)
      IF(LEFT(IS).NE.1) GO TO 35
      MA=-MA
   35 IF(LEFT(ISS).NE.1) GO TO 40
      MB=-MB
   40 IF(LEFT(IST).NE.1) GO TO 70
      MA=-MA
      MB=-MB
   70 IF(MA.EQ.1) GO TO 75
C ---  VX1 AND VX2 ARE WEAVING MOVEMENTS WHICH MUST CROSS EACH OTHER
C ---        IN SIMPLE (SECOND PART) WEAVING SECTION
      VX1=VNPR(IS)-TOSUM(I,1)-TOSUM(J,2)+TRPVEH(I,J)+TRPVEH(I+1,J)
      VX1=VX1-VPR(IS)
      VX2=TRPVEH(I,J)
      GO TO 80
   75 VX1=TOSUM(I,1)-TRPVEH(I,J)
      VX2=TOSUM(J,2)-TRPVEH(I,J)-TRPVEH(I+1,J)
   80 IF(MB.EQ.1) GO TO 85
```

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      VW1=VNPR(ISS)-TOSUM(I+1,1)-TOSUM(J,2)+TRPVEH(I+1,J)
      VW1=VW1-VPR(ISS)
      VW2=TRPVEH(I+1,J)
      RETURN
   85 VW1=TOSUM(I+1,1)-TRPVEH(I+1,J)
      VW2=TOSUM(J,2)-TRPVEH(I+1,J)
      RETURN
      END
      SUBROUTINE WVEFF
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/INTEG/I,J,IL,ITX,ITY,IS,IST,ISS,NNN(2)
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/REALS/FL1,FL2,VX1,VX2,VW1,VW2,RRR(4)
      DIMENSION EF(3),V(3),D(3)
C --- ET IS THE TRUCK FACTOR
      ET=TBF(IS)
      KS=1
C --- V(1) IS MODIFIED TOTAL WEAVING VOLUME IN PCPH (PASSENGER CARS
C ---        PER HOUR) OF THE SIMPLE PART OF WEAVING SECTION
      V(1)=(VW1+VW2)/ET
C --- D(1) IS THE LENGTH OF SIMPLE PART OF WEAVING SECTION
      D(1)=FL1
      GO TO (10,5,5),ITY
C --- IF WEAVING SECTION IS ITY  = 2 OR 3, V(2), D(2), V(3) AND D(3)
C ---        MUST BE DEFINED ACCORDING TO THE HIGHWAY CAPACITY MANUAL
    5 V(2)=(VX1+VX2)*FL1/ET/(FL1+FL2)
      D(2)=FL1
      V(3)=V(2)*FL2/FL1
      D(3)=FL2
      KS=3
C --- DO LOOP 30 FINDS WEAVING INFLUENCE FACTOR EF FOR EACH
C ---        COMBINATION OF D (DISTANCE) AND V (TOTAL WEAVING VOLUME)
C ---        ACCORDING TO FIGURE 7.4 OF HIGHWAY CAPACITY MANUAL
   10 DO 30 L=1,KS
      TWV=V(L)
      EF(L)=1.
      WIF=1.
C --- P 74 IS THE LENGTH OF THE WEAVING SECTION
   12 P74=6.711+WIF*(-3.636+WIF*(1.248-WIF*.2042))
      IF(TWV.GE.1500) GO TO 20
      SLOPE=3.298+WIF*(-2.429+WIF*(1.154-WIF*.2068))
      P74=TWV*(SLOPE+TWV*(P74-SLOPE*1.5)/2250.)
      GO  TO  26
   20 SLOPE=7.087+WIF*(-4.278+WIF*(1.415-WIF*.2132))
      P74=P74*1000.+SLOPE*(TWV-1500.)
   26 IF(D(L).GE.P74) GO TO 30
      EF(L)=EF(L)+.1
C --- WIF IS INCREMENTED BY .1 UNTIL P74 EXCEEDS D
      WIF=WIF+.1
C --- WIF CANNOT BE GREATER THAN 3., BUT EF IS COMPARED TO 2.99
C ---        BECAUSE OF TRUNCATION BY A BINARY MACHINE (CDC 6400)
      IF(EF(L).LT.2.99) GO TO 12
   30 CONTINUE
C --- MAKE VW2 THE SMALLER OF VW1 AND VW2
      IF(VW2.GT.VW1) VW2=VW1
C --- IF ITYP = 1 SIMPLE WEAVING, JUMP TO 43
      IF(ITY.EQ.1) GO TO 43
```

```
C --- MAKE VX2 THE SMALLER OF VX1 AND VX2
      IF(VX2.GT.VX1) VX2=VX1
C --- CHANGE THE WEAVING INFLUENCE FACTORS INTO VEHICLE
C ---       EFFECTIVENESSES ACCORDING TO H. C. M.
      EF(2)=(EF(2)-1.)*VX2
      EF(3)=(EF(3)-1.)*VX2
   43 EF(1)=(EF(1)-1.)*VW2
      GO TO (55,50,80),ITY
   50 EF(1) = EF(1) + EF(2) * FL1 / (FL1+FL2)
C --- IN THE CASE OF SIMPLE WEAVING, THE EFFECTIVENESS IS THE SAME
C ---       AS EF(1) FOR ALL SECTIONS INVOLVED IN THE WEAVING SECTION
C ---       (FROM IS, TO ISS)
   55 DO 60 K=IS,ISS
   60 EFF(K)=EF(1)+EFF(K)
      IF(ITY.NE.1) GO TO 70
   65 IL=1
   67 I=I+1
      RETURN
   70 ISS=ISS+1
      DO 75 K=ISS,IST
C --- FOR MULTIPLE WEAVING, THE EF MUST BE COMBINED ACCORDING TO
C ---       H. C. M.
   75  EFF(K) = EF(3) * FL2 / (FL1+FL2)
      GO TO 65
   80 EF(1) = EF(1) + EF(2) * FL1 / (FL1+FL2)
      IL=2
      DO 85 K=IS,ISS
   85  EFF(K) = EF(3) * FL2 / (FL1+FL2)
      DO 90 K=ISS,IST
   90  EFF(K)=EF(1)
      GO TO 67
      END
      SUBROUTINE QUEUP (ITX)
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/INTEG/K,IO,ID,L,NNN(6)
      COMMON/MAIN1NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/REALS/CN,RRR(9)
      COMMON/TIME/RA(50),TT(50),TD(50),TTP(50),TDP(50)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C --- THE FIRST TIME THROUGH, ITX = 2.  MOST OF THE TIME IN QUEUP
C ---       AND DISQ, ITX WILL BE 3.  WHEN THE RA ARRAY IS FIXED,
C ---       ITX = 1 WILL CAUSE AN EXIT FROM THE (QUEUP,DISQ) PAIR.
      IF(ITX.EQ.3) GO TO 3
    2 IO=1
      ID=1
      ITX=3
C --- L=0 INITIALIZES INDICATORS IN THE LX ARRAY IN CASE OF QUEUE
C ---       BEING TOTALLY DISPERSED IN THIS TIME INTERVAL
      L=0
      K=0
    3 K=K+1
      IF(K.LE.NSEC) GO TO 6
    4 ITX=1
```

```
      K=NSEC
      RETURN
C --- IN CASE THERE IS A QUEUE IN SECTION K - 1 TO BE INCREASED OR
C ---      DECREASED, STATEMENTS 6 THRU 15 WILL FIND THE VALUES OF
C ---      IO AND ID FROM WHICH THE DESTINATION PATTERN OF THE QUEUE
C ---      MAY BE FOUND.  NO(IO) MUST BE EQUAL TO OR LESS THAN I.
C ---      ND(ID) MUST BE GREATER THAN I.
    6 IF(NO(IO+1).GT.K-1) GO TO 10
      IO=IO+1
      GO TO 6
   10 IF(ND(ID).GT.K-1) GO TO 20
      ID=ID+1
      GO TO 10
   20 RA(K)=0
C --- CN IS THE NUMBER BY WHICH DEMAND EXCEEDS CAPACITY
      CN=VNPR(K)-CAPS(K)+EFF(K)
C --- IF CN IS POZITIVE, A QUEUE MUST FORM IN SECTION K - 1
C --- IF CN IS NEGATIVE, CHECK FOR EXISTANCE OF A QUEUE IN SECTION
C ---      K - 1
      IF(CN) 47,3,18
C --- IF THERE IS A QUEUE IN K - 1, CHECK IF K IS FULLY JAMMED, AND
C ---      GO ON TO NEXT SECTION IF IT IS, SINCE THE QUEUE MAY NOT
C ---      BE DISCHARGED
   47 IF(K.EQ.1) GO TO 3
      IF(H(K-1).LE.0.0001) GO TO 3
      FL=XLENGM(K)
      IF(FL-H(K).LE.0.0001) GO TO 3
C --- NO... CHECK IF ADDED VOLUME OF CN IN K - 1 WILL CAUSE V/C TO
C ---      EXCEED 1.
      IF(VNPR(K-1)+EFF(K-1)-CN.LT.CAPS(K-1)) GO TO 52
C --- IF IT WILL, REDEFINE CN SO THAT V/C IN K - 1 WILL EQUAL UNITY
      CN=VNPR(K-1)-CAPS(K-1)+EFF(K-1)
C --- INITIALIZE FOR FINDING APPROXIMATE NUMBER OF VEHICLES IN QUEUE
   52 SS=0.
      MJ=K-1
   61 FL1=H(MJ)
      V=VNPR(MJ)
      C=CAPS(MJ)-EFF(MJ)
C --- FIND DENSITY OF SECTION MJ FROM SPEED CURVE FOR FREE FLOW
      J=0
      IF(IP(MJ).EQ.1HP.AND.NPL.NE.0) J=1
      D1=V/SPEED(MJ,V/C,J)
C --- CHANGE VOLUME BY AMOUNT LN AND FIND DENSITY UNDER JAMMED
C ---      CONDITIONS
      V=VNPR(MJ)-CN
      IF(V.LE.C+0.05) GO TO 63
      K=MJ+1
      CALL PAGE(1)
      PRINT 1000,MJ
C --- IF QUEUE SPLIT, SEPARATE THE TWO QUEUES BY SMALL (.0002) DIS.
      H(K)=H(K)-.0002
      IO=1
      ID=1
      GOTO 6
   63 IF(IP(MJ).EQ.1HP.AND.NPL.NE.0) J=1
      D2=V/SPEED(MJ,-V/C,J)
C --- NUMBER OF CARS IN QUEUE IS APPROXIMATELY (D2 - D1) * LENGTH OF
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C ---       QUEUE
      SS=SS+(D2-D1)*FL1
      FL2=XLENGM(MJ)
C --- IF SECTION MJ IS FULLY JAMMED, REPEAT PROCEDURE FOR SECTION
C ---       MJ - 1
      IF(FL1+0.0001.LT.FL2) GO TO 69
   66 MJ=MJ-1
C --- IF THE QUEUE GOES ALL THE WAY THROUGH SECTION, ADD THE NUMBER
C ---       OF CARS IN THE QUEUE OF FIRST ON-RAMP
      IF(MJ.GT.0) GO TO 61
   68 SS=SS+RQ(1,1)
C --- MULTIPLY NUMBER OF CARS IN QUEUE BY FOUR TO FIND THE RATE CSS
C ---       WHICH WILL DISCHARGE THE ENTIRE QUEUE IN ONE FOURTH OF AN
C ---       HOUR AND MAKE IT NEGATIVE BECAUSE THE CARS ARE
C ---       DISCHARGING
   69 CSS=-SS*FAC(1)*1.15
C --- THE FACTOR 4.6 IS THE PRODUCT OF 4. (QUARTERS OF AN HOUR) TIME
C ---       TIMES 1.15, A FACTOR FOUND TO EMPIRICALLY NECESSARY IN
C ---       ORDER TO MORE CLOSELY APPROXIMATE THE RATE OF DISCHARGE
C ---       NEEDED TO DISPERSE QUEUE IN 1/4 - HOUR.
C --- COMPARE CSS WITH CN AND MAKE CN THE SMALLEST OF RATES OF
C ---       DISCHARGE
      IF(CSS.LE.CN) GO TO 18
C --- IF CSS IS A SMALLER RATE THAN CN, THE QUEUE WILL DISCHARGE AT
C ---       RATE CSS EVEN THOUGH V/C OF THE BOTTLENECK IS LESS THAN
C ---       ONE BECAUSE ERRORS WILL RESULT IN TAILQ AND QTIME IF THE
C ---       WHOLE QUEUE DISCHARGES IN LESS THAN ONE FOURTH OF AN HOUR
   71 CN=CSS
C --- INCREASE L AND RECORD SECTION NUMBER WHERE QUEUE SHOULD NOT
C ---       BE DURING NEXT TIME INTERVAL.
      L=L+1
      LX(L)=K-1
   18 RA(K-1)=CN
      RETURN
 1000 FORMAT(11X,13H* QUEUE SPLIT  ,I3)
      END
      SUBROUTINE TRAVEL
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/INTEG/K,NNN(9)
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/REALS/SS,RRR(9)
      COMMON/TIME/RA(50),TT(50),TD(50),TTP(50),TDP(50)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
      SS=1.0/FAC(1)
   50 IF(RA(K)) 10,20,30
   10 CALL TAILQ
      CALL QTIME
      GO TO 40
   30 CALL QCOLL
      GO TO 40
   20 VC=VNPR(K)/(CAPS(K)-EFF(K))
      J=0
      IF(IP(K).EQ.1HP.AND.NPL.NE.0) J=1
      S=SPEED(K,VC,J)
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      D=VNPR(K)/S
      TT(K)=XLENGM(K)*D/FAC(1)
      TD(K)=XLENGM(K)*VNPR(K)/FAC(1)
   40 K=K-1
      IF(K.GT.0) GO TO 50
      RETURN
      END
      SUBROUTINE TAILQ
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/INTEG/I,NNN(8),IY
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/TIME/RA(50),TT(50),TD(50),TTP(50),TDP(50)
      COMMON/VOLS1VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C ---   TAILQ WILL FIND SECTION NUMBER OF TAIL OF QUEUE
      IY=I
    2 FL=XLENGM(I)
C --- IS SECTION FULLY JAMMED
C --- NO... TAIL OF QUEUE FOUND, RETURN
      IF(FL-H(I).GT.0.0001) RETURN
C --- YES... CALCULATE V/C AND TRAVEL TIME
      J=0
      IF(IP(I).EQ.1HP.AND.NPL.NE.0) J=1
      V=VNPR(I)
      C=CAPS(I)-EFF(I)
      VP=RA(I)
      VC2=(V-VP)/C
C --- FIND SPEED, DENSITY AND TRAVEL TIME
   10 S2=SPEED(I,-VC2,J)
      D2=(V-VP)/S2
      TT(I)=FL*D21FAC(1)
      TD(I)=FL*(V-VP)/FAC(1)
C --- IF I = 1,RETURN AND QTIME WILL HANDLE POSSIBILITY OF QUEUE OUT
C ---       OF SECTION 1
      IF(I.EQ.1) RETURN
C --- TRANSMIT RA TO NEXT SECTION AND REPEAT ABOVE PROCESS
      RA(I-1)=RA(I)
      I=I-1
      GO TO 2
      END
      SUBROUTINE QTIME
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/INTEG/I,NN(2),L,NNN(6)
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/REALS/SS,RRR(9)
      COMMON/TIME/RA(50),TT(50),TD(50),TTP(50),TDP(50)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C --- INITIALIZE
      FC=1.0/FAC(1)
      SAVE=0.
   15 IX=I
```

```
C --- TEST FOR TAIL OF QUEUE IN SECTION 1
      IF(I.NE.1) GOTO 16
      FL=XLENGM(1)
C --- IS SECTION FULLY JAMMED
      IF(FL-H(1).GT.0.0001) GO TO 16
C --- NO... GO TO 16
C --- IT IS FULLY JAMMED... CAN THE RATE OF DISCHARGE RA DEPLETE THE
C ---        RAMP QUEUE IN ONE FOURTH OF AN HOUR
C --- NO... GO TO 12
C --- YES... CONTINUE
C ---      SS WILL USUALLY BE .25 HOURS.IF QCOLL CALL TAILQ AND QTIME
C ---      BECAUSE OF QUEUE COLLISION, SS WILL BE TIME OF COLLISION
    5 IF(RA(1)+RQ(1,1)/SS .GE.0.0) GO TO 12
      SAVE=-RQ(1,1)/RA(1)
      RD(1)=RD(1)+RQ(1,1)*SAVE/2.0
      RQ(1,1)=0.0
      GO TO 16
   12 RQ(1,1)=RQ(1,1)+RA(1)*SS
      RD(1)=RD(1)+SS*(RQ(1,1)-RA(1)*SS/2.0)
C --- RAMP DELAY UNITS ARE     VEH-HRS
      RETURN
C --- SAVE IS THE TIME AT WHICH QUEUE TAIL LEAVES SECTION I - 1 AND
C ---        ENTERS SECTION I
   16 T1=SAVE
      J=0
      IF(IP(I).EQ.1HP.AND.NPL.NE.0) J=1
      V=VNPR(I)
      C=CAPS(I)-EFF(I)
C --- COMPUTE VC1, THE V/C RATION IN THE FREEFLOW SECTION
      VC1=V/C
      VP=RA(I)
C --- COMPUTE VC2, THE V/C RATIO  IN THE JAMMED SECTION
      VC2=(V-VP)/C
   17 S1=SPEED(I,VC1,J)
      IF(IP(I).EQ.1HP.AND.NPL.NE.0) J=1
      S2=SPEED(I,-VC2,J)
C --- D1 IS THE DENSITY IN FREEFLOW
      D1=V/S1
C --- D2 IS THE DENSITY OF QUEUE
      D2=(V-VP)/S2
      IF(ABS(D2-D1).GT.0.0001) GO TO 100
      G=100000.0
      GO TO 105
C --- G IS THE VELOCITY OF TAIL OF QUEUE
  100 G=-VP/(D2-D1)
C --- T2 IS TIME IN HOURS FROM BEGINNING OF TIME INTERVAL THAT TAIL
C ---        OF QUEUE LEAVES SECTION I
  105 T2=H(I)/G+T1
      IF(T2.GE.SS) GO TO 25
C --- IF T2 IS LE2S THAN 1/4 HOUR, TAIL OF QUEUE WILL LEAVE SECTION
C ---        I
   18 FL=XLENGM(I+1)
      IF(FL-H(I+1).GT.0.0001) GO TO 27
   20 SAVE=T2
C --- ITX = 2 MEANS TAIL OF QUEUE CONTINUES INTO SECTION I + 1
C ---        DURING THIS TIME INTERVAL.  CONTINUE PROCESSING
      ITX=2
```

```
      GO TO 30
   25 T2=SS
C --- IF T2 IS GREATER THAN 1/4 HOUR, SET IT TO 1/4 HOUR AND COMPARE
C ---         TRAVEL TIME
C --- ITX = 1 MEANS THAT THE QUEUE HAS COMPLETELY DISPERSED OR
C ---         T2 = 1/4 HOUR.  EXIT FROM DEQ1.
   27 ITX=1
   30 FL=XLENGM(I)
C --- THIS EXPRESSION FOR TRAVEL TIME IS FOUND BY CONSIDERING THE
C ---         JAMMED SECTION TO BE OF TWO PARTS--1. JAMMED AND 2. FREE-
C ---         FLOW.  THE LENGTHS OF THESE TWO SECTIONS CHANGE WITH TIME
C ---         BUT THEIR DENSITIES REMAIN THE SAME
      TT(I) = FL * D2 * T1 + (D2-D1) * (T2-T1) * ((T1-T2) / 2. * G +
     X  H(I)) + ( FC-T1) * FL * D1
      TD(I)=FL*(V-VP)*T1-VP*(T2-T1)*((T1-T2)/2.*G+H(I))+( FC-T1)*FL*V
      H(I)=H(I)-G*(T2-T1)
      IF(H(I).LT.0.005) H(I)=0.0
      GOTO(31,32),ITX
   31 IF(T2.GE.SS) GO TO 48
C --- IF T2 IS LE2S THAN  1/4 - HOUR, IT MUST BE THE FINAL DISPERSED
C ---         PART OF THE QUEUE.  PRINT THE TIME.
   43 PRINT 1000,I,T2
      CALL PAGE(1)
      IF(L.LE.0) GO TO 99
C --- IF LX(L) POINTED TO THIS SECTION, REDUCE L BY ONE.
      IF(LX(L)-I) 99,97,97
   48 IF(L.LE.0) GO TO 99
      IF(+C+TCLXULDD8+0 TO  99
C --- IF T2=.25 AND LX(L) POINTS TO THIS SECTION, REMOVE QUEUE
C ---         AND PUNCH LENGTH OF QUEUE THUS REMOVED.
   58 LL=LX(L)
      IF(SS.NE. FC) GO TO 97
      DO 95 JK=I,LL
      IFT=H(JK)*5280.
      CALL PAGE(1)
      PRINT 1001,JK,IFT
   95 H(JK)=0.
   97 L=L-1
   99 I=IX
      SS=FC
      RETURN
   32 RA(I)=0
      I=I+1
      GO TO 16
 1000 FORMAT(16X,4HSEC ,I2,8X,4HT2= ,F5.3)
 1001 FORMAT(16X,4HSEC ,I2,5X,6HCLEAR ,I4)
      END
      SUBROUTINE QCOLL
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/INTEG/I,NNN(8),IY
      COMMON/MAIN1NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/REALS/SS,RRR(9)
      COMMON/TIME1RA(50),TT(50),TD(50),TTP(50),TDP(50)
```

```
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
C --- SAVE HAS THE SAME FUNCTION HERE AS IN QTIME
      FC=1.0/FAC(1)
      TX=0.
C --- TX IS THE TIME OF THE LAST QUEUE COLLISION.
      VPQ=0.
      QC=0.
      SAVE=0.
    2 T1=SAVE
      J=0
      IF(IP(I).EQ.1HP.AND.NPL.NE.0) J=1
      V=VNPR(I)
      C=CAPS(I)-EFF(I)
      VC1=V/C
      VP=RA(I)
      VC2=(V-VP)/C
      S1=SPEED(I,VC1,J)
      IF(IP(I).EQ.1HP.AND.NPL.NE.0) J=1
      S2=SPEED(I,-VC2,J)
C --- COMPUTE VC1, VC2, D1 AND D2
      D1=V/S1
      D2=(V-VP)/S2
C ---     QC=1. DURING QUEUE COLLISION
      IF(QC.LE.0) GO TO 3
  100 FL=XLENGM(I)
      IF(FL-H(I).GT.0.0001) GO TO 3
  105 VC3=(V-VPQ)/C
      IF(IP(I).EQ.1HP.AND.NPL.NE.0) J=1
      S1=SPEED(I,-VC3,J)
C ---     DURING QUEUE COLLISION, D1  REPRESENTS CONGESTED FLOW
      D1=(V-VPQ)/21
      IF(ABS(D2-D1).LE.0.00001) GO TO 10
      G=(VP-VPQ)/(D2-D1)
      GO TO 4
    3 QC=0.
      IF(ABS(D2-D1).LE.0.00001) GO TO 10
      G=VP/(D2-D1)
      GO TO 4
   10 G=1.0/0.000001
    4 FL=XLENGM(I)
C --- FIND T2, THE TIME TAIL OF QUEUE LEAVES SECTION I
      T2=(FL-H(I))/G+T1
C --- IF T2 EXCEEDS 1/4 HOUR, QUEUE DOES NOT LEAVE SECTION I.
C ---      SET ITX = 1.
      IF(T2.GE.FC) GO TO 12
C --- IF T2 IS LE2S THAN 1/4 HOUR AND I = 1, THEN QUEUE LEAVES
C ---      SECTION 1 AND  RQ(1) AND  RD(1) MUST BE FOUND BY A
C ---      PROCEDURE SIMILAR TO THAT USED IN QTIME
   55 IF(I.GT.1) GO TO 5
   56 PRINT 1000
      CALL PAGE(1)
      RQ(1,1)=RQ(1,1)+VP*(FC-T2)
      RD(1)=RQ(1,1)* FC -(VP*( FC -T2)* FC /2.0)
      GO TO 25
    5 PQ=RA(I-1)
      IF(H(I-1).LE.0.0001) GO TO 9
C --- IF NEW QUEUE COLLISION IS A VERY SHORT TIME FROM OLD QUEUE
```

```
C ---       COLLISION, DO NOT PRINT MESSAGE.
    7 IF(T2-TX.LE.0.0001) GO TO 9
C --- IF QUEUE LEAVES SECTION I AND SECTION I - 1 ALREADY HAS A
C ---       QUEUE, THEN QUEUE COLLISION
    6 PRINT 1001,I,T2
      CALL PAGE(1)
      QC=1.
      TX=T2
C  ---     VPQ IS THE VALUE NEEDED TO MAKE D1 CONGESTED DENSITY
      VPQ=VPQ+PQ
      IY=0
   29 IF(PQ) 62,9,64
C  ---     IF COLLISION WITH DECREASING QUEUE OCCURES, SET SS TO
C  ---     TIME T2 AND CALL DEQ DEQ1.
   62 SS=T2
      SSS=T2
      K=I
      I=I-1
      CALL TAILQ
      CALL QTIME
      I=K
C  ---     SET SS FOR REMAINDER OF TIME INTERVAL
      SS=FC-T2
      T2=SSS
      SAVE=T2
      GO TO 68
   64 SAVE=T2*(1-PQ/(VP+PQ))
      TX=SAVE
      GO TO 68
    9 SAVE=T2
C  ---     IF RA IS MINUS AT THIS POINT, IT MUST HAVE BEEN SET
C  ---    IN QTIME  AND SHOULD BE ZEROED OUT
      IF(PQ) 67,68,6
   67 RA(I-1)=0.0
   68 ITX=2
C --- ITX = 2 MEANS QUEUE LEAVES SECTION I
      IF(I-1 .NE. IY) GO TO 130
      IF(H(I-1) .GT. .0001) GO TO 130
      RA(I-1)=RA(I)
      GO TO 140
  130 RA(I-1)=RA(I)+RA(I-1)
  140 IF(RA(I-1)) 25,13,13
   12 T2=FC
   25 ITX=1
C --- COMPUTE TRASEL TIME AND FIND LENGTH OF QUEUE AT THE END OF
C ---       TIME PERIOD
   13 TT(I)=FL*D1*T2+(D2-D1)*(T2-T1)*((T2-T1)/2.*G+H(I))+( FC-T2)*FL*D2
      TD(I)=FL*V*T2-VP*(T2-T1)*((T2-T1)/2.*G+H(I))+( FC-T2)*FL*(V-VP)
      H(I)=H(I)+G*(T2-T1)
      IF(ITX.EQ.1) RETURN
   16 I=I-1
      SS=FC
      GO TO 2
 1000 FORMAT(11X,15HQ OUT OF SEC 1   )
 1001 FORMAT(11X,16HQUEUE COLLISION ,I3,5H T2= ,F5.3)
      END
      FUNCTION SPEED(NNSEC,VC,IFLAB)
```

```
      COMMON/CURVE/NCRV(5,2),XXSF(20,5),YYSF(20,5),NDS(50,3)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
C***  THE FOLLOWING CARD IS AN ARITHMETIC FUNCTION STATEMENT FOR A
C***  CUBIC POWER FUNCTION.
      POLY(A,B,C,D)=A+VC*(B+VC*(C+VC*D))
      IFLAG=IFLAB
      DS=NDS(NNSEC,IFLAG+1)
      IF(IFLAG.GE.1) IFLAG=IFLAG-1
      OPSD=0.
      IF(DS.LE.5) GO TO 100
   22 IF(VC.GE.0) GO TO 3
      SPEED=VC*(20.*VC-8.)
      RETURN
C --- DESIGN SPEED OF 65 MPH WAS DEVELOPED FOR STUDY SECTION SIX
C ---         OF THE EAST-SHORE FREEWAY.
    3 IF(DS.NE.65) GO TO 12
      IF(VC.GE.0.95) GO TO 8
    7 SPEED=63.-8.421*VC
      RETURN
    8 SPEED=-7823.6*VC**2+14856.2*VC-6997.4
      RETURN
 6    SPEED=OPSD-DS/10.*(1.-VC)
      RETURN
   12 DZ=0.1*(DS-40.)
      NN=LANE(NNSEC,IFLAG+1)
      IF(IFLAG.EQ.0) NN=NN-LANE(NNSEC,2)
      IF(NN.GT.4) NN=4
      IF(VC.LE.1.0) GO TO 45
   35 PRINT 1001
      GO TO 6      ***** SEE ERRATA AT THE END OF LISTING
                   *
  4N2 ***************  9999999999999999999999999999999999999999!!!!!!!!!!!!!!!!!!!!
C***  PRIOR PART OF PROGRAM CHECKS FOR N, DS, OR VC  OUT OF RANGE.
      GO TO (52,54,58),K
   52 OPSD=POLY(50.,-22.,0.,0.)
      GO TO 6
   54 L=1
      IF(VC.GT.0.81) L=2
      GO TO 65
   58 L=1
      IF(VC.GT.0.75) L=2
   65 K=L+(NN-2)*2+(K-2)*6
      GO TO (70,72,74,76,78,80,82,84,86,88,90,92),K
   70 OPSD=POLY(60.,-25.,0.,0.)
      GO TO 6
   72 OPSD=POLY(108.8,-477.9,845.3,-446.7)
      GO TO 6
   74 OPSD=POLY(6*.,-22.03,-3.214,0.)
      GO TO 6
   76 OPSD=POLY(135.1,-548.6,906.6,-463.6)
      GO TO 6
   78 OPSD=POLY(6*.,-18.49,-6.964,0.)
      GO TO 6
   80 OPSD=POLY(136.8,-538.4,878.9,-447.8)
      GO TO 6
   82 OPSD=POLY(70.,-22.94,-10.62,0.)
      GO TO 6
   84 OPSD=POLY(1112.8,-3924.1,4821.8,-1980.5)
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      GO TO 6
   86 OPSD=POLY(70.,-22.76,-4.73,0.)
      GO TO 6
   88 OPSD=POLY(607.48,-2052.3,2539.4,-1059.4)
      GO TO 6
   90 OPSD=POLY(7*.,-20.375,-5.625,0.)
      GO TO 6
   92 OPSD=POLY(666.95,-2234.1,2728.7,-1125.9)
      GO TO 6
  100 NC=IFIX(DS)
      DO 105 I=1,5
      IF(NC.EQ.NCRV(I,1)) GO TO 110
  105 CONTINUE
  200 PRINT 1000,NC
      CALL PAGE(3)
      DS=70.0
      GO TO 22
  110 JT=NCRV(I,2)
      IF(VC.LT.0) GO TO 150
      IF(VC.GE.0.995) GO TO 130
      DO 145 K=1,JT
      IF(XXSF(K,I).GT.VC) GO TO 140
  145 CONTINUE
      K=JT
  140 A=(VC-XXSF(K-1,I))/(XXSF(K,I)-XXSF(K-1,I))
      B=(XXSF(K,I)-VC)/(XXSF(K,I)-XXSF(K-1,I))
  170 SPEED=A*YYSF(K,I)+B*YYSF(K-1,I)
      RETURN
  130 IXZ=1.0
  133 DO 135 K=1,JT
      IF(XXSF(K,I).NE.IXZ) GO TO 135
      SPEED=YYSF(K,I)
      RETURN
  135 CONTINUE
      GO TO 200
  150 IF(VC.GT.-0.995) GO TO 152
      IXZ=-1.0
      GO TO 133
  152 DO 155 K=1,JT
      IF(XXSF(K,I).GE.0.0) GO TO 155
      IF(XXSF(K,I).GT.VC) GO TO 160
  155 CONTINUE
      K=JT
  160 B=(XXSF(K,I)-VC)/(XXSF(K,I)-XXSF(K-1,I))
      A=(VC-XXSF(K-1,I))/(XXSF(K,I)-XXSF(K-1,I))
      GO TO 170
 1000 FORMAT(//,11X,*SPEED CURVE *I2* NOT FOUND OR NO VALUE FOR VC =+ OR
     1 - 1.0 */11X,* DESIGN SPEED SET TO 70 MPH.*)
 1001 FORMAT(16H VC NOT IN (0,1))
      END
      SUBROUTINE OUTIT
      COMMON/DESIGN/XLENGF(50),CAPS(50),CAPFP(50),XLENGM(50)
      COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
      COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
      COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
      COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
     1           TOSUM(20,2)
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      COMMON/OUTS/CVM,CPM,NTOTAL(50),CVMP,CPMP
      COMMON/QUEUES/H(50),QD(50),EFF(50),TBF(50)
      COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
      COMMON/TIME/RA(50),TT(50),TD(50),TTP(50),TDP(50)
      COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
      CALL PAGE(3)
      IF(NPL.EQ.0) PRINT 1005
      IF(NPL.NE.0) PRINT 1002
  100 IO=1
      ID=1
      DTT=0
      ISNB=0
      DO 15 I=1,N2EC
C --- OFR AND ONR ARE OFF-RAMP AND ON-RAMP DEMANDS OF SECTION I
      OFR=0
      ONR=0
C --- IF THERE IS AN ON-RAMP IN SECTION I, SET OFR AND  INCREMENT IO
      IF(NO(IO).NE.I) GO TO 41
      IF(TOSUM(IO,1).LT.1) TOSUM(IO,1)=0.0
      ONR=TOSUM(IO,1)
      IO=IO+1
C --- IF THERE IS AN OFF-RAMP IN SECTION I, SET IFR
   41 IF(ND(ID).NE.I) GO TO 45
      OFR=TOSUM(ID,2)
      ID=ID+1
   45 LI=H(I)*5280.0
      IF(H(I).GE.XLENGM(I)-0.020) LI=XLENGF(I)
      ISR=2H
      IF(H(I).LE.0.0001) GO TO 8
C --- ISR IS A SET TO ASTERISK (*) IF THERE IS A QUEUE IN SECTION I
      ISR=2H *
C --- VNPR(I) IS ALTERED BY RA(I) EVEN THOUGH RA(I) MAY NOT HAVE HAD
C ---       FULL EFFECT DURING THE ENTIRE TIME INTERVAL
      VNPR(I)=VNPR(I)-RA(I)
    8 V=VNPR(I)
C --- IF V IS NEGATIVE, RA HAS EXCEEDED V FOR SOME SECTION.
      IF(V.LE.0.) ISNB=I
      CAPI=CAPS(I)-EFF(I)
      VC=V/CAPI
C --- DT IS THE TIME IN MINUTES FOR ONE CAR TO TRAVERSE SECTION I
      DT=FAC(1)*T3(I)*60.0/V
      DTT=DTT+DT
      FL=XLENGM(I)
C --- XS IS THE AVERAGE SPEED (MPH)
      XS=TD(I)/TT(I)
      XDEN=VNPR(I)/(XS*(LANE(I,1)-LANE(I,2)))
C --- XDEN IS THE DENSITY OF CARS (VPM/LANE) IN SECTION I
      TDP(I)=0.0
      TTP(I)=0.0
      CALL PAGE(1)
      IF(NPL.NE.0) GO TO 120
      PRINT 1001,I,ONR,OFR,NTOTAL(I),VNPR(I),CAPI,EFF(I),VC,XDEN,XS,ISR,
     1DT,XLENGF(I),LI,RA(I)
      GO TO 105
  120 IF(IP(I).EQ.1HP) GO TO 130
      N=1HN
      PRINT 1003,I,ONR,OFR,NTOTAL(I),N,LANE(I,1),VNPR(I),CAPI,EFF(I),VC,
```

```
   1XDEN,XS,DT,ISR,XLENGF(I),LI,RA(I)
    GO TO 105
130 CAPP=CAPFP(I)*NPL
    N=1HU
    LAN=LANE(I,1)-NPL
    VCP=VPR(I)/CAPP
    ITWO=2
    D=VPR(I)/SPEED(I,VCP,ITWO)
    TTP(I)=XLENGM(I)*D/FAC(1)
    TDP(I)=XLENGM(I)*VPR(I)/FAC(1)
    PDT=FAC(1)*3TP(I)*60.0/VPR(I)
    PS=TDP(I)/TTP(I)
    PDEN=VPR(I)/(PS*NPL)
    PRINT 1004,I,ONR,OFR,NTOTAL(I),NPL,VPR(I),CAPP,VCP,PDEN,PS,PDT,N,
   1LAN,VNPR(I),CAPI,EFF(I),VC,XDEN,XS,DT,ISR,XLENGF(I),LI,RA(I)
107 VPR(I)=TDP(I)*FAC(1)/FL
105 VNPR(I)=TD(I)*FAC(1)/FL
 15 CONTINUE
    IF(ISNB.NE.*) PRINT 1008,ISNB
    II=1
    DO 90 IO=1,NORG
    DK=RD(IO)+XMD(IO)
    IF(DK.EQ.0) GO TO 90
    IJ=NO(IO)
    BRD=RD(IO)*RQ(IO,2)
    BMD=XMD(IO)*BV(IJ,1)
    BVD=RQ(IO,1)*RQ(IO,2)
    BVMD=XMQ(IO)*BV(IJ,1)
    EBN10=1.0/EBN-1.0
    RDIO=RD(IO)+BRD*EBN10
    XMDIO=XMD(IO)+BMD*EBN10
    RQIO=RQ(IO,1)+BVD*EBN10
    XMQIO=XMQ(IO)+BVMD*EBN10
    IF(II.NE.1) GO TO 25
    CALL PAGE(2)
    PRINT 1006
    II=2
 25 CALL PAGE(4)
    DX=RDIO+XMDIO
    DK=XMQIO+RQIO
    PRINT 1007,IO,RQIO,RDIO,XMQIO,XMDIO,DK,DX
 90 CONTINUE
    RETURN
1001 FORMAT(I4,2F6.0,I6,3F6.0,F5.2,2F5.0,1X,A2,F6.2,F6.0,I6,F6.0)
1002 FORMAT(25X,*RESERVED PRIORITY OPERATIONS*,30X,*UNRESERVED OR NORMA
   1L OPERATIONS*/24X,31(*.*),4X,68(*.*)/* SUB FINAL DEMD. ORIG.  PS V
   2OL  CAP  V/C  DEN  MPH TRAV    UN  NL  VOL  CAP  WEAVE  V/C DEN
   3MPH  TRAV Q  LENG  QUEUE   */* SEC   ORG  DES TOTAL*20X*V/M/L
   4TIME    NORM *15X*EFF      V/M/L      TIME *1H*9X, *FEET    RA *)
1003 FORMAT(X,I2,2F6.0,I6,40X,A1,I3,3F6.0,F5.2,2F5.0,F5.2,A2,F6.0,I6,
   1F6.0)
1004 FORMAT(X,I2,2F6.0,I6,1X,I2,2F6.0,F4.2,2F5.0,F5.2,6X,A1,I3,3F6.0,
   1F5.2,2F5.0,F5.2,A2,F6.0,I6,F6.0)
1005 FORMAT(* SUB FINAL DEMAND ORIG.  VOL  FWRY WEAVE  V/C DENS  MPH
   1 TRAV  LENG QUEUE    RA  */* SEC   ORG   DES TOTAL*9X*CAP   EFF
   2   V/M/L*8X*TIME*8X*FEET*)
1006 FORMAT(/30X,20HQUEUE LENGTH   DELAY/30X,22HVEHICLES      VEH-HRS)
```

```
1007 FORMAT(/3X7HON-RAMP,I4,4X,11HINPUT POINT,3X,2F8.2/16X,*MERGING POI
    1NT*,3X,2F8.2/24X,*TOTAL*,3X,2F8.2)
1008 FORMAT(/16H *** WARNING *** ,* N-PRIME EXCEEDS DEMAND IN SECTION *
    1 I2, *.  THIS CAUSES NEGATIVE VOLUME.* /16X,*  REDUCE TEMPORARY ON
    2-RAMP LIMIT2 FOR ONE OR MORE DOWNSTREAM RAMPS AND RE-RUN.*/)
     END
     SUBROUTINE TIMEOUT
     COMMON/DESIGN2/IP(50),LEFT(50),LANE(50,2),NO(20),ND(20),PRI(7)
     COMMON/INFOR/IFL(5),NG1,FAC(20),EBN,EBL
     COMMON/MAIN/NORG,NDES,NOTS,IOCS,IOP,IPAGE,NSEC,PLC,NGP,GF,NPL
     COMMON/ODS/TRIPS(20,20,2),CARTRP(20,20),TRPVEH(20,20),SUM(20,2,2),
    1              TOSUM(20,2)
     COMMON/OUTS1CVM,CPM,NTOTAL(50),CVMP,CPMP
     COMMON/RAMP1/RQ(20,2),RD(20),XMQ(20),XMD(20),LX(10)
     COMMON/RAMP2/RLIM(20),FRL(20),RDIS(50),RVOL(50),IXX(9),VXX(9),RXX
     COMMON/SLIC/PCTVEH(5,5),BUSOC(5),AVE,IXXX(5,5),REVON(5,5),ITSLT(8)
     COMMON/VOLS/VPR(50),VNPR(50),VPRIN(50),POFF(20,2),VAL(50),BV(50,2)
     COMMON/TIME/RA(50),TT(50),TD(50),TTP(50),TDP(50)
     DIMENSION TRIP(20,20)
     EBFAC=EBL/EBN
     KON=0
     IS=NDES-1
     DO 22 ID=1,IS
     IF(TOSUM(ID=2).LE.FRL(ID)) GO TO 22
     CALL PAGE(2)
     PRINT 1002,ID,FRL(ID)
  22 CONTINUE
C --- INITIALIZE
     XUM=0.0
     TTSUM = 0.
     TTT = 0.
C --- FAC(2) IS OUTPUT CONTROL WHICH, WHEN ZERO, SUPPRESSES OUTPUT
C ---       TABLES
     IF(FAC(2).EQ.0) GO TO 99
   2 IO=1
     ID=1
     CALL PAGE(0)
     NSM=0
     TMP=0.0
     TM=0.0
     DO 70 I=1,NSEC
     V=VNPR(I)
C ---  DT IS THE TIME (.01 MINUTES) REQUIRED FOR ONE VEHICLE TO
C ---       TRAVERSE SECTION I
     DT=FAC(1)*6*00.0*TT(I)/V
     TM=TM+DT
     DTP=0.0
     IF(NPL.EQ.0) GO TO 100
     IF(IP(I).EQ.1HP) GO TO 105
     TMP=TMP+DT
     DTP=DT
     GO TO 100
 105 DTP=FAC(1)*6000.0*TTP(I)/VPR(I)
     TMP=TMP+DTP
C ---  TM IS THE TIME REQUIRED TO TRAVEL FROM SECTION 1 TO SECTION I
 100 IF(ND(ID).NE.I) GO TO 60
C --- TO REDUCE STORAGE REQUIREMENTS, RAMP DISTANCES IN RDIS ARE
```

```
C ---       DESTROYED AND REPLACED BY TIME SEPARATION FROM SECTION 1
C ---       TO SECTION WITH OFF-RAMP
C ---RDIS IS RESTORED IN SUBROUTINE RSM
      RDIS(ID)=TM
      SUM(ID,2,1)=TMP
      ID=ID+1
   60 IF(NO(IO).NE.I) GO TO 70
C ---SIMILARLY RAMP VOLUMES IN RVOL ARE REPLACED BY TIME SEPARATION
C ---       FOR ON-RAMPS
      RVOL(IO)=TM-DT
      SUM(IO,1,1)=TMP-DTP
      IO=IO+1
   70 CONTINUE
C --- PRINT HEADING
      CALL PAGE(NORG+2)
      PRINT 1004
C --- KON IS ALWAYS ZERO
      PRINT 1006,KON,(I,I=1,NDES)
      DO 75 IO=1,NORG
      IF(TOSUM(IO,1).NE.0) GO TO 65
      DT=0.0
      GO TO 66
   65 DT=FAC(1)*60.0*RD(IO)/TOSUM(IO,1)*100.0
   66 DO 80 ID=1,NDES
C ---  TM IS TIME FROM ON-RAMP IO TO OFF-RAMP ID
      TMP=SUM(ID,2,1)-SUM(IO,1,1)
      TM=RDIS(ID)-RVOL(IO)
C --- IF  TM IS NEGATIVE, ID PRECEEDS IO
      IF(TM.GE.0) GO TO 73
   72 T=0.
      TRIP(IO,ID)=0.0
C ---TOSUM IS NO LONGER USED, SO AGAIN REUSE OF THIS ARRAY REDUCES
C ---       STORAGE REQUIREMENTS
      TOSUM(ID,2)=0.0
      GO TO 74
   73 TOSUM(ID,2)=TM
      T=TM+DT
      TRIP(IO,ID)=TMP
C --- MULTIPLY TIME SEPARATION BY NUMBER OF VEHICLES MAKING A  TRIP
C ---       AND STORE THE RESULTANT TRAVEL TIME IN CARTRP , TRIPS
      TVAL=TRPVEH(IO,ID)-TRIPS(IO,ID,1)*(EBN-1.0)
      T=T*TVAL/(FAC(1)*60.0)
   74 CARTRP(IO,ID)=T
   80 CONTINUE
C --- OUTPUT THE TIME SEPARATIONS BETWEEN ON-RAMP IO AND ALL OFF-
C ---       RAMPS
      PRINT 1009,IO,(TOSUM(ID,2),ID=1,NDES)
   75 CONTINUE
      IF(NPL.NE.0) GO TO 87
      CALL PAGE(NORG+4)
      PRINT 1010
      PRINT 1006,KON,(I,I=1,NDES)
C --- DO LOOP 85 OUTPUTS TRAVEL TIMES
      DO 85 IO=1,NORG
      PRINT 1009,IO,(CARTRP(IO,ID),ID=1,NDES)
   85 CONTINUE
   87 IF(NPL.EQ.0) GO TO 99
```

```
      CALL PAGE(NORG+4)
      PRINT 1001
       PRINT 1006,KON,(I,I=1,NDES)
      DO 185 IO=1,NORG
  185 PRINT 1009,IO,(TRIP(IO,ID),ID=1,NDES)
   99 CONTINUE
      IF(NPL.NE.0) GO TO 200
      XUMB=0.0
      XUMBA=0.0
      DO 9 IO=1,NORG
      I=NO(IO)
      RRD=RD(IO)+XMD(IO)
      XUMB=XUMB+RD(IO)*RQ(IO,2)
      XUMBA=XUMBA+XMD(IO)*BV(I,1)
C --- FIND INPUT DELAY, XUM
    9 XUM=XUM+RRD
      VMB=0.0
      XUMB=XUMB+XUMBA
      BUSS=0.0
      VM=0.
      DO 5 I=1,NSEC
      VM=VM+TD(I)
C --- XUM TRAVEL TIMES FOR EACH SECTION TO GET TOTAL TRAVEL TIME
C ---       TTSUM
      TTSUM=TTSUM+TT(I)
      VMB=TD(I)*BV(I,1)+VMB
    5 BUSS=BUSS+TT(I)*BV(I,1)
C --- ADD SUM TO TTSUM TO GET TTT AND OUTPUT ALL THREE
      PTS=(TTSUM-BUSS)*AVE+BUSS*BUSOC(1)/EBN
      PSM=(XUM-XUMB)*AVE+(XUMB/EBN)*BUSOC(1)
      TTSUM=TTSUM-BUSS+BUSS/EBN
      XUM=XUM-XUMB+XUMB/EBN
      TTT=TTSUM+XUM
      FAC(4)=FAC(4)+TTSUM
      FAC(5)=FAC(5)+XUM
      T45=FAC(4)+FAC(5)
      PTT=PTS+PSM
      FAC(6)=FAC(6)+PTS
      FAC(7)=FAC(7)+PSM
      T67=FAC(6)+FAC(7)
      CALL PAGE(6)
      PRINT 1011,TTSUM,PTS,FAC(4),FAC(6),XUM,PSM,FAC(5),FAC(7),TTT,PTT,
     1T45,T67
      PM=(VM-VMB)*AVE+VMB*BUSOC(1)/EBN
      VM=VM-VMB+VMB/EBN
      CVM=CVM+VM
      CPM=CPM+PM
      PRINT 1012,VM,PM,CVM,CPM
      IF(IFL(1).NE.NOTS) RETURN
      FAC(19)=T45
      FAC(20)=T67
      RETURN
  200 CONTINUE
      PRIOCC=0.0
      PRIPEN=0.0
      OOROCC=0.0
      OORPEN=0.0
```

```
      IF(PLC.NE.6.0) GO TO 240
  245 PVE=0.0
      PAE=AVE
      GO TO 250
  240 NPLC=IFIX(PLC)
      DO 260 I=1,5
      IF(I.GE.NPLC) GO TO 265
      OOROCC=OOROCC+PCTVEH(I,1)*FLOAT(I)
      OORPEN=OORPEN+PCTVEH(I,1)
      GO TO 260
  265 PRIOCC=PRIOCC+PCTVEH(I,1)*I
      PRIPEN=PRIPEN+PCTVEH(I,1)
  260 CONTINUE
      IF(PRIPEN.EQ.0.0) GO TO 245
      PVE=PRIOCC/PRIPEN
      PAE=OOROCC/OORPEN
  250 CONTINUE
      XUMBA=XUBURA=0.0
      XUMN=0.0
      XUMUR=XUMB=XUBUR=0.0
      DO 210 IO=1,NORG
      I=NO(IO)
      IF(IP(I).EQ.1HP) GO TO 215
      RRD=RD(IO)+XMD(IO)
      XUMN=XUMN+RRD
      XUMB=XUMB+RD(IO)*RQ(IO,2)
      XUMBA=XUMBA+XMD(IO)*BV(I,1)
      GO TO 210
  215 RURV=RD(IO)+XMD(IO)
      XUMUR=XUMUR+RURV
      XUBUR=XUBUR+RD(IO)*RQ(IO,2)
      XUBURA=XUBURA+XMD(IO)*BV(I,1)
  210 CONTINUE
      VM=VMP=VMUR=0.0
      TTN=TTUR=TTR=0.0
      BNOR=BUR=BPRI=0.0
      VMB=VMURB=VMPB=0.0
      DO 220 I=1,NSEC
      IF(IP(I).EQ.1HP) GO TO 230
      VM=VM+TD(I)
      VMB=TD(I)*BV(I,1)+VMB
      TTN=TTN+TT(I)
      BNOR=BNOR+T3(I)*BV(I,1)
      GO TO 220
  230 VMUR=VMUR+TD(I)
      VMURB=VMURB+TD(I)*BV(I,1)
      TTUR=TTUR+TT(I)
      BUR=BUR+TT(I)*BV(I,1)
      VMP=VMP+TDP(I)
      VMPB=VMPB+TDP(I)*BV(I,2)
      TTR=TTR+TTP(I)
      BPRI=BPRI+TTP(I)*BV(I,2)
  220 CONTINUE
      PTSN=(TTN-BNOR)*AVE+BNOR*BUSOC(1)/EBN
      PTSUR=(TTUR-BUR)*PAE+BUR*BUSOC(1)/EBN
      PTSR=(TTR-BPRI)*PVE+BPRI*BUSOC(1)/EBL
      XUMB=XUMB+XUMBA
```

```
      XUBUR=XUBUR+XUBURA                                                 TIM 223
      PSMUR=(XUMUR-XUBUR)*AVE+XUBUR*BUSOC(1)/EBN                         TIM 224
      PSMN=(XUMN-XUMB)*AVE+XUMB*BUSOC(1)/EBN                             TIM 225
      PTN=PTSN+PSMN                                                      TIM 226
      PTUR=PSMUR+PTSUR                                                   TIM 227
      EBN10=1.0/EBN-1.0                                                  TIM 228
      TTN=TTN+BNOR*EBN10                                                 TIM 229
      TTUR=TTUR+BUR*EBN10                                                TIM 230
      XUMN=XUMN+XUMB*EBN10                                               TIM 231
      XUMUR=XUMUR+XUBUR*EBN10                                            TIM 232
      TTR=TTR-BPRI+BPRI/EBL                                              TIM 233
      TNT=TTN+XUMN                                                       TIM 234
      TUR=TTUR+XUMUR                                                     TIM 235
      FAC(4)=FAC(4)+TTN                                                  TIM 236
      FAC(5)=FAC(5)+TTUR                                                 TIM 237
      FAC(6)=FAC(6)+TTR                                                  TIM 238
      FAC(7)=FAC(7)+XUMN                                                 TIM 239
      FAC(8)=FAC(8)+XUMUR                                                TIM 240
      T10=FAC(5)+FAC(8)+ FAC(4)+FAC(7)+FAC(6)                            TIM 241
      FAC(10)=FAC(10)+PTSN                                               TIM 242
      FAC(11)=FAC(11)+PTSUR                                              TIM 243
      FAC(12)=FAC(12)+PTSR                                               TIM 244
      FAC(13)=FAC(13)+PSMN                                               TIM 245
      FAC(14)=FAC(14)+PSMUR                                              TIM 246
      T30=FAC(11)+FAC(14)+ FAC(10)+FAC(13)+FAC(12)                       TIM 247
      CALL PAGE(8)                                                       TIM 248
      PRINT 1005,TTN,PTSN,FAC(4),FAC(10),TTUR,PTSUR,FAC(5),FAC(11),TTR,  TIM 249
     1PTSR,FAC(6),FAC(12),XUMN,PSMN,FAC(7),FAC(13),XUMUR,PSMUR,FAC(8),   TIM 250
     2FAC(14)                                                            TIM 251
      A10=TUR+TNT+TTR                                                    TIM 252
      A15=PTN+PTUR+PTSR                                                  TIM 253
      V15=(VM-VMB)*AVE+(VMP-VMPB)*PVE+(VMUR-VMURB)*PAE                   TIM 254
      V15=V15+((VMB+VMURB)/EBN+VMPB/EBL)*BUSOC(1)                        TIM 255
      VM=VM+VMB*EBN10                                                    TIM 256
      VMUR=VMUR+VMURB*EBN10                                              TIM 257
      VMP=VMP-VMPB+VMPB/EBL                                              TIM 258
      V10=VMUR+VM+VMP                                                    TIM 259
      CVM=CVM+V10                                                        TIM 260
      CPM=CPM+V15                                                        TIM 261
      CALL PAGE(4)                                                       TIM 262
      PRINT 1008,510,V15,CVM,CPM                                         TIM 263
      PRINT 1007,A10,A15,T10,T30                                         TIM 264
      IF(IFL(1).NE.NOTS) RETURN                                          TIM 265
      IF(FAC(20).NE.0.0) GO TO 500                                       TIM 266
      FAC(19)=T10                                                        TIM 267
      FAC(20)=T30                                                        TIM 268
      RETURN                                                             TIM 269
  500 T1000=FAC(2*)-T30                                                  TIM 270
      T1001=FAC(19)-T10                                                  TIM 271
      CALL PAGE(4)                                                       TIM 272
      PRINT 1014,FAC(19),FAC(20)                                         TIM 273
      PRINT 1013,T1001,T1000                                             TIM 274
      RETURN                                                             TIM 275
 1001 FORMAT(/* TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES*)          TIM 276
 1002 FORMAT(/16H AT OFF-RAMP NO.,I3,3X,14HDEMAND EXCEEDS, F6.0,         TIM 277
     118H VEHICLES PER HOUR)                                             TIM 278
 1004 FORMAT(/* TRAVEL TIME FOR ONE NON-PRIORITY TRIP  .01 MINUTES*/)    TIM 279
```

```
1005 FORMAT(/36X,*CURRENT TIME INTERVAL*,10X,*CUMULATIVE VALUES  */* FR
    1EEWAY TRAVEL TIME (NOR) *2(F8.0* VEH-HRS *F8.0* PASS-HRS*5X)/ * FR
    2EEWAY TRAVEL TIME (UNR) *2(F8.0* VEH-HRS *F8.0* PASS-HRS*5X)/ * FR
    3EEWAY TRAVEL TIME (RES) *2(F8.0* VEH-HRS *F8.0* PASS-HRS*5X)/9X,
    4*INPUT DELAY (NOR) *2(F8.0* VEH-HRS *F8.0* PASS-HRS *4X)/9X,
    5*INPUT DELA8 (UNR) *2(F8.0* VEH-HRS *F8.0* PASS-HRS *4X)//)
1006 FORMAT(1X,I2,1X,10I6//)
1007 FORMAT(* TOTAL TRAVEL TIME UNDER*/* PRIORITY OPERATIONS*,7X,2(F8.0
    1,* VEH-HRS *F8.0* PASS-HRS*5X)/)
1008 FORMAT(* TOTAL TRAVEL DISTANCE*,5X,2(F8.0* VEH-MI. *F8.0* PASS-MI.
    1*5X)/)
1009 FORMAT(1X,I2,1X,10F6.0)
1010 FORMAT(///33H TOTAL TRAVEL TIME IN .01 VEH-HRS/)
1011 FORMAT(/31X,21HCURRENT TIME INTERVAL,20X,17HCUMULATIVE VALUES /
    121H FREEWAY TRAVEL TIME=,2(F9.0,9H VEH-HRS ,F9.0,9H PASS-HRS,5X)/
    28X,13H INPUT DELAY=,2(F9.0,9H VEH-HRS ,F9.0,9H PASS-HRS,5X)/
    321H   TOTAL TRAVEL TIME=,2(F9.0,9H VEH-HRS ,F9.0,9H PASS-HRS,5X))
1012 FORMAT(21H TOTAL TRAV DISTANCE=,2(F9.0,9H VEH-MI. ,F9.0,9H PASS-MI
    1.,5X))
1013 FORMAT(/* TRAVEL TIME SAVINGS OVER NON-PRIORITY OPERATION = *,15X,
    1F8.1,* VEH-HRS *,F8.1,* PASS-HRS*/)
1014 FORMAT(* TOTAL TRAVEL TIME UNDER NON-PRIORITY OPERATIONS *,17X,
    1F8.0* VEH-HRS *F8.0* PASS-HRS*/)
     END
```

** ERRATA:

Card Number	Statement
SLICE 10	DIMENSION NUMB(20)
SLICE 11	DO 5 K=1,20
SLICE 12	5 NUMB(K)=K
SPEED 32	45 K=DZ

APPENDIX D

Example Listing of Input Data for New Design, Two Reserved Lanes, Shifts (CDC 6400 Control Cards)

```
E2296,1,200,60000,500. LEW AFTER 25 NEW DESIGN, TWO RESERVED LANES  WITH SHIFTS
REQUEST,PRIFRE.0025
CLDR,I=PRIFRE.(UNLOAD).
'
MODEL APPLICATION TO MARIN ROUTE 101 NEW DESIGN WITH TWO RESERVED LANE,SHIFTS
 20   4.    2.    2. 2              5
  1  410000          200   3   3   3  .97    O    TOLL BOOTH
  2P 4 7200 1500   400   4   4   4  .97      ACCELERATION AREA,START RESERVED LANES
  3P 4 7200 1500  5400   5   5   5  .97       GOLDEN GATE BRIDGE
  4P 4 6890 1500   600   5   5   5  .97
  5P 4 6751 1500   300   5   5   5  .97       WRONG WAY BUS CROSSOVER
  6P 4 6752 1500   600   5   5   5  .97    D  NEGLECT VISTA POINT ON-OFF RAMP,SMALL V
  7P 4 6500 1500   600   5   5   5  .72       ALEXANDER (FORMERELY SAUSALITO)
  8P 4 6500 1500  3000   5   5   5  .72    O
  9P 4 6400 1500  1050   5   5   5  .72       WALDO TUNNEL
 10P 4 6500 1500  1600   5   5   5  .72    D
 11P 4 6961 1500  2320   5   5   5  .97       SPENCER
 12P 4 7294 1500  2500   5   5   5  .97   OD
 13P 4 7294 1500   550   5   5   5  .97       RODEO
 14P 4 7294 1500  4850   5   5   5  .97   OD
 15P 4 7294 1500  1300   5   5   5  .97       MARIN CITY
 16P 4 7470 1500  1000   5   5   5  .97   OD  CAPACITY  ADJUSTED  LARGE WEAVE EFFECT
 17P 4 7294 1500  1400   5   5   5  .97       BUS CROSSOVER
 18  4 7294       3000   5   5   5  .97   OD  MAILINE-RICHARDSON BAY BRIDGE
 19  3 5820        800   5   5   5  .97
 20  3 5820       3600   5   5   5  .97   OD  MAINLINE SOUTH OF TIBURON OFF
 1500
   3  0.0     25.      .65    24.     .85    24.     .95    23.    1.00  22.
   3 -1.00    22.     -0.0     0.
   4  0.0     49.      .65    37.     .85    33.     .95    26.    1.00  22.
   4 -1.00    22.     -0.0     0.
   5  0.0     55.      .90    46.     .95    44.    1.00    30.   -1.00  30.
   5  -.95    26.     -.90    23.    -.50    10.   -0.0     0.
'
TIME SLICE 1  330-345
 40. 73.4 23.2  2.0  1.0   .4
 40.71.1625.1902.1801.0200.44
 40.68.8127.2402.3601.1100.48
 40.66.3729.3702.5401.2000.52
 40.63.8231.6002.7301.2000.56
                          1




 165 132      106 686 3003677
               13  13  10  26
               13  13  10  26

                   52  40 597
                          290
                          157
TIME SLICE 2  345-400
 40. 73.4 23.2  2.0  1.0   .4
 40.71.1625.1902.1801.0200.44
```

```
 40.68.8127.2402.3601.1100.48
 40.66.3729.3702.5401.2000.52
 40.63.8231.6002.7301.2900.56
       1                    1

                 1

                            1

152 158  46 106 804 3004012
      7  13  13  46  30   79
             26  40  20   79
              2   5        7
                 52  25  480
                         317
                         157
TIME SLICE 3 400-415
 33. 74.4 21.7  2.5  1.3   .1
 33.72.1123.6902.6901.3800.08
 33.69.8225.6902.9101.5000.08
 33.67.3727.7703.1501.6200.09
 33.64.8029.9503.4001.7500.10
                            1


164 105     111 904 3004738
              7  13  10  100
             13  13   5   20

                 32  42  663
                         288
                         158
'TIME SLICE 4  415-430
 33. 74.4 21.7  2.5  1.3   .1
 33.72.1123.6902.6901.3800.08
 33.69.8225.6902.9101.5000.08
 33.67.3727.7703.1501.6200.09
 33.64.8029.9503.4001.7500.10
  1    1                    4

                 1

                            1

183 157  46 1111047 3005219
          7  13  39  50   74
              7  13  10   23
                  2   2    3
                 38  50  749
                         262
                         104
```

```
TIME SLICE 5  430-445   PEAK HOUR BEGINS AT TOLL AREA
  42. 71.1 24.1  2.3  2.3   .2
  42.68.8725.9902.4502.4500.24
  42.66.6027.8902.6302.6300.25
  42.64.2229.8702.8202.8200.27
  42.61.7431.9403.0203.0100.29
      2                    7
                           1
               1   1

                   1       1


 219 192       751082 4006311
               27  55  20  62
                7  14  10  24

                   67  49 532
                          411
                          217
TIME SLICE 6  445-500
  42. 71.1 24.1  2.3  2.3   .2
  42.68.8725.9902.4502.4500.24
  42.66.6027.8902.6302.6300.25
  42.64.2229.8702.8202.8200.27
  42.61.7431.9403.0203.0100.29
   1  2                    15

               1   1

                           1


 219 192  48   621192 4005742
           7    7  14  10  17
               14  27  30  66

                   37  49 664
                          411
                          108
TIME SLICE 7  500-515
  43. 64.3 31.0  2.5  2.1   .1
  43.62.1532.8602.6902.2300.07
  43.59.9534.7702.8502.3500.08
  43.57.6636.7503.0202.4900.08
  43.55.2938.8103.1802.6200.09
   3  4            2       13

               1   2       1

                   1       1


 257 315  50   861058 3006505
           7   14  29  15  21
               14  29  20  52
```

```
                        71   42 690
                                286
                              . 286
TIME SLICE 8  515-530
  43. 64.3 31.0  2.5  2.1    .1
  43.62.1532.8602.6902.2300.07
  43.59.9534.7702.8502.3500.08
  43.57.6636.7503.0202.4900.08
  43.55.2938.8103.1802.6300.09
   2   5            2       21

                2   1       2

                    3       2


 271 686   21   501073 4005927
           7    7  14  10  19
                29  57 100 215

                    71   50 594
                            257
                            171
TIME SLICE 9  530-545
  43. 74.6 20.0  3.5  1.0    .9
  43.72.3621.7603.7801.1400.96
  43.70.0823.5604.0901.2301.04
  43.67.6925.4404.4201.3301.12
  43.65.1827.4104.7601.4401.20
   2   2                    11

                    2

                    2


 315 750   78   511147 4004736
           3    3   5   5  11
                27 134 100 248

                    33   25 298
                            188
                            160
TIME SLICE 10 545-600
  43. 74.6 20.0  3.5  1.0    .9
  43.72.3621.7603.7801.1400.96
  43.70.0823.5604.0901.2301.04
  43.67.6925.4404.4201.3301.12
  43.65.1827.4104.7601.4401.20
                    1       11


                    2


 274 616   47   471166 4004263
```

```
                7   7  13   10  17
                   54 107   50 164

                       33   25 284
                               241
                               214
TIME SLICE 11 600-615
  33. 66.0 26.3  4.4  2.2  1.1
  33.63.9227.9104.6702.3301.17
  33.61.7529.5904.9502.4801.23
  33.59.4931.3405.2402.6201.31
  33.57.1433.1505.5502.7701.39
   1   1                   5

                  1

                               1


 235 647   22   961279 5003072
            7    7  15   10  19
                14  29   50 259

                    37   50 346
                            235
                            116
TIME SLICE 12  615-630
  33. 66.0 26.3  4.4  2.2  1.1
  33.63.9227.9104.6702.3301.17
  33.61.7529.5904.9502.4801.23
  33.59.4931.3405.2402.6201.31
  33.57.1433.1505.5502.7701.39
   1   1           2       6

                  1

                   1       1


 184 206   51   741233 6002866
            7    7  14   10  19
                 7  14   20  46
                     1        6
                    37   25 364
                            235
                            116
TIME SLICE 13  630-645
  35. 70.9 22.2  3.3  2.5  1.1
  35.68.7823.8203.5402.6801.18
  35.66.5625.5203.7902.8701.26
  35.64.2527.2804.0503.0701.35
  35.61.8329.1204.3303.2801.44
                   1       1
```

```
 127 169       127 733 3002517
                 7  14  10  25
                 7  14  10  25

                    21  25 187
                           310
                           112
TIME SLICE 14  645-700
  35. 70.9 22.2  3.3  2.5  1.1
  35.68.7823.8203.5402.6801.18
  35.66.5625.5203.7902.8701.26
  35.64.2527.2804.0503.0701.35
  35.61.8329.1204.3303.2801.44
                     1       1


                     1


 127 169       127 733 3002517
                 7  14  10  25
                 7  14  10  25

                    21  25 187
                           310
                           112
END OD
```

APPENDIX E

Example PRIFRE Output Marin Route 101, New Design,

Two Reserved Lanes, Scheme 2-2

INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

VERSION 22.0
PAGE NO. 45

SUP SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	RESERVED PRIORITY OPERATIONS: PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UNRESERVED OR NORMAL OPERATIONS: UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	O *	LENG	QUEUE FEET	RA
1	3845.	0.	3845								N	4	3845.	10000.	0.	.38	39.	24.	.09		200.	0	0.
2	0.	0.	3845	2	804.	3000.	.27	9.	44.	.10	U	2	3040.	3600.	0.	.84	46.	33.	.14		400.	0	0.
3	0.	0.	3845	2	804.	3000.	.27	8.	52.	1.17	U	2	3040.	3600.	0.	.84	33.	47.	1.32		5400.	0	0.
4	0.	0.	3845	2	804.	3000.	.27	8.	52.	.13	U	2	3040.	3445.	0.	.88	33.	45.	.15		600.	0	0.
5	0.	0.	3845	2	804.	3000.	.27	8.	52.	.07	U	2	3040.	3375.	0.	.90	33.	46.	.07		300.	0	0.
6	0.	125.	3845	2	804.	3000.	.27	8.	52.	.13	U	2	3040.	3376.	0.	.90	33.	46.	.15		600.	0	0.
7	0.	0.	3720	2	804.	3000.	.27	8.	52.	.13	U	2	2915.	3250.	0.	.90	32.	46.	.15		600.	0	0.
8	48.	0.	3768	2	804.	3000.	.27	8.	52.	.65	U	2	2963.	3250.	0.	.91	33.	46.	.75		3000.	0	0.
9	0.	0.	3768	2	804.	3000.	.27	8.	52.	.23	U	2	2963.	3200.	0.	.93	33.	45.	.27		1050.	0	0.
10	0.	100.	3768	2	804.	3000.	.27	8.	52.	.35	U	2	2963.	3250.	0.	.91	33.	46.	.40		1600.	0	0.
11	0.	0.	3668	2	804.	3000.	.27	8.	52.	.50	U	2	2863.	3480.	0.	.82	31.	47.	.56		2320.	0	0.
12	48.	0.	3716	2	804.	3000.	.27	8.	52.	.54	U	2	2347.	3647.	0.	.64	26.	46.	.77	*	2500.	816	564.
13	0.	0.	3716	2	804.	3000.	.27	8.	52.	.12	U	2	2347.	3647.	0.	.64	32.	37.	.20	*	550.	550	564.
14	0.	100.	3716	2	804.	3000.	.27	8.	52.	1.05	U	2	2347.	3647.	0.	.64	50.	24.	2.60	*	4850.	4850	564.
15	0.	0.	3616	2	804.	3000.	.27	8.	52.	.23	U	2	2247.	3647.	0.	.62	75.	15.	1.01	*	1300.	1300	564.
16	522.	495.	4133	2	804.	3000.	.27	8.	52.	.22	U	2	2769.	2769.	966.	1.00	46.	30.	.38		1000.	0	0.
17	0.	0.	3559	2	804.	3000.	.27	8.	52.	.30	U	2	2274.	3647.	0.	.62	23.	49.	.33		1400.	0	0.
18	220.	236.	3779								N	4	3299.	7294.	0.	.45	16.	50.	.68		3000.	0	0.
19	0.	0.	3505								N	3	3063.	5820.	0.	.53	21.	50.	.18		800.	0	0.
20	119.	3182.	3624								N	3	3182.	5820.	0.	.55	21.	50.	.83		3600.	0	0.

Time Slice 1

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	192.	348.	467.	716.	853.	953.	1054.
2	0.	141.	260.	509.	646.	746.	847.
3	0.	0.	62.	312.	448.	549.	649.
4	0.	0.	0.	233.	369.	469.	570.
5	0.	0.	0.	0.	38.	138.	239.
6	0.	0.	0.	0.	0.	68.	168.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	169.	305.	410.	527.	577.	675.	776.
2	0.	123.	227.	345.	395.	493.	593.
3	0.	0.	54.	172.	222.	319.	420.
4	0.	0.	0.	105.	155.	253.	354.
5	0.	0.	0.	0.	22.	120.	221.
6	0.	0.	0.	0.	0.	68.	168.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	24. VEH-HRS	32. PASS-HRS	24. VEH-HRS	32. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	101. VEH-HRS	101. PASS-HRS	101. VEH-HRS	101. PASS-HRS
FREEWAY TRAVEL TIME (R-S)	20. VEH-HRS	45. PASS-HRS	20. VEH-HRS	45. PASS-HRS
INPUT DELAY (NOR)	0. VEH-HRS	0. PASS-HRS	0. VEH-HRS	0. PASS-HRS
INPUT DELAY (UNR)	0. VEH-HRS	0. PASS-HRS	0. VEH-HRS	0. PASS-HRS
TOTAL TRAVEL DISTANCE	5894. VEH-MI.	7575. PASS-MI.	5894. VEH-MI.	7575. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	145. VEH-HRS	178. PASS-HRS	145. VEH-HRS	178. PASS-HRS

Time Slice 1

QUEUE COLLISION 9 T2= .146
QUEUE COLLISION 8 T2= .155
Q OUT OF SEC 1

				RESERVED PRIORITY OPERATIONS							UNRESERVED OR NORMAL OPERATIONS												
SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	4236.	0.	4236								N	4	3522.	10000.	0.	.35	36.	24.	.11	*	200.	200	714.
2	0.	0.	4236	2	872.	3000.	.29	10.	44.	.10	U	2	2650.	3600.	0.	.74	49.	27.	.21	*	400.	400	714.
3	0.	0.	4236	2	872.	3000.	.29	8.	52.	1.18	U	2	2650.	3600.	0.	.74	38.	35.	2.12	*	5400.	5400	714.
4	0.	0.	4236	2	872.	3000.	.29	8.	52.	.13	U	2	2650.	3445.	0.	.77	50.	27.	.29	*	600.	600	714.
5	0.	0.	4236	2	872.	3000.	.29	8.	52.	.07	U	2	2650.	3375.	0.	.79	54.	24.	.16	*	300.	300	714.
6	0.	115.	4236	2	872.	3000.	.29	8.	52.	.13	U	2	2650.	3376.	0.	.78	55.	24.	.32	*	600.	600	714.
7	0.	0.	4121	2	872.	3000.	.29	8.	52.	.13	U	2	2535.	3250.	0.	.78	53.	24.	.32	*	600.	600	714.
8	143.	0.	4264	2	872.	3000.	.29	8.	52.	.65	U	2	2678.	3250.	0.	.82	52.	25.	1.50	*	3000.	3000	572.
9	0.	0.	4264	2	872.	3000.	.29	8.	52.	.23	U	2	2678.	3200.	0.	.84	52.	26.	.52	*	1050.	1050	522.
10	0.	121.	4264	2	872.	3000.	.29	8.	52.	.35	U	2	2678.	3250.	0.	.82	51.	26.	.76	*	1600.	1600	522.
11	0.	0.	4137	2	872.	3000.	.29	8.	52.	.51	U	2	2556.	3480.	0.	.73	56.	23.	1.23	*	2320.	2320	522.
12	127.	43.	4264	2	872.	3000.	.29	8.	52.	.55	U	2	2683.	3647.	0.	.74	72.	19.	1.55	*	2500.	2500	522.
13	0.	0.	4219	2	872.	3000.	.29	8.	52.	.12	U	2	2640.	3647.	0.	.72	76.	17.	.36	*	550.	550	522.
14	11.	110.	4230	2	872.	3000.	.29	8.	52.	1.06	U	2	2651.	3647.	0.	.73	76.	17.	3.17	*	4850.	4850	522.
15	0.	0.	4116	2	872.	3000.	.29	8.	52.	.28	U	2	2541.	3647.	0.	.70	77.	16.	.90	*	1300.	1300	522.
16	424.	603.	4540	2	872.	3000.	.29	8.	52.	.22	U	2	2965.	2965.	770.	1.00	49.	30.	.38		1000.	0	0.
17	0.	0.	3822	2	872.	3000.	.29	8.	52.	.31	U	2	2362.	3647.	0.	.65	24.	49.	.33		1400.	0	0.
18	241.	240.	4063								N	4	3475.	7294.	0.	.48	17.	50.	.68		3000.	0	0.
19	0.	0.	3778								N	3	3235.	5820.	0.	.56	22.	49.	.18		800.	0	0.
20	119.	3354.	3897								N	3	3354.	5820.	0.	.58	23.	49.	.83		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	1.47	.18
		MERGING POINT	0.	0.
		TOTAL	1.47	.18

Time Slice 2

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	269.	546.	814.	1167.	1295.	1396.	1497.
2	0.	249.	516.	870.	998.	1098.	1200.
3	0.	0.	153.	506.	634.	735.	836.
4	0.	0.	0.	317.	445.	546.	647.
5	0.	0.	0.	0.	38.	139.	240.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	170.	307.	412.	530.	580.	678.	780.
2	0.	123.	[illegible]	346.	396.	495.	596.
3	0.	0.	55.	172.	223.	321.	422.
4	0.	0.	0.	106.	156.	254.	356.
5	0.	0.	0.	0.	22.	120.	222.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NPR)	26. VEH-HRS	34. PASS-HRS	50. VEH-HRS	66. PASS-HRS
FREEWAY TRAVEL TIME ([illegible])	155. VEH-HRS	157. PASS-HRS	256. VEH-HRS	258. PASS-HRS
FREEWAY TRAVEL TIME ([illegible]S)	22. VEH-HRS	49. PASS-HRS	42. VEH-HRS	94. PASS-HRS
INPUT DELAY (NPR)	0. VEH-HRS	0. PASS-HRS	0. VEH-HRS	0. PASS-HRS
INPUT DELAY (UNP)	0. VEH-HRS	0. PASS-HRS	0. VEH-HRS	0. PASS-HRS
TOTAL TRAVEL DISTANCE	5092. VEH-MI.	7948. PASS-MI.	11986. VEH-MI.	15523. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	203. VEH-HRS	240. PASS-HRS	348. VEH-HRS	41[illegible]. PASS-HRS

Time Slice 2

QUEUE COLLISION 9 T2= .000
QUEUE COLLISION 8 T2= .000
QUEUE COLLISION 7 T2= .000
QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF SEC 1

SUB SEC	FINAL DRG	DMD. DES	ORIG. TOTAL	RESERVED PRIORITY OPERATIONS PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UNRESERVED OR NORMAL OPERATIONS UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	4828.	0.	4828								N	4	3524.	10000.	0.	.35	40.	22.	.10	*	200.	200	1304.
2	0.	0.	4828	2	986.	3000.	.33	11.	43.	.11	U	2	2538.	3600.	0.	.70	58.	22.	.21	*	400.	400	1062.
3	0.	0.	4828	2	986.	3000.	.33	10.	52.	1.19	U	2	2538.	3600.	0.	.70	76.	17.	3.68	*	5400.	5400	1062.
4	0.	0.	4828	2	986.	3000.	.33	10.	52.	.13	U	2	2538.	3445.	0.	.74	72.	18.	.39	*	600.	600	907.
5	0.	0.	4828	2	986.	3000.	.33	10.	52.	.07	U	2	2538.	3375.	0.	.75	70.	18.	.19	*	300.	300	838.
6	0.	113.	4828	2	986.	3000.	.33	10.	52.	.13	U	2	2538.	3376.	0.	.75	70.	18.	.38	*	600.	600	838.
7	0.	0.	4703	2	986.	3000.	.33	10.	52.	.13	U	2	2425.	3250.	0.	.75	67.	18.	.38	*	600.	600	825.
8	99.	0.	4802	2	986.	3000.	.33	10.	52.	.66	U	2	2524.	3250.	0.	.78	66.	19.	1.80	*	3000.	3000	726.
9	0.	0.	4802	2	986.	3000.	.33	10.	52.	.23	U	2	2524.	3200.	0.	.79	65.	19.	.62	*	1050.	1050	676.
10	0.	70.	4802	2	986.	3000.	.33	10.	52.	.35	U	2	2524.	3250.	0.	.78	66.	19.	.96	*	1600.	1600	676.
11	0.	0.	4722	2	986.	3000.	.33	10.	52.	.51	U	2	2454.	3480.	0.	.71	74.	17.	1.58	*	2320.	2320	676.
12	39.	0.	4761	2	986.	3000.	.33	10.	52.	.55	U	2	2493.	3647.	0.	.68	78.	16.	1.78	*	2500.	2500	676.
13	0.	0.	4761	2	986.	3000.	.33	10.	52.	.12	U	2	2493.	3647.	0.	.68	78.	16.	.39	*	550.	550	676.
14	0.	89.	4761	2	986.	3000.	.33	10.	52.	1.07	U	2	2493.	3647.	0.	.68	78.	16.	3.45	*	4850.	4850	676.
15	0.	0.	4661	2	986.	3000.	.33	10.	52.	.29	U	2	2404.	3647.	0.	.66	79.	15.	.97	*	1300.	1300	676.
16	562.	494.	5223	2	986.	3000.	.33	10.	52.	.22	U	2	2659.	2659.	1076.	1.00	44.	30.	.38		1000.	0	0.
17	0.	0.	4689	2	986.	3000.	.33	10.	52.	.31	U	2	2165.	3647.	0.	.59	22.	49.	.32		1400.	0	0.
18	220.	192.	4709								N	4	3372.	7294.	0.	.46	17.	50.	.68		3000.	0	0.
19	0.	0.	4436								N	3	3180.	5820.	0.	.55	21.	50.	.18		800.	0	0.
20	121.	3301.	4557								N	3	3301.	5820.	0.	.57	22.	49.	.83		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	327.43	41.11
		MERGING POINT	0.	0.
		TOTAL	327.43	41.11
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	76.81	9.60
		TOTAL	76.81	9.60

Time Slice 3

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	494.	869.	1205.	1589.	1725.	1825.	1926.
2	0.	337.	673.	1057.	1193.	1293.	1394.
3	0.	0.	178.	562.	697.	798.	899.
4	0.	0.	0.	345.	480.	580.	682.
5	0.	0.	0.	0.	38.	138.	239.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	173.	310.	416.	534.	585.	683.	785.
2	0.	124.	230.	349.	399.	498.	599.
3	0.	0.	55.	174.	224.	323.	424.
4	0.	0.	0.	107.	157.	256.	357.
5	0.	0.	0.	0.	22.	120.	222.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	25. VEH-HRS	33. PASS-HRS	74. VEH-HRS	99. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	182. VEH-HRS	182. PASS-HRS	438. VEH-HRS	440. PASS-HRS
FREEWAY TRAVEL TIME (BUS)	25. VEH-HRS	56. PASS-HRS	67. VEH-HRS	150. PASS-HRS
INPUT DELAY (NOR)	41. VEH-HRS	54. PASS-HRS	41. VEH-HRS	54. PASS-HRS
INPUT DELAY (UNR)	10. VEH-HRS	13. PASS-HRS	10. VEH-HRS	13. PASS-HRS
TOTAL TRAVEL DISTANCE	5718. VEH-MI.	7689. PASS-MI.	17703. VEH-MI.	23212. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	282. VEH-HRS	337. PASS-HRS	630. VEH-HRS	755. PASS-HRS

Time Slice 3

249

QUEUE COLLISION 9 T2= .000
QUEUE COLLISION 8 T2= .000
QUEUE COLLISION 7 T2= .000
QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF SEC 1

				RESERVED PRIORITY OPERATIONS							UNRESERVED OR NORMAL OPERATIONS												
SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	5404.	0.	5404								N	4	3819.	10000.	0.	.38	43.	22.	.10	*	200.	200	1585.
2	0.	0.	5404	2	1085.	3000.	.36	13.	42.	.11	U	2	2732.	3600.	0.	.76	62.	22.	.21	*	400.	400	868.
3	0.	0.	5404	2	1085.	3000.	.36	11.	51.	1.19	U	2	2732.	3600.	0.	.76	74.	18.	3.33	*	5400.	5400	868.
4	0.	0.	5404	2	1085.	3000.	.36	11.	51.	.13	U	2	2732.	3445.	0.	.79	70.	20.	.35	*	600.	600	713.
5	0.	0.	5404	2	1085.	3000.	.36	11.	51.	.07	U	2	2732.	3375.	0.	.81	68.	20.	.17	*	300.	300	643.
6	0.	117.	5404	2	1085.	3000.	.36	11.	51.	.13	U	2	2732.	3376.	0.	.81	68.	20.	.34	*	600.	600	643.
7	0.	0.	5262	2	1085.	3000.	.36	11.	51.	.13	U	2	2615.	3250.	0.	.80	66.	20.	.34	*	600.	600	635.
8	139.	0.	5401	2	1085.	3000.	.36	11.	51.	.66	U	2	2754.	3250.	0.	.85	65.	21.	1.60	*	3000.	3000	496.
9	0.	0.	5401	2	1085.	3000.	.36	11.	51.	.23	U	2	2754.	3200.	0.	.86	63.	22.	.55	*	1050.	1050	446.
10	0.	96.	5601	2	1085.	3000.	.36	11.	51.	.35	U	2	2754.	3250.	0.	.85	65.	21.	.85	*	1600.	1600	446.
11	0.	0.	5279	2	1085.	3000.	.36	11.	51.	.51	U	2	2658.	3480.	0.	.76	72.	19.	1.42	*	2320.	2320	446.
12	41.	33.	5320	2	1085.	3000.	.36	11.	51.	.55	U	2	2699.	3647.	0.	.74	76.	19.	1.60	*	2500.	2500	446.
13	0.	0.	5280	2	1085.	3000.	.36	11.	51.	.12	U	2	2666.	3647.	0.	.73	76.	18.	.36	*	550.	550	446.
14	8.	84.	5288	2	1085.	3000.	.36	11.	51.	1.07	U	2	2674.	3647.	0.	.73	76.	18.	3.13	*	4850.	4850	446.
15	0.	0.	5196	2	1085.	3000.	.36	11.	51.	.29	U	2	2591.	3647.	0.	.71	77.	17.	.88	*	1300.	1300	446.
16	639.	513.	5825	2	1085.	3000.	.36	11.	51.	.22	U	2	2515.	2515.	1220.	1.00	42.	30.	.38		1000.	0	0.
17	0.	0.	4955	2	1085.	3000.	.36	11.	51.	.31	U	2	2002.	3647.	0.	.55	20.	50.	.32		1400.	0	0.
18	292.	204.	5157								N	4	3291.	7294.	0.	.45	16.	50.	.68		3000.	0	0.
19	0.	0.	4842								N	3	3087.	5820.	0.	.53	21.	50.	.18		800.	0	0.
20	79.	3166.	4921								N	3	3166.	5920.	0.	.54	21.	50.	.83		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	723.69	131.39
		MERGING POINT	0.	0.
		TOTAL	723.69	131.39
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	255.45	41.53
		TOTAL	255.45	41.53

Time Slice 4

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	450.	785.	1086.	1435.	1561.	1661.	1762.
2	0.	300.	602.	951.	1077.	1176.	1277.
3	0.	0.	160.	509.	634.	734.	835.
4	0.	0.	0.	313.	439.	539.	640.
5	0.	0.	0.	0.	38.	138.	238.
6	0.	0.	0.	0.	0.	68.	168.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	174.	312.	418.	538.	589.	687.	788.
2	0.	125.	232.	351.	402.	500.	601.
3	0.	0.	55.	175.	226.	324.	425.
4	0.	0.	0.	107.	158.	257.	357.
5	0.	0.	0.	0.	22.	121.	221.
6	0.	0.	0.	0.	0.	68.	168.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	24. VEH-HRS	32. PASS-HRS	99. VEH-HRS	131. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	177. VEH-HRS	178. PASS-HRS	615. VEH-HRS	618. PASS-HRS
FREEWAY TRAVEL TIME (PASS)	27. VEH-HRS	64. PASS-HRS	94. VEH-HRS	213. PASS-HRS
INPUT DELAY (NOR)	131. VEH-HRS	172. PASS-HRS	173. VEH-HRS	226. PASS-HRS
INPUT DELAY (UNR)	42. VEH-HRS	54. PASS-HRS	51. VEH-HRS	67. PASS-HRS
TOTAL TRAVEL DISTANCE	6028. VEH-MI.	8314. PASS-MI.	23732. VEH-MI.	31526. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	401. VEH-HRS	501. PASS-HRS	1032. VEH-HRS	1256. PASS-HRS

Time Slice 4

* QUEUE SPLIT 10
* QUEUE SPLIT 9
SEC 10 T2= .241
QUEUE COLLISION 8 T2= .000
QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF SEC 1

				RESERVED PRIORITY OPERATIONS							UNRESERVED OR NORMAL OPERATIONS												
SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	6088.	0.	6088								N	4	4641.	10000.	0.	.46	53.	22.	.10	*	200.	200	1447.
2	0.	0.	6088	2	1433.	3000.	.48	18.	40.	.11	U	2	3205.	3600.	0.	.89	73.	22.	.21	*	400.	400	395.
3	0.	0.	6088	2	1433.	3000.	.48	14.	50.	1.22	U	2	3205.	3600.	0.	.89	71.	23.	2.70	*	5400.	5400	395.
4	0.	0.	6088	2	1433.	3000.	.48	14.	50.	.14	U	2	3205.	3445.	0.	.93	65.	25.	.27	*	600.	600	240.
5	0.	0.	6088	2	1433.	3000.	.48	14.	50.	.07	U	2	3205.	3375.	0.	.95	62.	26.	.13	*	300.	300	170.
6	0.	127.	6088	2	1433.	3000.	.48	14.	50.	.14	U	2	3205.	3376.	0.	.95	62.	26.	.26	*	600.	600	170.
7	0.	0.	5927	2	1433.	3000.	.48	14.	50.	.14	U	2	3078.	3250.	0.	.95	60.	26.	.26	*	600.	600	170.
8	122.	0.	6049	2	1433.	3000.	.48	14.	50.	.68	U	2	3200.	3250.	0.	.98	56.	29.	1.18	*	3000.	3000	50.
9	0.	0.	6049	2	1433.	3000.	.48	14.	50.	.24	U	2	3200.	3200.	0.	1.00	53.	30.	.40	*	1050.	1050	0.
10	0.	110.	6049	2	1433.	3000.	.48	14.	50.	.36	U	2	3200.	3250.	0.	.98	51.	32.	.58		1600.	0	-21.
11	0.	0.	5904	2	1433.	3000.	.48	14.	50.	.52	U	2	3214.	3480.	0.	.92	52.	31.	.84	*	2320.	182	-104.
12	44.	0.	5948	2	1433.	3000.	.48	14.	50.	.57	U	2	3258.	3647.	0.	.89	71.	23.	1.25	*	2500.	2500	-104.
13	0.	0.	5948	2	1433.	3000.	.48	14.	50.	.12	U	2	3258.	3647.	0.	.89	71.	23.	.27	*	550.	550	-104.
14	0.	59.	5948	2	1433.	3000.	.48	14.	50.	1.10	U	2	3258.	3647.	0.	.89	71.	23.	2.42	*	4850.	4850	-104.
15	0.	0.	5866	2	1433.	3000.	.43	14.	50.	.29	U	2	3189.	3647.	0.	.87	72.	22.	.67	*	1300.	1300	-104.
16	479.	611.	6345	2	1433.	3000.	.48	14.	50.	.23	U	2	2879.	2879.	856.	1.00	48.	30.	.38		1000.	0	0.
17	0.	0.	5449	2	1433.	3000.	.43	14.	50.	.32	U	2	2268.	3647.	0.	.62	23.	49.	.33		1400.	0	0.
18	301.	245.	5750								N	4	4005.	7294.	0.	.55	20.	50.	.69		3000.	0	0.
19	0.	0.	5399								N	3	2760.	5820.	0.	.65	26.	49.	.19		800.	0	0.
20	159.	3919.	5558								N	3	3919.	5820.	0.	.67	27.	48.	.85		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	1085.41	226.14
		MERGING POINT	0.	0.
		TOTAL	1085.41	226.14
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	452.42	88.46
		TOTAL	452.42	88.46

Time Slice 5

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	368.	610.	820.	1089.	1194.	1295.	1399.
2	0.	216.	425.	695.	799.	901.	1004.
3	0.	0.	125.	394.	498.	600.	703.
4	0.	0.	0.	242.	346.	448.	551.
5	0.	0.	0.	0.	38.	139.	243.
6	0.	0.	0.	0.	0.	69.	172.
7	0.	0.	0.	0.	0.	0.	85.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	178.	319.	428.	550.	602.	703.	806.
2	0.	128.	237.	359.	411.	512.	615.
3	0.	0.	57.	179.	231.	331.	435.
4	0.	0.	0.	110.	162.	262.	366.
5	0.	0.	0.	0.	23.	123.	227.
6	0.	0.	0.	0.	0.	69.	172.
7	0.	0.	0.	0.	0.	0.	85.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	50. VEH-HRS	43. PASS-HRS	129. VEH-HRS	174. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	161. VEH-HRS	165. PASS-HRS	776. VEH-HRS	783. PASS-HRS
FREEWAY TRAVEL TIME (BUS)	37. VEH-HRS	91. PASS-HRS	131. VEH-HRS	305. PASS-HRS
INPUT DELAY (NOR)	226. VEH-HRS	308. PASS-HRS	399. VEH-HRS	535. PASS-HRS
INPUT DELAY (UNR)	88. VEH-HRS	124. PASS-HRS	140. VEH-HRS	191. PASS-HRS
TOTAL TRAVEL DISTANCE	7379. VEH-MI.	10783. PASS-MI.	31110. VEH-MI.	42309. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	543. VEH-HRS	731. PASS-HRS	1575. VEH-HRS	1987. PASS-HRS

Time Slice 5

INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

QUEUE COLLISION 10 T2= .157
QUEUE COLLISION 9 T2= .157
QUEUE COLLISION 8 T2= .131
QUEUE COLLISION 5 T2= .118
QUEUE COLLISION 4 T2= .098
QUEUE COLLISION 2 T2= .071
Q OUT OF SEC 1

				RESERVED PRIORITY OPERATIONS							UNRESERVED OR NORMAL OPERATIONS												
SUB SEC	FINAL DPG	DEMD. DPS	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	5795.	0.	5795								N	4	4373.	10000.	0.	.44	48.	23.	.10	*	200.	200	1422.
2	0.	0.	5795	2	1325.	3000.	.44	16.	41.	.11	U	2	3041.	3600.	0.	.84	67.	23.	.21	*	400.	400	559.
3	0.	0.	5795	2	1325.	3000.	.44	13.	51.	1.21	U	2	3041.	3600.	0.	.84	67.	23.	2.86	*	5400.	5400	559.
4	0.	0.	5795	2	1325.	3000.	.44	13.	51.	.13	U	2	3041.	3445.	0.	.88	62.	24.	.29	*	600.	600	404.
5	0.	0.	5795	2	1325.	3000.	.44	13.	51.	.07	U	2	3041.	3375.	0.	.90	59.	26.	.14	*	300.	300	334.
6	0.	132.	5795	2	1325.	3000.	.44	13.	51.	.13	U	2	3041.	3376.	0.	.90	59.	26.	.28	*	600.	600	334.
7	0.	0.	5632	2	1325.	3000.	.44	13.	51.	.13	U	2	2909.	3250.	0.	.90	57.	25.	.28	*	600.	600	334.
8	39.	0.	5671	2	1325.	3000.	.44	13.	51.	.67	U	2	2948.	3250.	0.	.91	56.	26.	1.37	*	3000.	3000	302.
9	0.	0.	5671	2	1325.	3000.	.44	13.	51.	.24	U	2	2948.	3200.	0.	.92	53.	28.	.45	*	1050.	1050	252.
10	0.	116.	5671	2	1325.	3000.	.44	13.	51.	.36	U	2	2948.	3250.	0.	.91	52.	29.	.67	*	1600.	1600	252.
11	0.	0.	5526	2	1325.	3000.	.44	13.	51.	.52	U	2	2832.	3480.	0.	.81	61.	23.	1.16	*	2320.	2320	252.
12	104.	33.	5630	2	1325.	3000.	.44	13.	51.	.56	U	2	2936.	3647.	0.	.81	74.	20.	1.43	*	2500.	2500	252.
13	0.	0.	5590	2	1325.	3000.	.44	13.	51.	.12	U	2	2903.	3647.	0.	.80	74.	20.	.32	*	550.	550	252.
14	0.	53.	5590	2	1325.	3000.	.44	13.	51.	1.09	U	2	2903.	3647.	0.	.80	74.	20.	2.81	*	4850.	4850	252.
15	0.	0.	5528	2	1325.	3000.	.44	13.	51.	.29	U	2	2851.	3647.	0.	.78	74.	19.	.77	*	1300.	1300	252.
16	552.	597.	6080	2	1325.	3000.	.44	13.	51.	.22	U	2	2685.	2685.	1050.	1.00	45.	30.	.38		1000.	0	0.
17	0.	0.	5147	2	1325.	3000.	.44	13.	51.	.31	U	2	2088.	3647.	0.	.57	21.	49.	.32		1400.	0	0.
18	301.	242.	5648								N	4	3720.	7294.	0.	.51	19.	50.	.68		3000.	0	0.
19	0.	0.	5090								N	3	3478.	5820.	0.	.60	24.	49.	.19		800.	0	0.
20	79.	3557.	5169								N	3	3557.	5820.	0.	.61	24.	49.	.84		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	1401.40	310.85
		MERGING POINT	0.	0.
		TOTAL	1401.40	310.85
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	631.90	135.56
		TOTAL	631.90	135.56

Time Slice 6

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	370.	633.	859.	1202.	1317.	1418.	1520.
2	0.	236.	493.	805.	920.	1021.	1123.
3	0.	0.	143.	455.	570.	671.	773.
4	0.	0.	0.	281.	396.	496.	599.
5	0.	0.	0.	0.	38.	138.	241.
6	0.	0.	0.	0.	0.	68.	171.
7	0.	0.	0.	0.	0.	0.	84.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	176.	317.	425.	546.	598.	698.	800.
2	0.	127.	235.	357.	408.	508.	610.
3	0.	0.	56.	177.	229.	329.	431.
4	0.	0.	0.	109.	161.	260.	363.
5	0.	0.	0.	0.	22.	122.	224.
6	0.	0.	0.	0.	0.	68.	171.
7	0.	0.	0.	0.	0.	0.	84.

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	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	27. VEH-HRS	41. PASS-HRS	156. VEH-HRS	215. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	167. VEH-HRS	170. PASS-HRS	943. VEH-HRS	953. PASS-HRS
FREEWAY TRAVEL TIME (PTS)	134. VEH-HRS	92. PASS-HRS	165. VEH-HRS	397. PASS-HRS
INPUT DELAY (NOR)	311. VEH-HRS	424. PASS-HRS	710. VEH-HRS	959. PASS-HRS
INPUT DELAY (UNR)	136. VEH-HRS	187. PASS-HRS	275. VEH-HRS	378. PASS-HRS
TOTAL TRAVEL DISTANCE	6886. VEH-MI.	10529. PASS-MI.	37997. VEH-MI.	52838. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	675. VEH-HRS	915. PASS-HRS	2250. VEH-HRS	2901. PASS-HRS

Time Slice 6

QUEUE COLLISION 9 T2= .000
QUEUE COLLISION 8 T2= .000
QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF SEC 1

SUB SEC	FINAL DEG	DEMD. DIS	ORIG. TOTAL	RESERVED PRIORITY OPERATIONS: RS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UNRESERVED OR NORMAL OPERATIONS: UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	6050.	0.	6050								N	4	4693.	10000.	0.	.47	53.	22.	.10	*	200.	200	1357.
2	0.	0.	6050	2	1723.	3000.	.57	22.	38.	.12	U	2	2964.	3600.	0.	.82	67.	22.	.21	*	400.	400	636.
3	0.	0.	6050	2	1723.	3000.	.57	17.	49.	1.25	U	2	2964.	3600.	0.	.82	72.	21.	2.99	*	5400.	5400	636.
4	0.	0.	6050	2	1723.	3000.	.57	17.	49.	.14	U	2	2964.	3445.	0.	.86	68.	22.	.31	*	600.	600	481.
5	0.	0.	6050	2	1723.	3000.	.57	17.	49.	.07	U	2	2964.	3375.	0.	.88	66.	22.	.15	*	300.	300	411.
6	0.	157.	6050	2	1723.	3000.	.57	17.	49.	.14	U	2	2964.	3376.	0.	.88	67.	22.	.31	*	600.	600	411.
7	0.	0.	5864	2	1723.	3000.	.57	17.	49.	.14	U	2	2807.	3250.	0.	.86	64.	22.	.31	*	600.	600	411.
8	61.	0.	5925	2	1723.	3000.	.57	17.	49.	.69	U	2	2869.	3250.	0.	.88	64.	22.	1.52	*	3000.	3000	382.
9	0.	0.	5925	2	1723.	3000.	.57	17.	49.	.24	U	2	2868.	3200.	0.	.90	63.	23.	.52	*	1050.	1050	332.
10	0.	190.	5925	2	1723.	3000.	.57	17.	49.	.37	U	2	2868.	3250.	0.	.88	64.	22.	.81	*	1600.	1600	332.
11	0.	0.	5696	2	1723.	3000.	.57	17.	49.	.54	U	2	2678.	3480.	0.	.77	71.	19.	1.41	*	2320.	2320	332.
12	88.	24.	5784	2	1723.	3000.	.57	17.	49.	.58	U	2	2766.	3647.	0.	.76	75.	18.	1.54	*	2500.	2500	332.
13	0.	0.	5744	2	1723.	3000.	.57	17.	49.	.13	U	2	2732.	3647.	0.	.75	75.	18.	.35	*	550.	550	332.
14	0.	72.	5744	2	1723.	3000.	.57	17.	49.	1.12	U	2	2732.	3647.	0.	.75	75.	18.	3.05	*	4850.	4850	332.
15	0.	0.	5662	2	1723.	3000.	.57	17.	49.	.30	U	2	2660.	3647.	0.	.73	76.	17.	.85	*	1300.	1300	332.
16	567.	595.	6229	2	1723.	3000.	.57	17.	49.	.23	U	2	2705.	2705.	1030.	1.00	45.	30.	.38		1000.	0	0.
17	0.	0.	5388	2	1723.	3000.	.57	17.	49.	.32	U	2	2110.	3647.	0.	.58	21.	49.	.32		1400.	0	0.
18	200.	193.	5588								N	4	4039.	7294.	0.	.55	20.	49.	.69		3000.	0	0.
19	0.	0.	5324								N	3	3845.	5820.	0.	.66	26.	48.	.19		800.	0	0.
20	200.	4045.	5324								N	3	4045.	5820.	0.	.70	28.	48.	.85		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	1740.72	392.76
		MERGING POINT	0.	0.
		TOTAL	1740.72	392.76
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	761.59	174.10
		TOTAL	761.59	174.10

Time Slice 7

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	407.	724.	1019.	1358.	1480.	1582.	1686.
2	0.	285.	580.	919.	1042.	1143.	1247.
3	0.	0.	154.	493.	616.	717.	821.
4	0.	0.	0.	305.	427.	528.	632.
5	0.	0.	0.	0.	38.	139.	243.
6	0.	0.	0.	0.	0.	69.	173.
7	0.	0.	0.	0.	0.	0.	85.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	181.	326.	437.	561.	614.	716.	820.
2	0.	130.	242.	306.	419.	520.	624.
3	0.	0.	58.	182.	235.	337.	440.
4	0.	0.	0.	112.	165.	266.	370.
5	0.	0.	0.	0.	23.	124.	228.
6	0.	0.	0.	0.	0.	69.	173.
7	0.	0.	0.	0.	0.	0.	85.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	31. VEH-HRS	48. PASS-HRS	187. VEH-HRS	263. PASS-HRS
FREEWAY TRAVEL TIME (UHR)	175. VEH-HRS	186. PASS-HRS	1118. VEH-HRS	1139. PASS-HRS
FREEWAY TRAVEL TIME (BUS)	45. VEH-HRS	114. PASS-HRS	211. VEH-HRS	511. PASS-HRS
INPUT DELAY (NOR)	393. VEH-HRS	560. PASS-HRS	1102. VEH-HRS	1519. PASS-HRS
INPUT DELAY (UHR)	174. VEH-HRS	260. PASS-HRS	449. VEH-HRS	638. PASS-HRS
TOTAL TRAVEL DISTANCE	7299. VEH-MI.	11673. PASS-MI.	45295. VEH-MI.	64511. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	818. VEH-HRS	1168. PASS-HRS	3068. VEH-HRS	4070. PASS-HRS

Time Slice 7

QUEUE COLLISION 9 T2= .000
QUEUE COLLISION 8 T2= .000
QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF SEC 1

SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	RESERVED PRIORITY OPERATIONS: PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UNRESERVED OR NORMAL OPERATIONS: UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	5966.	0.	5966								N	4	4709.	10000.	0.	.47	54.	22.	.10	*	200.	200	1257.
2	0.	0.	5966	2	1616.	3000.	.54	21.	39.	.12	U	2	3084.	3600.	0.	.86	70.	22.	.21	*	400.	400	516.
3	0.	0.	5965	2	1616.	3000.	.54	16.	50.	1.24	U	2	3084.	3600.	0.	.86	71.	22.	2.84	*	5400.	5400	516.
4	0.	0.	5965	2	1616.	3000.	.54	16.	50.	.14	U	2	3084.	3445.	0.	.90	67.	23.	.30	*	600.	600	361.
5	0.	0.	5966	2	1616.	3000.	.54	16.	50.	.07	U	2	3084.	3375.	0.	.91	65.	24.	.14	*	300.	300	291.
6	0.	163.	5966	2	1616.	3000.	.54	16.	50.	.14	U	2	3084.	3376.	0.	.91	65.	24.	.29	*	600.	600	291.
7	0.	0.	5772	2	1616.	3000.	.54	16.	50.	.14	U	2	2922.	3250.	0.	.90	64.	23.	.30	*	600.	600	291.
8	40.	0.	5812	2	1616.	3000.	.54	16.	50.	.69	U	2	2962.	3250.	0.	.91	63.	24.	1.44	*	3000.	3000	288.
9	0.	0.	5812	2	1616.	3000.	.54	16.	50.	.24	U	2	2962.	3200.	0.	.93	60.	25.	.49	*	1050.	1050	238.
10	0.	407.	5812	2	1616.	3000.	.54	16.	50.	.37	U	2	2962.	3250.	0.	.91	63.	24.	.77	*	1600.	1600	238.
11	0.	0.	5321	2	1616.	3000.	.54	16.	50.	.53	U	2	2555.	3480.	0.	.73	73.	18.	1.50	*	2320.	2320	238.
12	291.	17.	5612	2	1616.	3000.	.54	16.	50.	.57	U	2	2846.	3647.	0.	.78	74.	19.	1.49	*	2500.	2500	238.
13	0.	0.	5592	2	1616.	3000.	.54	16.	50.	.13	U	2	2828.	3647.	0.	.78	75.	19.	.33	*	550.	550	238.
14	0.	58.	5592	2	1616.	3000.	.54	16.	50.	1.11	U	2	2828.	3647.	0.	.78	75.	19.	2.91	*	4850.	4850	238.
15	0.	0.	5528	2	1616.	3000.	.54	16.	50.	.30	U	2	2770.	3647.	0.	.76	75.	18.	.80	*	1300.	1300	238.
16	511.	633.	6039	2	1616.	3000.	.54	16.	50.	.23	U	2	2825.	2825.	910.	1.00	47.	30.	.38		1000.	0	0.
17	0.	0.	5175	2	1616.	3000.	.54	16.	50.	.32	U	2	2192.	3647.	0.	.60	22.	49.	.32		1400.	0	0.
18	180.	299.	5355								N	4	3996.	7294.	0.	.55	20.	50.	.69		3000.	0	0.
19	0.	0.	4963								N	3	3697.	5820.	0.	.64	25.	49.	.19		800.	0	0.
20	120.	3817.	5083								N	3	3817.	5820.	0.	.66	26.	48.	.84		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	2055.00	474.46
		MERGING POINT	0.	0.
		TOTAL	2055.00	474.46
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	874.87	204.49
		TOTAL	874.87	204.49

Time Slice 8

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	388.	687.	985.	1309.	1427.	1529.	1632.
2	0.	269.	568.	892.	1010.	1111.	1214.
3	0.	0.	149.	472.	590.	692.	795.
4	0.	0.	0.	291.	409.	510.	613.
5	0.	0.	0.	0.	38.	139.	242.
6	0.	0.	0.	0.	0.	69.	172.
7	0.	0.	0.	0.	0.	0.	84.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	180.	323.	434.	557.	610.	711.	814.
2	0.	129.	240.	363.	416.	517.	620.
3	0.	0.	57.	181.	234.	335.	438.
4	0.	0.	0.	111.	164.	265.	368.
5	0.	0.	0.	0.	23.	124.	227.
6	0.	0.	0.	0.	0.	69.	172.
7	0.	0.	0.	0.	0.	0.	84.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	30. VEH-HRS	48. PASS-HRS	217. VEH-HRS	311. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	173. VEH-HRS	186. PASS-HRS	1292. VEH-HRS	1305. PASS-HRS
FREEWAY TRAVEL TIME (BUS)	42. VEH-HRS	115. PASS-HRS	253. VEH-HRS	6[illegible]6. PASS-HRS
INPUT DELAY (NOR)	474. VEH-HRS	677. PASS-HRS	1577. VEH-HRS	2196. PASS-HRS
INPUT DELAY (UNR)	204. VEH-HRS	311. PASS-HRS	654. VEH-HRS	949. PASS-HRS
TOTAL TRAVEL DISTANCE	7207. VEH-MI.	11962. PASS-MI.	52503. VEH-MI.	76473. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	924. VEH-HRS	1338. PASS-HRS	3992. VEH-HRS	5407. PASS-HRS

Time Slice 8

* QUEUE SPLIT 10
* QUEUE SPLIT 9
S C 10 T2= .241
QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF S C 1

RESERVED PRIORITY OPERATIONS

SUB SEC	FINAL ORG	DIMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME
1	5626.	0.	5626							
2	0.	0.	5626	2	994.	3000.	.33	12.	43.	.11
3	0.	0.	5626	2	994.	3000.	.33	10.	52.	1.19
4	0.	0.	5626	2	994.	3000.	.33	10.	52.	.13
5	0.	0.	5626	2	994.	3000.	.33	10.	52.	.07
6	0.	187.	5626	2	994.	3000.	.33	10.	52.	.13
7	0.	0.	5336	2	994.	3000.	.33	10.	52.	.13
8	20.	0.	5406	2	994.	3000.	.33	10.	52.	.66
9	0.	0.	5406	2	994.	3000.	.33	10.	52.	.23
10	0.	438.	5406	2	994.	3000.	.33	10.	52.	.35
11	0.	0.	4841	2	994.	3000.	.33	10.	52.	.51
12	385.	47.	5226	2	994.	3000.	.33	10.	52.	.55
13	0.	0.	5166	2	994.	3000.	.33	10.	52.	.12
14	0.	52.	5166	2	994.	3000.	.33	10.	52.	1.07
15	0.	0.	5106	2	994.	3000.	.33	10.	52.	.29
16	271.	790.	5377	2	994.	3000.	.33	10.	52.	.22
17	0.	0.	4381	2	994.	3000.	.33	10.	52.	.31
18	141.	325.	4522							
19	0.	0.	4125							
20	120.	3395.	4245							

UNRESERVED OR NORMAL OPERATIONS

UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
N	4	4365.	10000.	0.	.44	50.	22.	.10	*	200.	200	1261.
U	2	3367.	3600.	0.	.94	77.	22.	.21	*	400.	400	233.
U	2	3367.	3600.	0.	.94	67.	25.	2.44	*	5400.	5400	233.
U	2	3367.	3445.	0.	.98	60.	28.	.24	*	600.	600	78.
U	2	3367.	3375.	0.	1.00	56.	30.	.11	*	300.	300	9.
U	2	3367.	3376.	0.	1.00	56.	30.	.23	*	600.	600	9.
U	2	3180.	3250.	0.	.98	56.	28.	.24	*	600.	600	9.
U	2	3200.	3250.	0.	.98	56.	29.	1.18	*	3000.	3000	9.
U	2	3200.	3200.	0.	1.00	53.	30.	.40	*	1050.	1050	0.
U	2	3200.	3250.	0.	.98	51.	32.	.58		1600.	0	-21.
U	2	2783.	3480.	0.	.80	37.	37.	.72		2320.	0	0.
U	2	3168.	3647.	0.	.87	52.	31.	.99		2500.	0	0.
U	2	3120.	3647.	0.	.86	59.	27.	.26		550.	0	0.
U	2	3425.	3647.	0.	.94	67.	25.	2.17	*	4850.	4485	-305.
U	2	3374.	3647.	0.	.93	69.	25.	.60	*	1300.	1300	-305.
U	2	3251.	3251.	484.	1.00	54.	30.	.38		1000.	0	0.
U	2	2461.	3647.	0.	.67	25.	48.	.33		1400.	0	0.
N	4	3600.	7294.	0.	.49	18.	50.	.68		3000.	0	0.
N	3	3275.	5820.	0.	.56	22.	49.	.18		800.	0	0.
N	3	3395.	5820.	0.	.58	23.	49.	.83		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	2370.26	553.16
		MERGING POINT	0.	0.
		TOTAL	2370.26	553.16
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	974.41	231.31
		TOTAL	974.41	231.31

Time Slice 9

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	334.	573.	737.	978.	1076.	1177.	1279.
2	0.	216.	379.	620.	718.	819.	921.
3	0.	0.	93.	334.	432.	533.	634.
4	0.	0.	0.	217.	315.	416.	518.
5	0.	0.	0.	0.	38.	139.	241.
6	0.	0.	0.	0.	0.	68.	170.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	173.	310.	416.	535.	585.	684.	786.
2	0.	124.	230.	349.	399.	498.	600.
3	0.	0.	55.	174.	224.	323.	425.
4	0.	0.	0.	107.	157.	256.	358.
5	0.	0.	0.	0.	22.	121.	222.
6	0.	0.	0.	0.	0.	68.	170.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	26. VEH-HRS	38. PASS-HRS	243. VEH-HRS	349. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	150. VEH-HRS	154. PASS-HRS	1442. VEH-HRS	1479. PASS-HRS
FREEWAY TRAVEL TIME (RES)	25. VEH-HRS	69. PASS-HRS	278. VEH-HRS	695. PASS-HRS
INPUT DELAY (NOR)	553. VEH-HRS	739. PASS-HRS	2130. VEH-HRS	2935. PASS-HRS
INPUT DELAY (UNR)	231. VEH-HRS	318. PASS-HRS	885. VEH-HRS	1266. PASS-HRS
TOTAL TRAVEL DISTANCE	6756. VEH-MI.	9686. PASS-MI.	59259. VEH-MI.	86160. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	986. VEH-HRS	1318. PASS-HRS	4978. VEH-HRS	6725. PASS-HRS

Time Slice 9

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	341.	577.	695.	906.	1011.	1112.	1213.
2	0.	211.	329.	540.	645.	746.	847.
3	0.	0.	61.	272.	377.	478.	580.
4	0.	0.	0.	198.	303.	404.	505.
5	0.	0.	0.	0.	38.	139.	240.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	172.	308.	414.	532.	582.	680.	782.
2	0.	124.	229.	347.	397.	496.	597.
3	0.	0.	55.	173.	223.	321.	423.
4	0.	0.	0.	106.	156.	255.	356.
5	0.	0.	0.	0.	22.	120.	222.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	26. VEH-HRS	37. PASS-HRS	269. VEH-HRS	387. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	137. VEH-HRS	139. PASS-HRS	1579. VEH-HRS	1617. PASS-HRS
FREEWAY TRAVEL TIME (BUS)	23. VEH-HRS	64. PASS-HRS	300. VEH-HRS	759. PASS-HRS
INPUT DELAY (NOR)	620. VEH-HRS	829. PASS-HRS	2750. VEH-HRS	3764. PASS-HRS
INPUT DELAY (UNR)	248. VEH-HRS	340. PASS-HRS	1134. VEH-HRS	1606. PASS-HRS
TOTAL TRAVEL DISTANCE	6488. VEH-MI.	9214. PASS-MI.	65747. VEH-MI.	95374. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	1054. VEH-HRS	1408. PASS-HRS	6032. VEH-HRS	8132. PASS-HRS

Time Slice 10

INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING
UNIVERSITY OF CALIFORNIA
BERKELEY, CALIFORNIA

QUEUE COLLISION 5 T2= .000
QUEUE COLLISION 4 T2= .000
QUEUE COLLISION 2 T2= .000
Q OUT OF SEC 1

RESERVED PRIORITY OPERATIONS

SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME
1	5123.	0.	5123							
2	0.	0.	5123	2	904.	3000.	.30	10.	43.	.10
3	0.	0.	5123	2	904.	3000.	.30	9.	52.	1.18
4	0.	0.	5123	2	904.	3000.	.30	9.	52.	.13
5	0.	0.	5123	2	904.	3000.	.30	9.	52.	.07
6	0.	171.	5123	2	904.	3000.	.30	9.	52.	.13
7	0.	0.	4918	2	904.	3000.	.30	9.	52.	.13
8	40.	0.	4958	2	904.	3000.	.30	9.	52.	.66
9	0.	0.	4958	2	904.	3000.	.30	9.	52.	.23
10	0.	381.	4958	2	904.	3000.	.30	9.	52.	35
11	0.	0.	4497	2	904.	3000.	.30	9.	52.	.31
12	280.	34.	4777	2	904.	3000.	.30	9.	52.	.55
13	0.	0.	4737	2	904.	3000.	.30	9.	52.	.12
14	0.	74.	4737	2	904.	3000.	.30	9.	52.	1.06
15	0.	0.	4657	2	904.	3000.	.30	9.	52.	.28
16	261.	847.	4918	2	904.	3000.	.30	9.	52.	.22
17	0.	0.	3924	2	904.	3000.	.30	9.	52.	.31
18	180.	312.	4104							
19	0.	0.	3742							
20	160.	3361.	3902							

UNRESERVED OR NORMAL OPERATIONS

SUB SEC	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	N	4	4240.	10000.	0.	.42	48.	22.	.10	*	200.	200	883.
2	U	2	3331.	3600.	0.	.93	76.	22.	.21	*	400.	400	269.
3	U	2	3331.	3600.	0.	.93	68.	25.	2.50	*	5400.	5400	269.
4	U	2	3331.	3445.	0.	.97	61.	27.	.25	*	600.	600	114.
5	U	2	3331.	3375.	0.	.99	58.	29.	.12	*	300.	300	44.
6	U	2	3331.	3376.	0.	.99	58.	29.	.24	*	600.	600	44.
7	U	2	3160.	3250.	0	.97	57.	28.	.25	*	600.	600	44.
8	U	2	3200.	3250.	0	.98	56.	29.	1.18	*	3000.	3000	44.
9	U	2	3200.	3200.	0	1.00	53.	30.	.40	*	1050.	1050	0.
10	U	2	3200.	3250.	0.	.98	47.	34.	.53		1600.	0	0.
11	U	2	2819.	3480.	0.	.81	30.	47.	.56		2320.	0	0.
12	U	2	3099.	3647.	0.	.85	33.	47.	.61		2500.	0	0.
13	U	2	3065.	3647.	0.	.84	33.	47.	.13		550.	0	0.
14	U	2	3238.	3647.	0.	.89	58.	28.	1.94	*	4850.	1531	-173.
15	U	2	3164.	3647.	0.	.87	72.	22.	.67	*	1300.	1300	-173.
16	U	2	3271.	3271.	464.	1.00	55.	30.	.38		1000.	0	0.
17	U	2	2424.	3647.	0.	.66	25.	48.	.33		1400.	0	0.
18	N	4	3513.	7294.	0.	.48	17.	50.	.68		3000.	0	0.
19	N	3	3201.	5820.	0.	.55	22.	50.	.18		800.	0	0.
20	N		3361.	5820.	0.	.58	23.	49.	.83		3600.	0	0.

		QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP 1	INPUT POINT	2591.03	620.16
	MERGING POINT	0.	0.
	TOTAL	2591.03	620.16
ON-RAMP 5	INPUT POINT	0.	0.
	MERGING POINT	1013.07	248.45
	TOTAL	1013.07	248.45

Time Slice 10

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RESERVED PRIORITY OPERATIONS

SUB SEC	FINAL ORG	DEMD. DIS	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME
1	4019.	0.	4019							
2	0.	0.	4019	2	839.	3000.	.28	10.	44.	.10
3	0.	0.	4019	2	839.	3000.	.29	8.	52.	1.18
4	0.	0.	4019	2	839.	3000.	.28	8.	52.	.13
5	0.	0.	4019	2	839.	3000.	.29	8.	52.	.07
6	0.	163.	4019	2	839.	3000.	.28	8.	52.	.13
7	0.	0.	3856	2	839.	3000.	.28	8.	52.	.13
8	40.	0.	3896	2	839.	3000.	.28	8.	52.	.65
9	0.	0.	3896	2	839.	3000.	.28	8.	52.	.23
10	0.	462.	3896	2	839.	3000.	.28	8.	52.	.35
11	0.	0.	3451	2	839.	3000.	.29	8.	52.	.51
12	243.	21.	3694	2	839.	3000.	.28	8.	52.	.54
13	0.	0.	3674	2	839.	3000.	.28	8.	52.	.12
14	0.	86.	3674	2	839.	3000.	.28	8.	52.	1.06
15	0.	0.	3591	2	839.	3000.	.28	8.	52.	.28
16	298.	967.	3889	2	839.	3000.	.29	8.	52.	.22
17	0.	0.	2959	2	839.	3000.	.28	8.	52.	.30
18	161.	432.	3120							
19	0.	0.	2703							
20	79.	2872.	2782							

UNRESERVED OR NORMAL OPERATIONS

SUB SEC	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	N	4	4164.	10000.	0.	.42	47.	22.	.10	*	200.	200	-145.
2	U	2	3323.	3600.	0.	.92	76.	22.	.21	*	400.	400	-145.
3	U	2	3323.	3600.	0.	.92	68.	24.	2.52	*	5400.	5400	-145.
4	U	2	3323.	3445.	0.	.96	61.	27.	.25	*	600.	600	-145.
5	U	2	3323.	3375.	0.	.98	58.	29.	.12	*	300.	300	-145.
6	U	2	3323.	3376.	0.	.98	58.	29.	.24	*	600.	600	-145.
7	U	2	3160.	3250.	0.	.97	57.	28.	.25	*	600.	600	-145.
8	U	2	3200.	3250.	0.	.98	56.	29.	1.18	*	3000.	3000	-145.
9	U	2	3200.	3200.	0.	1.00	53.	30.	.40	*	1050.	1050	-145.
10	U	2	3200.	3250.	0.	.98	47.	34.	.53		1600.	0	0.
11	U	2	2738.	3480.	0.	.79	29.	47.	.56		2320.	0	0.
12	U	2	2648.	3647.	0.	.73	30.	44.	.72	*	2500.	1031	333.
13	U	2	2628.	3647.	0.	.72	40.	33.	.21	*	550.	550	333.
14	U	2	2628.	3647.	0.	.72	64.	20.	2.77	*	4850.	4850	333.
15	U	2	2542.	3647.	0.	.70	77.	16.	.90	*	1300.	1300	333.
16	U	2	3189.	3189.	546.	1.00	53.	30.	.38		1000.	0	0.
17	U	2	2222.	3647.	0.	.61	23.	49.	.33		1400.	0	0.
18	N	4	3224.	7294.	0.	.44	16.	51.	.67		3000.	0	0.
19	N	3	2793.	5820.	0.	.48	19.	50.	.18		800.	0	0.
20	N	3	2872.	5820.	0.	.49	19.	50.	.82		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	2554.71	1290.98
		MERGING POINT	0.	0.
		TOTAL	2554.71	1290.98
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	926.26	242.47
		TOTAL	926.26	242.47

Time Slice 11

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	343.	579.	700.	988.	1116.	1216.	1316.
2	0.	211.	332.	620.	748.	848.	948.
3	0.	0.	65.	353.	481.	581.	681.
4	0.	0.	0.	269.	397.	497.	597.
5	0.	0.	0.	0.	38.	138.	238.
6	0.	0.	0.	0.	0.	67.	167.
7	0.	0.	0.	0.	0.	0.	82.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	171.	307.	412.	529.	579.	677.	777.
2	0.	123.	223.	245.	396.	493.	593.
3	0.	0.	54.	172.	222.	320.	420.
4	0.	0.	0.	106.	156.	254.	353.
5	0.	0.	0.	0.	22.	120.	219.
6	0.	0.	0.	0.	0.	67.	167.
7	0.	0.	0.	0.	0.	0.	82.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	23. VEH-HRS	35. PASS-HRS	292. VEH-HRS	421. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	142. VEH-HRS	144. PASS-HRS	1721. VEH-HRS	1761. PASS-HRS
FREEWAY TRAVEL TIME (PRI)	21. VEH-HRS	53. PASS-HRS	321. VEH-HRS	812. PASS-HRS
INPUT DELAY (NOR)	1291. VEH-HRS	1886. PASS-HRS	4041. VEH-HRS	5650. PASS-HRS
INPUT DELAY (UNR)	242. VEH-HRS	357. PASS-HRS	1376. VEH-HRS	1963. PASS-HRS
TOTAL TRAVEL DISTANCE	6074. VEH-MI.	8370. PASS-MI.	71821. VEH-MI.	103744. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	1719. VEH-HRS	2474. PASS-HRS	7751. VEH-HRS	10607. PASS-HRS

Time Slice 11

QUEUE COLLISION 10 T2= .130
Q OUT OF SEC 1

SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	N NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
				RESERVED PRIORITY OPERATIONS							UNRESERVED OR NORMAL OPERATIONS												
1	3590.	0.	3590								N	4	3556.	10000.	0.	.36	43.	20.	.11	*	200.	200	34.
2	0.	0.	3590	2	816.	3000.	.27	9.	44.	.10	U	2	2737.	3600.	0.	.76	68.	20.	.23	*	400.	400	34.
3	0.	0.	3590	2	816.	3000.	.27	8.	52.	1.17	U	2	2737.	3600.	0.	.76	71.	19.	3.21	*	5400.	5400	34.
4	0.	0.	3590	2	816.	3000.	.27	8.	52.	.13	U	2	2737.	3445.	0.	.79	66.	21.	.33	*	600.	600	34.
5	0.	0.	3590	2	816.	3000.	.27	8.	52.	.07	U	2	2737.	3375.	0.	.81	63.	22.	.16	*	300.	300	34.
6	0.	128.	3590	2	816.	3000.	.27	8.	52.	.13	U	2	2737.	3376.	0.	.81	63.	22.	.32	*	600.	600	34.
7	0.	0.	3462	2	816.	3000.	.27	8.	52.	.13	U	2	2609.	3250.	0.	.80	61.	21.	.32	*	600.	600	34.
8	40.	0.	3502	2	816.	3000.	.27	8.	52.	.65	U	2	2649.	3250.	0.	.82	60.	22.	1.55	*	3000.	3000	34.
9	0.	0.	3502	2	816.	3000.	.27	8.	52.	.23	U	2	2649.	3200.	0.	.83	58.	23.	.53	*	1050.	1050	34.
10	0.	164.	3502	2	816.	3000.	.27	8.	52.	.35	U	2	2649.	3250.	0.	.82	51.	26.	.77	*	1600.	1600	551.
11	0.	0.	3359	2	816.	3000.	.27	8.	52.	.50	U	2	2485.	3480.	0.	.71	57.	22.	1.29	*	2320.	2320	551.
12	62.	46.	3421	2	816.	3000.	.27	8.	52.	.54	U	2	2547.	3647.	0.	.70	74.	17.	1.68	*	2500.	2500	551.
13	0.	0.	3381	2	816.	3000.	.27	8.	52.	.12	U	2	2501.	3647.	0.	.69	78.	16.	.39	*	550.	550	551.
14	5.	71.	3386	2	816.	3000.	.27	8.	52.	1.05	U	2	2506.	3647.	0.	.69	78.	16.	3.43	*	4850.	4850	551.
15	0.	0.	3323	2	816.	3000.	.27	8.	52.	.28	U	2	2435.	3647.	0.	.67	79.	15.	.96	*	1300.	1300	551.
16	295.	1001.	3618	2	816.	3000.	.27	8.	52.	.22	U	2	3199.	3199.	536.	1.00	53.	30.	.38		1000.	0	0.
17	0.	0.	2722	2	816.	3000.	.27	8.	52.	.30	U	2	2198.	3647.	0.	.60	22.	49.	.32		1400.	0	0.
18	161.	500.	2883								N	4	3178.	7294.	0.	.44	16.	51.	.67		3000.	0	0.
19	0.	0.	2434								N	3	2678.	5820.	0.	.46	18.	50.	.18		800.	0	0.
20	79.	2757.	2513								N	3	2757.	5820.	0.	.47	18.	50.	.81		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	2491.69	622.41
		MERGING POINT	0.	0.
		TOTAL	2491.69	622.41
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	808.14	216.67
		TOTAL	808.14	216.67

Time Slice 12

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	432.	741.	1027.	1409.	1543.	1642.	1742.
2	0.	277.	564.	945.	1079.	1179.	1278.
3	0.	0.	166.	547.	681.	781.	880.
4	0.	0.	0.	343.	476.	576.	675.
5	0.	0.	0.	0.	38.	138.	237.
6	0.	0.	0.	0.	0.	67.	167.
7	0.	0.	0.	0.	0.	0.	81.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	171.	307.	412.	529.	579.	677.	777.
2	0.	123.	228.	345.	395.	493.	592.
3	0.	0.	54.	172.	222.	319.	419.
4	0.	0.	0.	105.	155.	253.	353.
5	0.	0.	0.	0.	22.	119.	219.
6	0.	0.	0.	0.	0.	67.	167.
7	0.	0.	0.	0.	0.	0.	81.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	22. VEH-HRS	34. PASS-HRS	313. VEH-HRS	455. PASS-HRS
FREEWAY TRAVEL TIME (UNR)	172. VEH-HRS	178. PASS-HRS	1893. VEH-HRS	1939. PASS-HRS
FREEWAY TRAVEL TIME (RES)	20. VEH-HRS	52. PASS-HRS	342. VEH-HRS	864. PASS-HRS
INPUT DELAY (NOR)	622. VEH-HRS	909. PASS-HRS	4664. VEH-HRS	6559. PASS-HRS
INPUT DELAY (UNR)	217. VEH-HRS	326. PASS-HRS	1593. VEH-HRS	2289. PASS-HRS
TOTAL TRAVEL DISTANCE	5550. VEH-MI.	7925. PASS-MI.	77371. VEH-MI.	111669. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	1053. VEH-HRS	1500. PASS-HRS	8804. VEH-HRS	12107. PASS-HRS

Time Slice 12

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RESERVED PRIORITY OPERATIONS

SUB SEC	FINAL ORG	DMD. DES	ORIG. TOTAL	PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME
1	2827.	0.	2827							
2	0.	0.	2827	2	584.	3000.	.19	6.	45.	.10
3	0.	0.	2827	2	584.	3000.	.19	6.	53.	1.16
4	0.	0.	2827	2	584.	3000.	.19	6.	53.	.13
5	0.	0.	2827	2	584.	3000.	.19	6.	53.	.06
6	0.	90.	2827	2	584.	3000.	.19	6.	53.	.13
7	0.	0.	2737	2	584.	3000.	.19	6.	53.	.13
8	40.	0.	2777	2	584.	3000.	.19	6.	53.	.64
9	0.	0.	2777	2	584.	3000.	.19	6.	53.	.22
10	0.	120.	2777	2	584.	3000.	.19	6.	53.	.34
11	0.	0.	2657	2	584.	3000.	.19	6.	53.	.50
12	40.	0.	2697	2	584.	3000.	.19	6.	53.	.54
13	0.	0.	2697	2	584.	3000.	.19	6.	53.	.12
14	0.	100.	2697	2	584.	3000.	.19	6.	53.	1.04
15	0.	0.	2597	2	584.	3000.	.19	6.	53.	.28
16	168.	825.	2765	2	584.	3000.	.19	6.	53.	.21
17	0.	0.	2205	2	584.	3000.	.19	6.	53.	.30
18	220.	356.	2425							
19	0.	0.	2180							
20	30.	3152.	2260							

UNRESERVED OR NORMAL OPERATIONS

SUB SEC	UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	N	4	3113.	10000.	0.	.31	35.	22.	.10	*	200.	200	-286.
2	U	2	2528.	3600.	0.	.70	57.	22.	.21	*	400.	400	-286.
3	U	2	2528.	3600.	0.	.70	76.	17.	3.70	*	5400.	5400	-286.
4	U	2	2528.	3445.	0.	.73	72.	18.	.39	*	600.	600	-286.
5	U	2	2528.	3375.	0.	.75	70.	18.	.19	*	300.	300	-286.
6	U	2	2528.	3376.	0.	.75	70.	18.	.38	*	600.	600	-286.
7	U	2	2438.	3250.	0.	.75	67.	18.	.38	*	600.	600	-286.
8	U	2	2478.	3250.	0.	.76	67.	19.	1.84	*	3000.	3000	-286.
9	U	2	2478.	3200.	0.	.77	65.	19.	.63	*	1050.	1050	-286.
10	U	2	2478.	3250.	0.	.76	67.	19.	.98	*	1600.	1600	-286.
11	U	2	2358.	3480.	0.	.68	75.	16.	1.67	*	2320.	2320	-286.
12	U	2	2398.	3647.	0.	.66	79.	15.	1.88	*	2500.	2500	-286.
13	U	2	2398.	3647.	0.	.66	79.	15.	.41	*	550.	550	-286.
14	U	2	2398.	3647.	0.	.66	79.	15.	3.64	*	4850.	4850	-286.
15	U	2	2298.	3647.	0.	.63	81.	14.	1.04	*	1300.	1300	-286.
16	U	2	3448.	3448.	287.	1.00	57.	30.	.38		1000.	0	0.
17	U	2	2623.	3647.	0.	.72	27.	48.	.33		1400.	0	0.
18	N	4	3428.	7294.	0.	.47	17.	50.	.68		3000.	0	0.
19	N	3	3072.	5820.	0.	.53	21.	50.	.18		800.	0	0.
20	N	3	3152.	5820.	0.	.54	21.	50.	.83		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	1	INPUT POINT	2420.18	1236.91
		MERGING POINT	0.	0.
		TOTAL	2420.18	1236.91
ON-RAMP	5	INPUT POINT	0.	0.
		MERGING POINT	563.37	171.49
		TOTAL	563.37	171.49

Time Slice 13

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	496.	879.	1234.	1640.	1782.	1883.	1983.
2	0.	345.	700.	1106.	1247.	1349.	1449.
3	0.	0.	188.	594.	735.	836.	937.
4	0.	0.	0.	364.	506.	607.	708.
5	0.	0.	0.	0.	38.	139.	240.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	168.	302.	405.	521.	570.	668.	769.
2	0.	121.	224.	340.	389.	487.	588.
3	0.	0.	54.	169.	218.	316.	417.
4	0.	0.	0.	104.	153.	251.	352.
5	0.	0.	0.	0.	21.	119.	220.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	24. VEH-HRS	34. PASS-HRS	338. VEH-HRS	489. PASS-HRS
FREEWAY TRAVEL TIME (UNP)	185. VEH-HRS	188. PASS-HRS	2078. VEH-HRS	2128. PASS-HRS
FREEWAY TRAVEL TIME (BUS)	14. VEH-HRS	35. PASS-HRS	356. VEH-HRS	899. PASS-HRS
INPUT DELAY (NOR)	1237. VEH-HRS	1740. PASS-HRS	5901. VEH-HRS	8300. PASS-HRS
INPUT DELAY (UNP)	171. VEH-HRS	247. PASS-HRS	1764. VEH-HRS	2536. PASS-HRS
TOTAL TRAVEL DISTANCE	5168. VEH-MI.	6816. PASS-MI.	82539. VEH-MI.	118485. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	1632. VEH-HRS	2245. PASS-HRS	10436. VEH-HRS	14352. PASS-HRS

Time Slice 13

SUB SEC	FINAL ORG	DEMD. DES	ORIG. TOTAL	RESERVED PRIORITY OPERATIONS PS	VOL	CAP	V/C	DEN V/M/L	MPH	TRAV TIME	UNRESERVED OR NORMAL OPERATIONS UN NORM	NL	VOL	CAP	WEAVE EFF	V/C	DEN V/M/L	MPH	TRAV TIME	Q *	LENG	QUEUE FEET	RA
1	2827.	0.	2827								N	4	3113.	10000.	0.	.31	35.	22.	.10	*	200.	200	-286.
2	0.	0.	2827	2	584.	3000.	.19	6.	45.	.10	U	2	2528.	3600.	0.	.70	57.	22.	.21	*	400.	400	-286.
3	0.	0.	2827	2	584.	3000.	.19	6.	53.	1.16	U	2	2528.	3600.	0.	.70	76.	17.	3.70	*	5400.	5400	-286.
4	0.	0.	2827	2	584.	3000.	.19	6.	53.	.13	U	2	2528.	3445.	0.	.73	72.	18.	.39	*	600.	600	-286.
5	0.	0.	2827	2	584.	3000.	.19	6.	53.	.06	U	2	2528.	3375.	0.	.75	70.	18.	.19	*	300.	300	-286.
6	0.	90.	2827	2	584.	3000.	.19	6.	53.	.13	U	2	2528.	3376.	0.	.75	70.	18.	.38	*	600.	600	-286.
7	0.	0.	2737	2	584.	3000.	.19	6.	53.	.13	U	2	2438.	3250.	0.	.75	67.	18.	.38	*	600.	600	-286.
8	40.	0.	2777	2	584.	3000.	.19	6.	53.	.64	U	2	2478.	3250.	0.	.76	67.	19.	1.84	*	3000.	3000	-286.
9	0.	0.	2777	2	584.	3000.	.19	6.	53.	.22	U	2	2478.	3200.	0.	.77	65.	19.	.63	*	1050.	1050	-286.
10	0.	120.	2777	2	584.	3000.	.19	6.	53.	.34	U	2	2478.	3250.	0.	.76	67.	19.	.98	*	1600.	1600	-286.
11	0.	0.	2657	2	584.	3000.	.19	6.	53.	.50	U	2	2358.	3480.	0.	.68	75.	16.	1.67	*	2320.	2320	-286.
12	40.	0.	2697	2	584.	3000.	.19	6.	53.	.54	U	2	2398.	3647.	0.	.66	79.	15.	1.88	*	2500.	2500	-286.
13	0.	0.	2697	2	584.	3000.	.19	6.	53.	.12	U	2	2398.	3647.	0.	.66	79.	15.	.41	*	550.	550	-286.
14	0.	100.	2697	2	584.	3000.	.19	6.	53.	1.04	U	2	2398.	3647.	0.	.66	79.	15.	3.64	*	4850.	4850	-286.
15	0.	0.	2597	2	584.	3000.	.19	6.	53.	.28	U	2	2298.	3647.	0.	.63	81.	14.	1.04	*	1300.	1300	-286.
16	168.	825.	2765	2	584.	3000.	.19	6.	53.	.21	U	2	3448.	3448.	287.	1.00	57.	30.	.38		1000.	0	0.
17	0.	0.	2205	2	584.	3000.	.19	6.	53.	.30	U	2	2623.	3647.	0.	.72	27.	48.	.33		1400.	0	0.
18	220.	356.	2425								N	4	3428.	7294.	0.	.47	17.	50.	.68		3000.	0	0.
19	0.	0.	2180								N	3	3072.	5820.	0.	.53	21.	50.	.18		800.	0	0.
20	80.	3152.	2260								N	3	3152.	5820.	0.	.54	21.	50.	.83		3600.	0	0.

			QUEUE LENGTH VEHICLES	DELAY VEH-HRS
ON-RAMP	INPUT POINT		2348.67	1201.15
	MERGING POINT		0.	0.
		TOTAL	2348.67	1201.15
ON-RAMP	INPUT POINT		0.	0.
	MERGING POINT		318.19	110.19
		TOTAL	318.19	110.19

Time Slice 14

TRAVEL TIME FOR ONE NON-PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	496.	879.	1234.	1640.	1782.	1883.	1983.
2	0.	345.	700.	1106.	1247.	1349.	1449.
3	0.	0.	188.	594.	735.	836.	937.
4	0.	0.	0.	364.	506.	607.	708.
5	0.	0.	0.	0.	38.	139.	240.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

TRAVEL TIME FOR ONE PRIORITY TRIP .01 MINUTES

0	1	2	3	4	5	6	7
1	168.	302.	405.	521.	570.	668.	769.
2	0.	121.	224.	340.	389.	487.	588.
3	0.	0.	54.	169.	218.	316.	417.
4	0.	0.	0.	104.	153.	251.	352.
5	0.	0.	0.	0.	21.	119.	220.
6	0.	0.	0.	0.	0.	68.	169.
7	0.	0.	0.	0.	0.	0.	83.

	CURRENT TIME INTERVAL		CUMULATIVE VALUES	
FREEWAY TRAVEL TIME (NOR)	24. VEH-HRS	34. PASS-HRS	362. VEH-HRS	524. PASS-HRS
FREEWAY TRAVEL TIME (UNP)	195. VEH-HRS	188. PASS-HRS	2263. VEH-HRS	2316. PASS-HRS
FREEWAY TRAVEL TIME (PRS)	14. VEH-HRS	35. PASS-HRS	370. VEH-HRS	934. PASS-HRS
INPUT DELAY (NOR)	1201. VEH-HRS	1690. PASS-HRS	7102. VEH-HRS	9990. PASS-HRS
INPUT DELAY (UNP)	110. VEH-HRS	158.. PASS-HRS	1874. VEH-HRS	2694. PASS-HRS
TOTAL TRAVEL DISTANCE	5168. VEH-MI.	6816. PASS-MI.	87707. VEH-MI.	125301. PASS-MI.
TOTAL TRAVEL TIME UNDER PRIORITY OPERATIONS	1535. VEH-HRS	2106. PASS-HRS	11972. VEH-HRS	16458. PASS-HRS
TOTAL TRAVEL TIME UNDER NON-PRIORITY OPERATIONS			2190. VEH-HRS	3175. PASS-HRS *

TRAVEL TIME SAVINGS OVER NON-PRIORITY OPERATION = -9781.5 VEH-HRS -13283.0 PASS-HRS

END OF SIMULATION FOR ABOVE CRITERION

*** 3175 pass-hrs for normal operations on New Design reflects a change made in Time Slice 4 0_7 = 104. Normal operations travel time used in Chapter 5 = 3192 so that the travel time savings equals 16458-3192 = 13266 pass-hrs.**

Time Slice 14

APPENDIX F

BASIC DATA REQUIRED FOR EVALUATION OF FREEWAY OPERATIONS ON PRIFRE MODEL (SEE CHAPTER 5 FOR MORE DETAIL)

1. DEMAND CHARACTERISTICS

a. Auto Origin-Destination Pattern for each 15 minute time interval during the peak period. (To be entered in O-D tables as hourly passenger flow rates.)

b. Bus Origin - Destination Pattern for each 15 minute time interval during the peak period. (To be entered in O-D tables as hourly flow rates - buses/hr.)

c. Vehicle Occupancy

   1. Average bus occupancy for each 15 minute time interval during the peak period.

   2. Auto occupancy distribution for each 15 minute time interval (expressed as % cars with 1, 2, 3, 4 or 5 passengers).

2. FREEWAY CHARACTERISTICS

a. Division of freeway section under study into subsections, each one homogeneous with respect to capacity, number of lanes, 0 or 1 on-ramps, 0 or 1 off-ramps, etc.

   1. Distance between Ramp Noses (feet)

   2. Subsection Lengths

   3. Presence of left hand or two lane on- and off-ramps

b. Capacity of each subsection under normal operations (observed capacity or calculated by *Highway Capacity Manual* methods).

c. Capacity of Reserved Lanes (see Chapter 5).

d. Speed-flow/capacity relationships for the normal, unreserved, and reserved lanes in each subsection (observed relationships, *Highway Capacity Manual* relationships shown in Fig. 9.1, or see Chapter 5).

3. STRATEGIES TO BE EVALUATED

a. Speed or density contour maps from local transport agencies. Current data.

b. Significant changes in freeway operations or demand characteristics due to occupancy shifts, modal split changes, socio-economic factors.

c. Annual traffic growth rate.

APPENDIX G

PRIFRE MANUAL CHECKS AND SAMPLE CALCULATIONS

APPENDIX G

EXAMPLE 4.1 SAMPLE CALCULATION FOR TIME SLICE 1

A. Volume Calculations

Original demands are assumed to instantaneously propagate downstream of the freeway. (Bus demands at on and off ramps are multiplied by the bus equivalency EBN and added to the car volumes. Under reserved lane operations, buses in the reserved lanes are multiplied by the bus equivalency EBL.) Figure 12b illustrates the equivalent vehicle volumes that are used to determine the volume capacity ratio for each subsection. The equivalent vehicle volume can be read from the computer output summary in Table 12 (in main body).

B. Weaving Effect Calculation

The effect of weaving on the capacity of a subsection is estimated by finding the weaving influence factor k from Fig. 7.4 of the Highway Capacity Manual. The weaving factor k is a function of the total weaving volume and the length of the weaving section. The weaving volume for each weaving movement is calculated from traffic demand under the merging capacity constraint; the length of each weaving section is already given. In time slice 1 of the hypothetical freeway a weaving effect of 424 vehicles is outputed for subsection number 6. The weaving volumes and the weaving length at subsection 6 (shown in next page) are used to find the k factor from Fig. 7.4 of the Highway Capacity Manual.

LENGTH: 2,640

	Buses		Cars		
VOLUME:	20(2)	+	384	=	424
	8(2)	+	1020	=	1,036
EQUIVALENT VEHICLES					1,460
FACTOR k				=	2.0

EFFECT = (k - 1.0) X smaller weaving volume

= (2.0 - 1.0) X (424 - 0) = 424 vph

The result of the manual calculation is the same as those made by the computer.

After weaving analysis is performed, PRIFRE decreases the capacity of a subsection by an amount equal to the weaving effect.

C. Average Occupancy

The average occupancy of a subsection is found by using the formulas assumed in Fig. G1. Example 4.1 illustrates the calculation of the average occupancy of priority and nonpriority vehicles.

$$\text{(G1a)}\quad \begin{array}{l}\text{AVERAGE OCCUPANCY}\\ \text{IN A SUBSECTION}\\ \text{OF A NORMAL SECTION}\end{array} = \frac{\overbrace{\left[\begin{pmatrix}\text{No. of}\\ \text{Buses}\end{pmatrix}\cdot\begin{pmatrix}\text{Bus}\\ \text{Occupancy}\end{pmatrix}\right]}^{\text{Bus Passengers}} + \overbrace{\left[\begin{pmatrix}\text{No. of}\\ \text{Cars}\end{pmatrix}\cdot\begin{pmatrix}\text{Car}\\ \text{Occupancy}\end{pmatrix}\right]}^{\text{Car Passengers}}}{\overbrace{\left[\text{No. of Buses + No. of Cars}\right]}^{\text{Number of Vehicles}}}$$

FIGURE G1

AVERAGE OCCUPANCY FORMULAS
(FOR EACH SUBSECTION)

(G1b) AVERAGE OCCUPANCY IN THE PRIORITY LANE OF A RESERVED SECTION

$$= \frac{\overbrace{\left[\begin{pmatrix}\text{No. of}\\ \text{Buses}\end{pmatrix}\cdot\begin{pmatrix}\text{Bus}\\ \text{Occupancy}\end{pmatrix}\right]}^{\text{Bus Passengers}} + \overbrace{\left[\begin{pmatrix}\text{No. of}\\ \text{Priority Cars}\end{pmatrix}\cdot\begin{pmatrix}\text{Average*}\\ \text{Occupancy of}\\ \text{Priority Cars}\end{pmatrix}\right]}^{\text{Priority Car Passengers}}}{\overbrace{\left[\text{No. of Buses + No. of Priority Cars}\right]}^{\text{Number of Vehicles}}}$$

(G1c) AVERAGE OCCUPANCY IN A SUBSECTION OF AN UNRESERVED SECTION

$$= \frac{\overbrace{\left[\begin{pmatrix}\text{No. of}\\ \text{Buses}\end{pmatrix}\cdot\begin{pmatrix}\text{Bus}\\ \text{Occupancy}\end{pmatrix}\right]}^{\text{Bus Passengers}} + \overbrace{\left[\begin{pmatrix}\text{No. of Non-}\\ \text{Priority Cars}\end{pmatrix}\cdot\begin{pmatrix}\text{Average*}\\ \text{Occupancy of}\\ \text{Non-priority Cars}\end{pmatrix}\right.}^{\text{Car Passengers from The Normal Sections}} + \overbrace{\left.\begin{pmatrix}\text{Cars from}\\ \text{On-Ramps}\end{pmatrix}\cdot\begin{pmatrix}\text{Average Occu-}\\ \text{pancy for the}\\ \text{Time Slice}\end{pmatrix}\right]}^{\text{Car Passengers from On-ramps in the Unreserved Section}}}{\overbrace{\text{No. of Buses + No. of Non-priority Cars}}^{\text{Number of vehicles}} + \text{No. of Cars from On-Ramps in the Unreserved Section}}$$

FIGURE G1 (continued)

AVERAGE OCCUPANCY FORMULAS

(FOR EACH SUBSECTION)

*See sample calculation in Example 4.1, page 279.

TIME SLICE 1 NO QUEUEING

ALL VALUES IN VEHICLES PER HOUR

BUS ORIGIN - DESTINATION TABLE

BUS OCCUPANCY 50.0

DESTINATIONS

ORIGINS	0	1	2	3
	1	-0.	10.	15.
	2	-0.	10.	10.
	3	-0.	-0.	8.
	4	-0.	-0.	5.

NON-BUS ORIGIN - DESTINATION TABLE

AVE. OCC. = 1.40 PERSONS/VEHICLE

DESTINATIONS

ORIGINS	0	1	2	3
	1	71.	214.	2143.
	2	57.	150.	400.
	3	0.	20.	1000.
	4	0.	0.	786.

PERCENT OCCUPANCY NON-BUSES

OCC. ONE = 71. PCT

OCC. TWO = 21. PCT

OCC. THREE = 6. PCT

OCC. FOUR = 1. PCT

OCC. FIVE = 1. PCT

SAMPLE CALCULATION FOR TIME SLICE 1

Sample calculation of average occupancy of priority and nonpriority cars for time slice 1, subsection 3

Given: a) Priority status cutoff = 3 passengers/car

b) Distribution of cars by occupancies:

Nonpriority status	1 passenger = 71%	
	2 passenger = 21%	
Priority status	3	6%
	4	1%
	5+	1%

Average occupancy (all cars) $= \frac{71(1) + 21(2) + 6(3) + 1(4) + 1(5)}{71 + 21 + 6 + 1 + 1} = 1.40$ pass/car

Average occupancy (Nonpriority cars) $= \frac{71(1) + 21(2)}{71 + 21} = 1.23$ pass/car

Average occupancy (priority cars) $= \frac{6(3) + 1(4) + 1(5)}{6 + 1 + 1} = 3.37$ pass/car

Average occupancy in Subsection 3.

Given: a) No. of buses = 45
Average bus occupancy = 50

b) No. of cars = 2,907 + 128 from 0_2
No. of priority cars = 6 + 1 + 1 = 8%
(2907) x (.08) = 233;

No. of Nonpriority cars = (2907 - 233) + 128 = 2802

EXAMPLE 4.1 (cont.)

1. Average occupancy-reserved lanes = (Formula from Fig. Glb)

$$= \frac{(45)\cdot(50) + (233)\cdot(3.37)}{45 + 233} = 10.9 \text{ pass/vehicle}$$

2. Average occupancy-unreserved lanes = (Formula from Fig. Glc)

$$= \frac{(0)\cdot(50) + (2{,}674)\cdot(1.23) + 128\ (1.40)}{0 + 2{,}674 + 128} = 1.24 \text{ pass/vehicle}$$

EXAMPLE 4.2

SAMPLE CALCULATION FOR TIME SLICE 1
SUBSECTION 2

'able :olumn ;umber	(See Table 11)
(1)	Length = 1 mile
(2)	Volume = 45 buses + 3,035 cars = 3,080 veh/hr
(3)	Equivalent volume = 45(2) + 3,035 = 3,125 veh/hr
(4)	Weaving effect: None
(5)	Capacity = 8,000 - weaving effect = 8,000 vph
(6)	$v/c = (3)/(5) = \frac{3125}{8000} = .39$
(7)	Operating speed: From Fig. 9.1 of <u>Highway Capacity Manual</u> For v/c = .39, 8-lane freeway, DS = 70 mph Operating speed = 61 mph
(8)	$\text{Average speed} = \text{operating speed} - \frac{\text{Design Speed}}{10}(1 - v/c)$ $= 61 - \frac{70}{10}(1 - .39) = 57 \text{ mph}$
(9)	$\text{Single Trip Travel Time} = \frac{\text{Subsection Length}}{\text{Average Speed}}$ $= \frac{1 \text{ m}}{57 \text{ mph}} = .0172 \text{ hrs}$
(10)	Single Trip Travel Time = .0172 x 60 = 1.05 min.
(11)	$\text{Average occupancy} = \frac{45(50) + 3035(1.4)}{45 + 3035} = 2.11$ (Using Equation of average occupancy in a normal section)
(12)	Travel Time (veh-hrs) = Number of vehicles in 15-minute time period x single trip travel time $= \frac{1}{4} \text{ hr } (3080 \frac{\text{veh}}{\text{hr}}) (.0172 \text{ hrs}) = 13.50 \text{ veh-hrs.}$

(13) Travel Time (pass.-hrs) = veh-hrs x average occupancy

$$= 13.50 \times 2.11 = 28 \text{ pass. hrs}$$

(14) Travel Distance (veh-mi) = Number of vehicles in 15-minute time period x subsection length

$$= 1/4 \text{ hr } (3080 \frac{\text{veh}}{\text{hr}}) (1 \text{ mile}) = 770 \text{ veh-miles}$$

(15) Travel Distance (pass-miles) = veh-miles x average occupancy

$$= 770 \times 2.11 = 1624.7 \text{ pass-miles}$$

TIME SLICE 2 QUEUE INCREASING

ALL VALUES IN VEHICLES PER HOUR

BUS ORIGIN - DESTINATION TABLE

BUS OCCUPANCY 50.0

DESTINATIONS

ORIGINS	0	1	2	3
	1	200.	200.	4600.
	2	200.	100.	500.
	3	0.	30.	1500.
	4	0.	0.	800.

NON-BUS ORIGIN - DESTINATION TABLE

AVE. OCC. = 1.40 PERSONS/VEHICLE

DESTINATIONS

ORIGINS	0	1	2	3
	1	-0.	15.	35.
	2	-0.	15.	15.
	3	-0.	-0.	10.
	4	-0.	-0.	5.

NON-BUS OCCUPANCY DISTRIBUTION

OCC. ONE = 71. PCT

OCC. TWO = 21. PCT

OCC. THREE = 6. PCT

OCC. FOUR = 1. PCT

OCC. FIVE = 1. PCT

EXAMPLE 4.3

SAMPLE CALCULATION FOR TIME SLICE 2

Subsection 4

Table Column No. (see Table 15)

(1) Length = ½ mile

(2) origin volume = 958 + 7780 cars = 7875 vph

origin equivalent vol. = 95 x 2 + 7780 cars = 7970 EQ veh/hr.

adjusted volume under merging capacity constraint

= origin equivalent vol. - Merging Queue =

= 7970 - 100* = 7870 EQ vph

adjusted volume under capacity constraint at subsection 6

= 7870 - RA = 7870 - 177

= 7693

(3) weaving = 307 EQ vph (Similar to calculation in Example 4.1 in Time Slice 1)

(4) capacity = original capacity - weaving effect

= 8000 - 307 = 9693

(5) $v/c = \frac{(2)}{(4)} = \frac{7693}{7693} = 1.00$

(6) From Fig. 9.1 H.C.M.

For v/c = 1.00, 8 lane freeway DS = 70

Operating speed = 36 mph

---

*100—see Fig. 14d in Chapter 4 main body, and merging calculation in Table G2.

(7) Average speed = operating speed $- \frac{DS}{10}$ (1 - v/c)

$$= 36 - \frac{70}{10}(1 - 1) = 36 \text{ mph}$$

(8) individual travel time = $\frac{\text{subsection length}}{\text{Avg. speed}}$

$$= \frac{\frac{1}{2}\text{ mi}}{36 \text{ mph}} = .0139 \text{ hr}$$

(9) individual travel time = .0139 x 60 = .83 min.

(10) adjusted volume (actual veh. per hr.) = $\frac{\text{original actual vol. (vph)}}{\text{original volume (eq. vph)}}$ X adjusted vol. (EQ. VPH) (2)

$$= \frac{7875}{7970} \times 7693 = 7548 \text{ vph}$$

(11) Avg. occ. = $\frac{95(50) + 7780\ (1.4)}{95 + 7780}$ = 1.99 pass/veh

(12) Travel Time (veh-hrs)

Number of veh. in 15 minutes time period x single

Trip Travel Time = $\frac{1}{4}$ hr(7875 $\frac{\text{veh}}{\text{hr}}$) (.0139 hrs)

= 26.41 veh-hrs

(13) Travel Time = (12) x (11)
(pass-hr.)

= 26.41 x 1.99 = 52.56 pass-hr

(14) Travel Distance (veh-miles) =

= no. of veh. in 15 min. time period X

subsection length =

= $\frac{1}{4}$ hr(7875 $\frac{\text{veh}}{\text{hr}}$) (.5 mile) = 950 veh-mile

(15) Travel Distance (pass-miles) = (veh-miles) x (avg. occ.)

= (14) x (11) = 950 x 1.99

= 1890 pass-miles

EXAMPLE 4.4

SAMPLE CALCULATION FOR TIME SLICE 2

Subsection 5 - Queueing

Table Column No. (See Table G-1)

(1) Length = 1 mile

(2) Capacity = 8000

(3) Volume (Equiv. vehicles):

a) Original Volume = 90B + 6980 cars = 7070 vph

b) Original Volume (Eq. vph) = 90(2) + 6980 = 7160 vph

c) Adj. Volume for Merging = 7160 - 100 = 7060 vph
Capacity Constraint

(4) Excess Demand (RA_5) = 0 because $D_5 < C_5$ and there is no queue left from any previous time slice.

(5) v/c = 7060/8000 = 0.88

(6) a) Operating speed (non-queueing) Fig. 9.1 of H.C.M.

v/c = 0.88, Operating Speed = 46 mph

b) $$\text{Average speed} = \text{op. speed} - \frac{DS}{10}(1 - v/c)$$

$$= 46 - \frac{70}{10}(1 - .88) = 45 \text{ mph}$$

(7) $$\text{Non-queueing density} = \frac{\text{Volume}}{\text{Average speed}} = \frac{(3)}{(6b)}$$

$$= \frac{7060 \text{ vph}}{45 \text{ mph}} = 156.9 \text{ vpm}$$

(8) Adjusted Volume = Volume - RA_6 = (3) - $(4)_6$ = 7060 - 177

= 6883 equiv. vph

(9) v/c for queueing (8)/(2) $= \frac{6883}{8000} = 0.86$

(10) Queueing Speed $S_2 = v/c \cdot (20 \cdot v/c + 8)$

$S_2 = .86 \cdot (20 \cdot .86 + 8)$

$S_2 = 21.7$ mph

(11) Queueing Density = (8)/(10) $= \frac{6883 \text{ vph}}{21.7 \text{ mph}}$

= 317.1 vpm

(12) Shock Wave Speed, r:

$$r = \frac{RA_6}{d' - d}$$

$$r = \frac{177}{317.1 - 156.9} = 1.1 \text{ mph}$$

(13) t' = time shock wave travels in subsection 5 = 0.25 hrs.

(14) Queue Length = $r \times t'$ = 1.1 mph $\times$ 0.25 hrs

= 0.275 mi = 1452 feet

(15) Travel time for non-queueing period =

Length $\times$ non-queueing density $\times$ min.[t' or 0.25]

$L \times d \times$ min.[t' or 0.25]

1 mi $\times$ 156.9 vpm $\times$ 0.25 hrs = 39.2 equiv. veh-hrs

(16) Travel time for transition period =

(Queueing density - non-queueing density)

$\times$ (time shock wave travels through subsection 5)^2 $\times$ shock wave speed $\times \frac{1}{2}$ =

$(d' - d) \times (t')^2 \times r \times \frac{1}{2}$ =

(317.1 - 156.9) vpm $\times$ $(0.25)^2$ hrs^2 $\times$ 1.1 mph $\times \frac{1}{2}$ =

= 5.5 equiv. veh. - hrs.

(17) Travel Time for Queueing Period =

$L \times \dot{d}' \times (0.25 - t') =$

1 mi $\times$ 317.1 vpm $\times$ (0.25 - 0.25) hrs = Ø equiv. veh-hrs.

(18) Total Travel Time = (15) + (16) + (17)

39.2 + 5.5 + 0 = 44.7 equiv. veh-hrs.

(19) Total Travel Time = (18) · ratio $\frac{\text{original actual volume}}{\text{original equiv. volume}}$

$$= 44.7 \times \frac{7070}{7160} = 44.1 \text{ veh-hrs.}$$

TABLE G1 QUEUE INCREASING CALCULATIONS FOR TIME SLICE 2

A - QUEUE LENGTH CALCULATION

No. of Sub-Section	(1) Length (feet)	(2) Capacity (uph)	(3) Volume (equiv-veh)	(4) Excess Demand RA	(5) v/c	(6) Speed Non-Queueing Oper. (a)	Avg. (b)	(7) Non-Queueing Density VPM	(8) Adjusted Volume (3)-(4)	(9) v/c for Queueing (8)/(2)	(10) Queueing Speed (mph)*	(11) Queueing Density (vpm)	(12) Shock Wave Speed (vpm)	(13) t′ (1)/(12)	(14) Queue Length
6	2640	7693	7693	+177	1.00	36	36	213.7	Queue forms at the junction of subsections 6 and 5					--	(12)x(13)*
5	5280	8000	7060	0	.88	46	45	156.9	6883	.86	21.7*	317.1	1.1	.25*	.275 mile = 1452 feet

B - TOTAL TRAVEL TIME CALCULATION

No. of Sub-Section	(15) Travel Time for Non-Queueing Period	(16) Travel Time for Transition Period	(17) Travel Time for Queueing Period	(18) Travel Time (15)+(16)+(17)	(19)
	L x d x min.* (t′, .25)	(d′ - d) x (t′)^2 x r x ½	L x d′ x(.250 - t′)	equiv. veh-hr	veh-hr
5	1 x 156.9 x .25 = 39.2	(317.1 - 156.9) (.25)^2 (1.1)½ = 5.5	1 x 317.1 (.25 - .25) = 0	44.7	44.7 x $\frac{7070}{7160}$ = 44.1

* These calculations are based on theory described in Chapter 2

TIME SLICE 3 QUEUE DECREASING

ALL VALUES IN VEHICLES PER HOUR

BUS ORIGIN - DESTINATION TABLE

BUS OCCUPANCY 50.0

DESTINATIONS

ORIGINS	0	1	2	3
	1	-0.	5.	10.
	2	-0.	10.	5.
	3	-0.	-0.	8.
	4	-0.	-0.	2.

NON-BUS ORIGIN - DESTINATION TABLE

AVE OCC. = 1.40 PERSONS/VEHICLES

DESTINATIONS

ORIGINS	0	1	2	3
	1	100.	200.	5412.
	2	50.	120.	300.
	3	0.	15.	1300.
	4	0.	0.	400.

NON-BUS OCCUPANCY DISTRIBUTION

OCC. ONE = 71. PCT

OCC. TWO = 21..PCT

OCC. THREE = 6. PCT

OCC. FOUR = 1. PCT

OCC. FIVE = 1. PCT

TABLE G2 QUEUE DECREASING CALCULATIONS FOR TIME SLICE 3

A - QUEUE LENGTH CALCULATION

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	
No. of Sub-Section	Previous Queue Length (feet)	Capacity (uph)	Volume (uph)	Excess Demand RA (uph)	v/c for Non-Queueing Flow	Non-Queueing Speed (mph)	Non-Queueing Density	Queueing Volume (3)-(4) (vph)	v/c Queueing flow	Queueing Speed (mph)	Queueing Density	Shock-wave speed (mph)	t (hrs)	T1
5	1396	8000	7423 + 84 7507	-89	.938	44.5	168.67	7595	.949	25.6	296.7	.695	.1745	--

QUEUE LENGTH = 1396 X .695 X .25 X 5280 = 477 feet

B. TOTAL TRAVEL TIME CALCULATION

	(1)	(2)	(3)	(1)+(2)+(3) = Equiv. vph
No. of Sub-Section	Travel Time for Non-Queueing Period	Travel Time for Transition Period	Travel Time for Queueing Period	Total Travel Time
	$L \times d \times (.250 - T1)$	$(d - d) \times t \times (H - \frac{t}{2} \times r)$	$L \times d' \times T1$	(vph)
5	$1 \times 168.87 \times .25$	$(296.7 - 168.67) \times .174 \times \left(\frac{1396}{5280} - \frac{174}{2} \times (-.695)\right)$	$1 \times 296.7 \times .0 = .0$	49.55

EXAMPLE 4.5

CALCULATION OF AVERAGE SPEED
QUEUEING SITUATION - SS 5
(See Table 15 - Column 7 - SS5)

1) Length of Section = ,,280 feet

2) Length of Queue = 1,396 feet

3) Speed in non-queueing part of subsection 5 = 44 mph

4) Speed in queueing part of subsection 5 = 21.7 mph

5) Avg. speed = $21.7 \text{ mph} \times \frac{1396}{5280} + 44 \text{ mph} \times \frac{5280 - 1396}{5280}$

$= 38.8 \text{ mph}$

EXAMPLE 4.6

Distribution of Queues for Time Slice 2 and 3

Table G3 shows the distribution of increasing merge and freeway queues when the merging capacity or freeway capacities have been exceeded for time slice 2. The merge capacity analysis in subsection 5 is shown in Table G3A. The effect of the merge queue (100 vph) is distributed downstream according to the destination pattern as shown in Table G3B. The effect of the freeway queue is distributed downstream as shown in Table G3C. See Chapter 4, Figs. 14c and 14f, for a pictorial representation of these distributed queues.

Similarly, Table G4 shows the distribution of decreasing merge and freeway queues for time slice 3. See Chapter 4, Figs. 15d and 15e, for a pictorial representation of these distributed queues.

TABLE G3 DISTRIBUTION OF QUEUES FOR TIME SLICE 2

A - MERGING CAPACITY ANALYSIS

Composition of Traffic Flow	Demand (vph)	% Traffic in Lane 1	Demand in Lane 1 (vph)
Through Traffic	5560	9+	500*
On-Ramp O_3	1600	100	1600*
Off-Ramp D_2	NON-INFLUENCING		
Total			2100
Merge Queue = 2100 - 2000 = 100 vph			

*From Table 8.3 From H.C.M.

B - DESTINATION PATTERN CALCULATION FOR MERGE QUEUE

	Off-Ramp / On-Ramp	D_2 (vph)	END D_3 (vph)	TOTAL
O D Demand	O_1	230	4670	
	O_2	130	530	
Destination Pattern	TOTAL	360	5200	5560
	RATIO	.0648	.9352	1.00
	MERGING QUEUE	6	94	100

C - DESTINATION PATTERN CALCULATION FOR FREEWAY QUEUE

	Off-Ramp / On-Ramp	D_2 (vph)	D_3 (vph)	TOTAL
O D Demand	O_1	230	4670	
	O_2	130	530	
	O_3	30	1570	
Destination Pattern	TOTAL	390	6770	7160
	RATIO	.055	.945	1.00
	FREEWAY QUEUE	10	167	177

TABLE G4 DESTINATION PATTERN CALCULATION FOR

MERGE & FREEWAY QUEUE - TS3 - SS5

	On-Ramp \ Off-Ramp	D_2	D_3	TOTAL
O D Demand	O_3 SS 5	365	7462	7827
Destination Pattern	Demand Ratio	.046	.954	1.00
	Merge Queue	4	80	84
	Freeway Queue	4	85	89

EXAMPLE 4.7

Merging Delay Calculation

Figure G2 shows how PRIFRE computes the merging delays that start in time slice 2 and end in time slice 4. The merge queue length (vehicles) shown on the vertical axis decreases at the start of time slice 3 and dissipates completely by the end of time slice 4 The merging delays (veh-hr) for each time slice is simply the area under each triangle. (see Tables 16, 17, 20 and 21, Chapter 4 for computer output of merging delays).

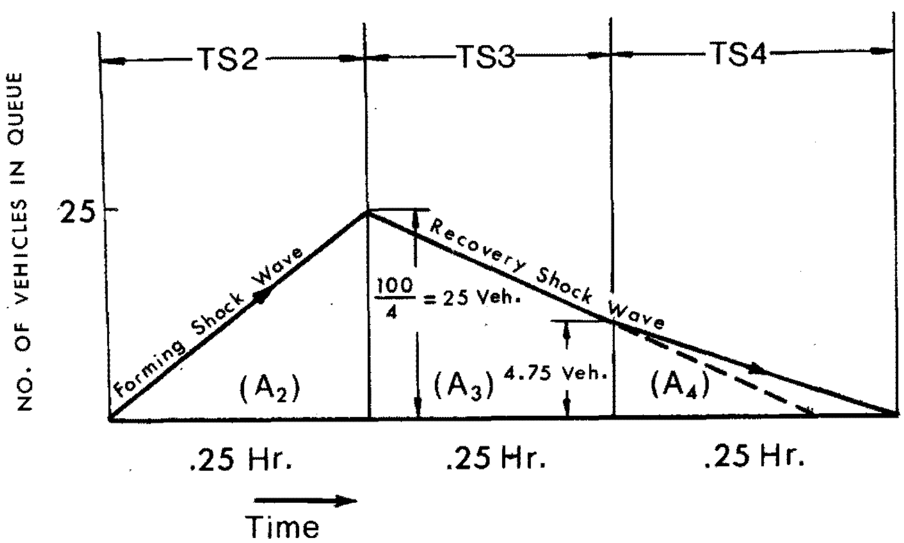

Figure G2 Merge Queue

MERGE DELAY:

<u>TS2</u>:

DELAY = Area A_2

$= \frac{1}{4}$ hr. Merge Queue (vph) $\times$ Time Delayed (T. Slice period)/2

$= (\frac{1}{4}$ hr. (100 vph) $\times \frac{1}{4}$ hr.)/2 = 3.13 veh-hrs

Avg. occ. = 2.02 pass/veh; (3.13)(2.02) = 6.22 pass-hrs

<u>TS3</u>:

DELAY = Area A_3

$= (\frac{25 + 4.75}{2})$ .25 = 3.79 veh. hr.

= 3.79 $\times$ 1.65* = 6.25 pass-hr.

<u>TS4</u>:

DELAY = Area A_4

= 4.75 $\times$ .25 $\times \frac{1}{2}$ = .59 veh-hrs

= .59 $\times$ 2 = 128 pass-hrs

---

*Avg. occ. of subsect. 5

APPENDIX H
Car Occupancy Shift Calculation Program

```
RUN.
LGO.
'
      PROGRAM [illegible] (INPUT,OUTPUT,TAPE5=INPUT)
      DIMENSION [illegible]C(5),TEMP(5),TEM(5)
C     THIS IS THE SHIFT CALCULATION PROGRAM DEVELOPED TO HELP CALCULATE THE NEW
C     OCCUPANCY DISTRIBUTIONS AFTER A PASSENGER SHIFT INTO PRIORITY STATUS CARS
C     IP IS THE PRIORITY STATUS CUTOFF
C     NS IS THE NUMBER OF DESIRED SHIFTS INTO PRIORITY STATUS CARS
C     SH IS THE PERCENT SHIFT FOR EACH DESIRED OCCUPANCY SHIFT
      READ 1000,IP,NS,SH
 1000 FORMAT(2I5,F10.5)
      READ 1001,(OCC(I),I=1,5)
 1001 FORMAT(5F5.2)
      SHFT=0.
      DO 3000 J=1,NS
      SHFT=SHFT+SH/100.
      T=0.
      DO 100 I=1,5
      TEMP(I)=OCC(I)*10.*FLOAT(I)
  100 T=T+TEMP(I)
      IIP=IP-1
      PNP=0.
      DO 110 I=1,IIP
  110 PNP=PNP+TEMP(I)
      PPP=0.
      DO 120 I=IP=5
  120 PPP=PPP+TEMP(I)
      SHF=PNP*SHFT
      DO 130 I=1,IIP
  130 TEMP(I)=TEMP(I)*(1.-SHF/PNP)
      DO 140 I=IP,5
  140 TEMP(I)=TEMP(I)*(1.+SHF/PPP)
      DO 150 I=1,5
  150 TEMP(I)=TEMP(I)/FLOAT(I)
      TOT=0.
      DO 160 I=1,5
  160 TOT=TOT+TEMP(I)
      TO=0.
      DO 170 I=1,5
      TEMP(I)=TEMP(I)/TOT
      TEM(I)=TEMP(I)*FLOAT(I)
  170 TO=TO+TEM(I)
      PRINT 2000,((I,OCC(I),TEMP(I)),I=1,5)
 2000 FORMAT(I5,2F10.4,/)
      PRINT 4000,(T,SHFT,TO,IP)
 4000 FORMAT(5X,3F10.4,4X,I2,//)
 3000 CONTINUE
      CALL EXIT
      STOP
      END

    2   18    5.
74.4221.77 2.47 1.27   .07
```

(Priority Status Cutoff=2, 18 shifts, 5% each shift)
(Initial Occupancy Distribution)

APPENDIX I

LISTING FOR PROGRAM "LCHANGE"

```
S2296. KHOSROW OVAICI
RUN.
LGO.
'
      PROGRAM LCHANGE(INPUT,OUTPUT)
*    *DETERMINATIN OF ACCEPTABLE GAP
*    *SYMBOLS ARE
*    *VR     =VOLUME IN   RESERVED LANE(VEH/HR.)
*    *VN     =VOLUME IN NORMAL LANE (VEH./HR.)
*    *SUNR   =SPEED  IN UNRESERVED LANE(MILE/HR.)
*    *VUNR   =VOLUME IN UNRESERVED LANE ( MILE/HR.)
*    *SN     =SPEED IN NORMAL LANE (VEH./HR.)
*    *SR     =  SPEED  IN   RESERVED LANE( MILE/HR.)
*    *N      =NUMBER OF LANE
*    *FXXX   =RELATIVE SPEED FACTOR
*    *HM     =MINIMUM HEAD WAY
*    *XP     =PROBABILITY OF CHANGING LANE
*    *AH     =AVERAGE HEADWAY
*    *GA     =ACCEPTABLE GAP
*    *DUR.UR=REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO
*    *       UNRE2ERVEDLANE (WITH XP PROBABILITY)
*    *DUR.R =,REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO
*    *       RESERVED LANE (WITH XP PROBABILITY)
*    *DR. UR=REQUIRE DISTANCE FOR CHANGING LANE FROM   RESERVED LANE TO
*    *       UNRE2ERVED LANE (WITH XP PROBABILITY)
*    *       BEGINNING OFTHE PRIORITY LANE.
*    *DP.OFF=REQOIRE DISTANCE FROM THE END OF THE PRIORITY LANE TO THE F
*    *       OFF-RAMP AFTER PRIORITY LANE.
    5 READ 10,VN,VR,VUNR,SN,SR,SUNR,GAR,GAUNR,HM,XP,N
   10 FORMAT(3F5.*,  6F5.2     ,F5.4,I1)
   60 IF(N.EQ.0) STOP
      SUNR1=.80*SUNR
      CALL DIST(SUNR1    ,SUNR,VUNR,HM,GAUNR,XP,DURUR)
      SN1= 0.80*SN
      CALL DIST( SN1,SN,VN,HM,GAUNR,XP,DNN)
      DONP=(N-1)*DNN
      DPOFF=DONP
      CALL DIST(SUNR,SR,VR,HM,GAR,XP,DURR)
      CALL DIST(SR,SUNR,VUNR,HM,GAUNR,XP,DRUR)
      DONPM=(N-2)*DURUR+DURR
      DPOFFM=(N-2)*DURUR+DRUR
      PRINT 1234
 1234 FORMAT( 1H1 *  INSTITUTE OF TRANSPORTATION AND TRAFFIC ENGINEERING
     C*/* UNIVERSITY OF CALIFORNIA*/* BERKELEY CALIFORNIA *)
      PRINT 101
  101 FORMAT( //*  INPUT DATA *//)
      PRINT 12,VN,VR,VUNR,SN,SR,SUNR,GAR,GAUNR,HM,XP,N
   12 FORMAT(// *  VN          =*,F5.0//*  VR         =*,F5.0//*  VUNR
     C =*,F5.0//*  SN          =*,F5.2//*  SR         =*,F5.2//*  SUNR
     C =*,F5.2//*  GAR         =*,F5.2//*  GAUNR        =*,F5.2//*  HM
     C =*,F5.2//*  XP           =*,F5.4//*  N           =*,I1///)
      PRINT 102
  102 FORMAT( ///*  OUT PUT CALCULATION ARE */*..........................
     C..............................................................*)
      PRINT 1111
 1111 FORMAT(///*** ALL   THE FOLLOWING VALUES ARE IN FEET ***)
      PRINT 1000,DNN
```

```
1000 FORMAT(///*  DNN       =* ,F10.0*      REQUIRE DISTANCE FOR CHANGING ITTE
    CLANE FROM NORMAL      LANE TO ADJACENT   NORMAL   LANE *)            ITTE
     PRINT 900,DURUR                                                      ITTE
 900 FORMAT(///*  DUR.UR   =* ,F10.0*      REQUIRE DISTANCE FOR CHANGING ITTE
    CLANE FROM UNRESERVED LANE TO ADJACENT UNRESERVED LANE *)             ITTE
     PRINT 700,DURR                                                       ITTE
 700 FORMAT(///*  DUR.R    =* ,F10.0*      REQUIRE DISTANCE FOR CHANGING ITTE
    CLANE FROM UNRESERVED LANE TO ADJACENT   RESERVED LANE *)             ITTE
     PRINT 800,DRUR                                                       ITTE
 800 FORMAT(///*  D R.UR   =* ,F10.0*      REQUIRE DISTANCE FOR CHANGING ITTE
    CLANE FROM  RESERVED LANE TO  ADJACENT UNRESERVED LANE *)             ITTE
     PRINT400,DONP                                                        ITTE
 400 FORMAT( ///*  DON.P   =*,F10.0 *  REQUIRE LANE CHANGING  DISTANCE ITTE
    CFROM  ONRAMP TO THE ENTRANCE OF THE PRIORITY LANE *)                 ITTE
     PRINT 500,DPOFF                                                      ITTE
 500 FORMAT( ///*  DP.OFF   =* ,F10.0 * REQUIRE LANE CHANGING  DISTANCEITTE
    CFROM EXIT OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP*)  ITTE
     PRINT300,DONPM                                                       ITTE
 300 FORMAT( ///*  DON.P.M =*,F10.0 *  REQUIRE LANE CHANGING  DISTANCE ITTE
    CFROM  ONRAMP TO THE  MIDDLE  OF THE PRIORITY LANE *)                 ITTE
     PRINT600,DPOFFM                                                      ITTE
 600 FORMAT( ///*  DP.OFF.M =* ,F10.0 * REQUIRE LANE CHANGING  DISTANCEITTE
    CFROM MIDDLE OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP*)ITTE
1112 FORMAT(   ///*  END OF ABOVE SIMULATION *)                           ITTE
     PRINT 1112                                                           ITTE
  70 GO TO 5                                                              ITTE
     END                                                                  ITTE
     SUBROUTINE DIST(S1,S2,V2,TA,GA,XP,D)                                 ITTE
      TM =3600/V2                                                         ITTE
     XN=(ALOG10(1-XP))/(ALOG10((1-   EXP   ((TA-GA)/(TM-TA)))) )         ITTE
     FS=(S1-S2)/(S2 )                                                     ITTE
     D=(S1*XN-S1)/(FS*V2)                                                 ITTE
     D=ABS(5280*D)                                                        ITTE
     RETURN                                                               ITTE
     END                                                                  ITTE
'
1550. 800.1800.44.0050.0035.00 3.50 2.50  .50.95  4
1550. 800.1800.44.0050.0035.00 3.50 2.50  .50.90  4
1550. 800.1800.44.0050.0035.00 3.50 2.50  .50.75  4
```

Example input for LCHANGE

FORMAT

VN	VR	VUNR	SN	SR	SUNR	GAR	GAUNR	HM	XP	N	
1 2 3 4 5	6 7 8 9 10	11 12 13 14 15	16 17 18 19 20	21 22 23 24 25	26 27 28 29 30	31 32 33 34 35	36 37 38 39 40	41 42 43 44 45	46 47 48 49 50	51	52 53
F5.0	F5.0	F5.0	F5.2	F5.2	F5.2	F5.2	F5.2	F5.2	F5.4	I1	

Input values:

1. With .95 probability

1550.	800.	1800.	44.00	50.00	35.00	3.50	2.50	0.50	.950	4

2. With .90 probability

1550.	800.	1800.	44.00	50.00	35.00	3.50	2.50	0.50	.900	4

3. With .75 probability

1550.	800.	1800.	44.00	50.00	35.00	3.50	2.50	0.50	.750	4

LCHANGE -- LANE CHANGING MODEL
FEDERAL HIGHWAY ADMINISTRATION
DEPARTMENT OF TRANSPORTATION

Example output of LCHANGE

INPUT DATA

VN	=1550.	VR	= 800.	VUNR	=1800.	SN	=44.00
SR	=50.00	SLNR	=35.00	GAR	= 3.50	GAUNR	= 2.50
HM	= 0.50	XP	=.9500	N	=4		

OUTPUT CALCULATIONS (ALL VALUES IN FEET)

DNN	=	3823.	REQUIRE DISTANCE FOR CHANGING LANE FROM NORMAL LANE TO ADJACENT NORMAL LANE
DUR.UR	=	3610.	REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT UNRESERVED LANE
DUR.R	=	2838.	REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT RESERVED LANE
DR.UR	=	3008.	REQUIRE DISTANCE FOR CHANGING LANE FROM RESERVED LANE TO ADJACENT UNRESERVED LANE
DON.P	=	11469.	REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE ENTRANCE OF THE PRIORITY LANE
DP.OFF	=	11469.	REQUIRE LANE CHANGING DISTANCE FROM EXIT OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP
DON.P.M	=	10058.	REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE MIDDLE OF THE PRIORITY LANE
DP.OFF.M	=	10228.	REQUIRE LANE CHANGING DISTANCE FROM MIDDLE OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP

END OF ABOVE SIMULATION

INPUT DATA

VN	=1550.	VR	= 800.	VUNR	=1800.	SN	=44.00
SR	=50.00	SUNR	=35.00	GAR	= 3.50	GAUNR	= 2.50
HM	= 0.50	XP	=.9000	N	=4		

OUTPUT CALCULATIONS (ALL VALUES IN FEET)

DNN	=	2800.	REQUIRE DISTANCE FOR CHANGING LANE FROM NORMAL LANE TO ADJACENT NORMAL LANE
DUR.UR	=	2680.	REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT UNRESERVED LANE
DUR.R	=	2003.	REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT RESERVED LANE
DR.UR	=	2233.	REQUIRE DISTANCE FOR CHANGING LANE FROM RESERVED LANE TO ADJACENT UNRESERVED LANE
DON.P	=	8399.	REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE ENTRANCE OF THE PRIORITY LANE
DP.OFF	=	8399.	REQUIRE LANE CHANGING DISTANCE FROM EXIT OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP
DON.P.M	=	7363.	REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE MIDDLE OF THE PRIORITY LANE
DP.OFF.M	=	7593.	REQUIRE LANE CHANGING DISTANCE FROM MIDDLE OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP

END OF ABOVE SIMULATION

INPUT DATA
....

VN	=1550.	VR	= 300.	VUNR	=1800.	SN	=44.00
SR	=50.00	SUNR	=35.00	GAR	= 3.50	GAUNR	= 2.50
HM	= 0.50	XP	=.7500	N	=4		

OUTPUT CALCULATIONS (ALL VALUES IN FEET)
....

DNN	=	1447.	REQUIRE DISTANCE FOR CHANGING LANE FROM NORMAL LANE TO ADJACENT NORMAL LANE
DUR.UR	=	1450.	REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT UNRESERVED LANE
DUR.R	=	900.	REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT RESERVED LANE
DR.UR	=	1208.	REQUIRE DISTANCE FOR CHANGING LANE FROM RESERVED LANE TO ADJACENT UNRESERVED LANE
DON.P	=	4341.	REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE ENTRANCE OF THE PRIORITY LANE
DP.OFF	=	4341.	REQUIRE LANE CHANGING DISTANCE FROM EXIT OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP
DON.P.M	=	3799.	REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE MIDDLE OF THE PRIORITY LANE
DP.OFF.M	=	4108.	REQUIRE LANE CHANGING DISTANCE FROM MIDDLE OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP

END OF ABOVE SIMULATION

```
INPUT DATA
**************************************************

VN        =1550.          VR        = 800.          VUNR      =1800.          SN        =44.00

SR        =50.00          SLNR      =35.00          GAR       = 3.50          GALNR     = 2.50

HM        = 0.50          XP        =.5000          N         =4


OUTPUT CALCULATIONS  (ALL VALUES IN FEET)
**************************************************

DNN         =      424.    REQUIRE DISTANCE FOR CHANGING LANE FROM NORMAL LANE TO ADJACENT NORMAL LANE

DUR.UR      =      520.    REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT UNRESERVED LANE

DUR.R       =       65.    REQUIRE DISTANCE FOR CHANGING LANE FROM UNRESERVED LANE TO ADJACENT RESERVED LANE

DR.UR       =      433.    REQUIRE DISTANCE FOR CHANGING LANE FROM RESERVED LANE TO ADJACENT UNRESERVED LANE

DON.P       =     1271.    REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE ENTRANCE OF THE PRIORITY LANE

DP.OFF      =     1271.    REQUIRE LANE CHANGING DISTANCE FROM EXIT OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP

DON.P.M     =     1104.    REQUIRE LANE CHANGING DISTANCE FROM ON RAMP TO THE MIDDLE OF THE PRIORITY LANE

DP.OFF.M    =     1472.    REQUIRE LANE CHANGING DISTANCE FROM MIDDLE OF THE PRIORITY LANE TO THE RIGHT HAND SIDE OFF RAMP

END OF ABOVE SIMULATION

LCHANGE (10/19/72) COMPLETED
```

APPENDIX J

ANNOTATED BIBLIOGRAPHY

A. Exclusive Lane Operations - Historical References

1. Cherniack, Nathan, "Transportation - A New Dimension of Traffic Engineering," Matson Memorial Award Paper, Institute of Traffic Engineers PROCEEDINGS, 33rd, 1963, pp. 38-48.

Cherniack discusses the concept of an all-highway type mass transit system utilizing buses and carpools operating in an exclusive or preferential reserved lane on urban expressways.

2. Zell, Charles, "San Francisco-Oakland Bay Bridge Trans-Bay Bus Riders Survey," HIGHWAY RESEARCH RECORD No. 114, Jan. 1965. pp. 169-179.

Zell surveyed bus riders in 1962 when an exclusive bus by-pass lane was in effect on the Bay Bridge. Bus patronage rose slightly.

3. Moskowitz, Karl, California Division of Highways, "Discussion of San Francisco-Oakland Bay Bridge TransBay Bus Riders Survey by Charles Zell," HIGHWAY RESEARCH RECORD No. 114, Jan. 1965. pp. 179-182.

Moskowitz discusses the use of exclusive bus lanes on freeways, and concludes that any such scheme, though encouraging occupancy shifts, would underutilize the freeway's inherent capacity.

4. May, Adolf D., A MATHEMATICAL MODEL FOR EVALUATING EXCLUSIVE BUS LANE OPERATIONS ON FREEWAYS, Institute of Transportation and Traffic Engineering, University of California, Berkeley, California, 1968.

May develops a mathematical model for evaluating potential travel time savings accruing from the implementation of various exclusive bus lane schemes. Model is computerized.

5. Highway Research Board, Special Report 87, 1965 HIGHWAY CAPACITY MANUAL, National Academy of Sciences -- National Research Council, Washington, D.C., 1965.

Handbook of traffic engineers. Used extensively in calculation of roadway capacities, speed-flow/capacity relationships, and queueing lengths and delays. General reference.

6. Stock, W.A., A COMPUTER MODEL FOR EXCLUSIVE BUS LANES ON FREEWAYS, Institute of Transportation and Traffic Engineering, University of California, Berkeley, California, July 1969.

Bill Stock improved the realism of the EXCBUS Model by incorporating a more realistic peak period demand over time; piecewise linear, triangular, or trapezoidal demand curves could be used. A variety of speed/flow submodels could now be used.

7. Morin, Donald A., and Curtis D. Reagan, "Reserved Lanes for Buses and Carpools," TRAFFIC ENGINEERING, V. 39, no. 10, July 1969. pp. 24-28.

Article discusses Moskowitz's conclusions, presents new passenger-time curves, and shows that by reserving an exclusive lane for both buses and carpools, and with occupancy shifts, passenger time savings could result.

8. Sparks, G.A., and Adolf D. May, A MATHEMATICAL MODEL FOR EVALUATING PRIORITY LANE OPERATIONS ON FREEWAYS, Institute of Transportation and Traffic Engineering, University of California, Berkeley, California, 1970.

A great improvement of the previous exclusive bus lane model, this model takes into account both carpools and buses. Many of the more serious limitations of the earlier model were eliminated.

9. Goodman, Joseph M., "Operation of a Freeway Priority System for Buses and Carpools," TRAFFIC ENGINEERING, V. 40, no. 7, April 1970. pp. 30-37.

Eleven different priority lane schemes are depicted and discussed. Attention is called to the fact that drastic changes in travel time result with changes in modal split, vehicle occupancy, highway capacity, and demand rates.

10. Makigami, Yaguchi, Lee Woodie, and Adolf D. May, BAY AREA FREEWAY OPERATIONS STUDY - FINAL REPORT - ANALYTICAL TECHNIQUES FOR EVALUATING FREEWAY IMPROVEMENTS, PART I OF III, THE FREEWAY MODEL, Institute of Transportation and Traffic Engineering, University of California, Berkeley, California, 1970.

A very thorough mathematical model which attempts to realistically duplicate actual freeway operations. The model takes into account the effects of on and off ramps, weaving sections, capacity restraints, varying demand patterns, and varying car occupancies, and can be used in both queueing and non-queueing situations.

11. Allen, B. L., and A. D. May, BAY AREA FREEWAY OPERATIONS STUDY - FINAL REPORT - ANALYTIC TECHNIQUES FOR EVALUATING FREEWAY IMPROVEMENTS - PART II OF III: ON THE SAN FRANCISCO-OAKLAND BAY BRIDGE, Institute of Transportation and Traffic Engineering, University of California, Berkeley, California, August 1970.

A general study using FREEQ to analyze present and future freeway operations on the Bay Bridge. As part of this improvement study, Allen briefly considered priority lane strategies.

12. California Department of Public Works, "Feasibility Study on an Exclusive Lane for Buses on the San Francisco-Oakland Bay Bridge," HIGHWAY RESEARCH RECORD NO. 303, 1970. pp. 17-29.

Report of a study evaluating the potential of reserving one or more lanes on the Bay Bridge exclusively for buses. The report concludes that such a lane is not feasible due to greatly increased delay to automobile users.

13. Stock, W. A., Jin Wang, and Adolf D. May, PRIORITY LANE OPERATIONS ON THE SAN FRANCISCO-OAKLAND BAY BRIDGE, Institute of Transportation and Traffic Engineering Special Report, University of California, Berkeley, California, 1971.

The two mathematical models EXCBUS (6) and FREEQ (10) were applied to this heavily traveled freeway section and various priority lane schemes were tested for their potential traveltime savings. Optimum strategies showed some savings could result if such a priority lane operation were implemented in the westbound a.m. peak direction.

14. California Department of Public Works, "Feasibility Study on an Exclusive Lane for Buses and Carpools on the San Francisco-Oakland Bay Bridge," Sacramento, Ca. 1971.

This is a brief summary report of work undertaken by ITTE at the University of California and the State Division of Highways to evaluate an exclusive lane on the Bay Bridge for both buses and carpools. This led to an experiment beginning in December 1971 to try such a scheme.

15. Voorhees, Alan M. and Associates, FEASIBILITY AND EVALUATION STUDY OF RESERVED LANES FOR BUSES AND CARPOOLS. Final report of a research project for the Department of Transportation, Washington, D.C. 1971.

A very detailed report discussing the benefits and relative merits of implementing priority lane schemes on urban freeways. The Memorial Freeway in Cleveland was selected as a study area and exclusive lane operations thoroughly evaluated.

16. FREEWAY LANES FOR HIGH OCCUPANCY VEHICLES (First Annual Progress Report). State of California, Department of Public Works, December 1971.

This is the first annual report to the State Legislature highlighting the priority operations projects in California. The Bay Bridge priority lanes and Los Angeles' surveillance and control projects with priority entry at ramps are discussed.

17. PROGRESS REPORT ON PUBLIC TRANSPORTATION IMPROVEMENT PROJECTS (HP 24). Urban Mass Transit Administration and Federal Highway Administration, January 1972.

Washington reports on several on-going projects around the country involving reversible lanes for buses, priority lanes for buses and carpools, ramp metering with priority entry for buses, and exclusive bus roadways.

18. California Division of Highways, District 04, PROJECT REPORT #3052. PHASE I FOR THE IMPROVEMENT OF ROUTE 101 IN MARIN COUNTRY FOR TRAFFIC AND BUSES BETWEEN THE GOLDEN GATE BRIDGE AND NOVATO. July 1971.

This report describes the feasibility of installing a wrong-way reversible bus lane for northbound p.m. peak-hour buses. Similarly, a southbound scheme is also discussed.

B. Exclusive Lane Operations - Bus Priority Projects

19. Port of New York Authority, PLAN FOR AN EXCLUSIVE BUS LANE ON I-495 FROM THE NEW JERSEY TURNPIKE TO THE LINCOLN TUNNEL. New York, 1967.

Implementation of an exclusive bus lane on a 2½ mile portion of I-495 during the morning rush hours involves the reversal of a median lane. Bus volumes in this corridor reach 500 per hour.

20. Howard, Needles, Tammen, and Bergendoff, BUS FACILITY STUDY - HENRY G. SHIRLEY MEMORIAL HIGHWAY IMPROVEMENT. New York, 1964.

A report detailing the feasibility of building special bus transit facilities in a traffic artery such as the Shirley Highway near Washington, D.C.

21. "Separate Lane Speeds Buses Across Bay Bridge," METROPOLITAN TRANSPORTATION, V. 58, No. 3, March 1962.

A brief article on how A-C Transit converted an unused lane into a high-speed bus operation lane during reconstruction of the bridge in 1962.

22. "Reserved Lanes Shorten Commuting Time," METROPOLITAN, V. 67, No. 5, Sept. 1971. pp. 25-28.

Several different exclusive bus lane schemes in operation around the United States are pictured and discussed briefly.

23. Texas Transportation Institute, A SYSTEM TO FACILITATE BUS RAPID TRANSIT ON URBAN FREEWAYS. Research report to the Department of Transportation, Washington, D.C., 1968.

This report describes the feasibility of using traffic surveillance and control techniques to provide priority operation for buses on freeways. Special bus entry ramps and metering of autos to maintain free flow would provide rapid bus transit.

24. Golden Gate Highway and Transportation District, CONCEPTS AND ALTERNATIVES FOR TRANSPORTATION FACILITIES. Summary of consultants' reports, San Francisco, 1970.

Discussion of five long-range transportation plans. Various bus operating schemes are included, among them exclusive bus lanes and reversible lanes.

25. Urban Mass Transit Administration, ACTIVE BUS PRIORITY PROJECTS. In cooperation with the Federal Highway Administration, Washington, D.C., 1971.

Discussion of: Shirley Highway; Seattle Bluestreak; Pittsburgh PATways; San Bernardino freeway median construction; I-495 reversible lane in New Jersey; SF-Oakland Bay Bridge, etc.

26. Virginia Department of Highways, FEASIBILITY STUDY OF RESERVED LANES FOR BUSES AND CARPOOLS. Final report of a research project for the Federal Highway Administration, 1971.

27. "Buses Get Exclusive Use of Freeway Median-Shirley Highway," CIVIL ENGINEERING, ASCE, v. 40, no. 7, July 1970. pp. 68-72.

An 8-mile long median strip is being reserved for exclusive use by buses in northern Virginia. Benefits include traveltime savings for both auto and bus commuters, and are seen to far outweigh the initial construction costs.

28. "Bus Lane Expedites Commuters - New Jersey Turnpike," FLEET OWNER, Feb. 1971. p. 9.

A short article describing how 35,000 New Jersey-Manhattan commuters will save 15-minutes or more during morning rush hours aboard some 800 buses traveling in a special lane.

29. "A-C Transit Exclusive Bus Lane By-Pass Lane- Peak-hour Traffic," Transportation Research Forum PAPERS, 11th Forum, 1970. pp. 425-436.

Description of the "Special Permit" lane for transbay buses which is used to by-pass long queues and toll booth stops, so that buses zip by cars in the a.m. rush hours.

30. Tri-State Transportation Commission, URBAN CORRIDOR DEMONSTRATION PROJECT - MANHATTAN CBD - NORTH JERSEY CORRIDOR FINAL REPORT. August 1971.

Three reports describing and evaluating techniques for improving bus mass transportation in this heavily traveled urban corridor. The second report deals specifically with bus priority and traffic controls.

31. "Busway-Freeway Rapid Transit," Automobile Manufacturers Association, Detroit, 1969.

A case is made for bus rapid transit on freeways by metering traffic at on ramps, giving preferential treatment to buses. Special bus roadways and reserved bus lanes are also considered.

32. Crain, John L., THE RAPID TRANSIT BUS CONCEPT, Stanford Research Institute, 1963.

Crain discusses the concept of rapid transit bus operations, such as operating buses on freeways or allocating express lanes for exclusive bus use.

33. Atlanta Transit System, Inc., RAPID BUSWAYS, Atlanta, 1967.

Approximately 32 miles of exclusive bus roadways are proposed for Metropolitan Atlanta, mostly using railroad rights-of-way. These five radial routes are inexpensive, provide excellent rides through the congested inner areas, and could be converted to rail transit at some future date.

34. Glennon, John C., "Balanced Transportation Through Efficient Use of Existing Facilities," TRAFFIC ENGINEERING, V. 40, no. 11, Aug. 1970. pp. 32-41.

This article describes research aimed at increasing the efficiency of freeways by employing freeway surveillance and ramp control to facilitate bus rapid transit on freeways. The people-moving capacity can be increased by as much as 100%.

35. Glennon, John C., and Virgil G. Stover, "A System for Bus Rapid Transit on Urban Freeways," TRAFFIC QUARTERLY, October 1969. pp. 465-484.

An excellent comparison of the economics of bus rapid transit on freeways with reserved bus roadways, a Skybus exclusive guideway, and rail rapid transit. Buses are allowed priority entry into a controlled freeway and move in mixed traffic.

36. Metropolitan Council of the Twin Cities Area, I-35W URBAN CORRIDOR DEMONSTRATION PROJECT: BUS-METERED FREEWAY SYSTEM. FINAL REPORT. 1971.

The report discusses several ways for improving traffic flow on this important freeway leading into the central business district of Minneapolis. The final plan opted for calls for ramp control with priority entry for express buses. Freeway speeds will be maintained above 40 mph with the ramp control.

37. Turner, Francis C., RESERVED BUS LANES, Bureau of Public Roads Instructional Memorandum 21-13-67. Aug. 1967.

"The FHWA urges the reservation of freeway lanes for the exclusive or preferential use of buses where and when conditions warrant." The FHWA's stated purpose is to aid every means of increasing the productivity of the existing highway system - i.e., the greater use of buses.

38. Bureau of Public Roads Circular Memorandum, MASS TRANSPORTATION AND THE URBAN HIGHWAY PROGRAM. Washington, D.C., April 1968.

The BPR issues a statement of policy which encourages agencies to submit applications for improving bus operations on freeways, especially with regard to exclusive lanes, reversible lanes, or priority entry ramps.

39. Turner, Francis C., "Moving People on Urban Highways," TRAFFIC QUARTERLY, V. 24, no. 3, July 1970. pp. 321-333.

Turner describes the BPR's part in encouraging planning and design for exclusive lanes on freeways for buses and carpools in several different cities. He emphasizes the need to think about moving people, not vehicles.

40. Messrs. Meyer, Kain, and Wohl, THE URBAN TRANSPORTATION PROBLEM. The RAND Corporation, Harvard University Press, 1965.

An objective and very thorough look at the urban transport problem in the United States. Economic, social, and environmental issues are addressed. Chapter 12 talks about express busways on freeways as being an inexpensive and excellent way to provide rapid transit for most American cities.

41. Kain, John F., "How to Improve Urban Transportation at Practically No Cost," in U.S. Congressional Joint Economic Session, 1969. pp. 1145-1156.

The best opportunity for improving the use of urban expressways at almost no cost is to provide for freeway bus rapid transit. Nearly every US city can benefit from some kind of freeway rapid transit and forego building massive new rail or freeway facilities at tremendous costs.

42. Texas Transportation Institute, GAP ACCEPTANCE AND TRAFFIC INTERACTION IN THE FREEWAY MERGING PROCESS. Bureau of Public Roads Research Project, completed October 1970. D. R. Drew and J. H. Buhr were principal researchers.

43. Baytheon Company, DEVELOPMENT OF MERGING CONTROL SYSTEMS. Bureau of Public Roads Research Project. T. White and D. Bushnell were the principal investigators.

44. ITTE, University of California, Los Angeles, EXIT RAMP EFFECTS ON FREEWAY SYSTEM OPERATION. Research project completed October 1970. Case, Mosher, and Weber were principal investigators.

Study includes mathematical models to analyze weaving and merging patterns upstream for motorists exiting from freeways.

45. Worrall, R. D., and A.G.R. Bullen, "An Empirical Analysis of Lane Changing on Multilane Highways," HIGHWAY RESEARCH RECORD No. 303, 1970. pp. 30-43.

This paper describes a macroscopic analysis of lane-changing behavior on multilane highways. It includes descriptions of the patterns and frequency of lane changing maneuvers observed under varying road and traffic conditions, as well as maneuver lengths and times, and gap acceptance and rejection by lane-changing vehicles.

46. Polytechnic Institute of Brooklyn, WEAVING AREA OPERATIONS STUDY. AASHO-FHWA Research Project. Completed March 1971.

47. Texas Transportation Institute, OPTIMIZING FLOW IN AN URBAN FREEWAY CORRIDOR. Bureau of Public Roads Research Project. Completed June 1971.

48. Texas Transportation Institute, FACTORS AFFECTING LEVEL OF SERVICE ON CONTROLLED ACCESS FACILITIES. Bureau of Public Roads Research Project.

49. Auto Traffic Systems Lab, AUTOMATIC TRAFFIC CONTROL FOR BUSES JOINING THE MOTORWAY. Research Project, Delft, Holland. Completed July 1970.

50. Wilbur Smith and Associates. A METHOD FOR ESTIMATING THE IMPACT OF TRAVEL TIME OR COST CHANGES ON DIVERSION OF CAR DRIVERS TO TRANSIT - WORK TRAVEL TO CBD. 1968.

A shortcut formula was prepared which can be used to measure the effect of cheaper and/or faster public transit on the use of cars in an urban area. This formula can be used to predict the number of drivers who could be expected to divert to transit riding for the home-work trip.