COMPUTER SIMULATION MODEL FOR EVALUATING PRIORITY OPERATIONS ON FREEWAYS

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The computerized model PRIFRE can be used to evaluate any number of different reserved-lane strategies. Although it was primarily intended to evaluate one-way normal priority-lane operations on the same side of the freeway median as the unreserved lanes, it can be used, with some manual interfacing, to evaluate wrong-way reversible lanes, separate bus roadways, and freeway design improvement strategies. Basic assumptions inherent in the model are given. Significant advantages of the PRIFRE over other models are described. The input, output, methodology for using the model, and interpretation of output are described. Traffic performance measures output to the user include single trip times, queuing times, total travel time, total travel distance, and messages. Search procedures and selection of best strategy are discussed, and areas for further research and improvement are indicated.

•THE urban freeway-expressway networks of cities in the United States 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 congestion and storage in the central city during working hours are also limited, and it is doubtful that much additional street and parking capacity can be provided. Lastly, public attention today is being focused more and more on the aesthetic and ecological disbenefits of overdependence on the automobile, with some observers calling for an outright ban on the use of automobiles in central cities.

One means of alleviating these transportation problems is to explore innovative methods of moving people rather than vehicles. Although entirely new systems to transport people could be constructed at considerable cost, the existing highway network could accommodate many more persons at a much lower cost if a proper redistribution of people to higher occupancy modes could be achieved (1). The reserved-lane concept is one promising method of attempting to achieve this goal; high-occupancy modes—buses and car pools—are given special preference in congested segments of freeways and expressways. This is accomplished by establishing separate lanes for these modes, allowing these vehicles to bypass traffic bottlenecks. Reserved lanes could be simply exclusive bus lanes; however, in most instances a single lane reserved exclusively for buses would be considerably underutilized from a vehicular capacity standpoint. For instance, 60 buses per hour carrying 50 passengers each would considerably underutilize a freeway lane that might be able to carry as many as 800 buses per hour, yet the lane would still be carrying 3,000 passengers per hour, more than might be expected from normal automobile traffic. Therefore, it will usually be more practical to use priority lanes for both buses and car pools and thereby increase the total benefits.

Some of the objectives for improving the urban transportation system through the use of priority-lane operations are to maximize the flow of people, minimize the total

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travel times, improve enviornmental factors such as air and noise pollution, minimize total travel costs, minimize the number of vehicles entering the downtown CBD, improve the quality of travel, and improve the safety of travel. Priority-lane operations should accomplish some or all of these objectives, particularly maximizing the flow of people on existing systems and improving the environment. A significant aspect of priority-lane operations is that it could offer a real choice in travel modes from the user's standpoint by equalizing total travel times by bus and automobile, something that our present transportation systems lack. A subsequent shift to buses and car pools, if exercised by enough people, could reduce traffic congestion significantly, postpone or eliminate the need to build additional freeways, and provide for an inexpensive mass transit alternative to a fixed-guideway rapid transit system.

HISTORICAL BACKGROUND

Traffic engineers around the country today are faced with investigating the many possible priority-lane strategies applicable to their particular situations. Many man-hours of hard work are required to analyze all of the more promising possibilities. A time-saving analytical tool is needed to evaluate and compare the various strategies.

Since 1968 a series of analytical models has been developed at the Institute of Transportation and Traffic Engineering (ITTE) at the University of California, Berkeley, to assist in the evaluation of reserved-lane schemes. These models differ only in their degree of sophistication and extensiveness of applicability. The basic philosophy of each is the same: The total travel time (passenger-hours) for the normal operation 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 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, 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 on curves given in the Highway Capacity Manual (Fig. 9.1, 5). This model was known as EXCBUS.

Next, Sparks and May (8) in 1969-70 broadened Stock's model to a full priority-lane model, permitting the evaluation of the mixed use of reserved lanes by both buses and car pools. The model, although now both a bus and car pool model, retained the EXCBUS name (19). 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 of using priority lanes (15).

As convenient as the preceding models were to use, they lacked the realism of having a demand pattern that 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 at grades, lane drops, ramp merges and diverges, and with weaving. Thus the need for a more realistic model was apparent. Such a model for normal freeway operations has been developed at ITTE by Makigami, Woodie, and May (10) as an aid for the evaluation of freeway improvements. This model, known as the freeway model, or FREEQ, does consider the effects of changing demands and capacities over both time and distance.

The latest research culminated in June 1972 with a very sophisticated and useful model named PRIFRE (20). This model has been computerized and can evaluate any number of different reserved-lane strategies.

MODEL DESCRIPTION

PRIFRE was developed primarily to evaluate one-way normal priority-lane operations, i.e., reserved lanes 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, and freeway design improvement strategies.

Basic Model Assumptions

Basic assumptions inherent in the model are as follows:

1. Traffic is treated as a compressible fluid where vehicles are not considered individually.
2. Within each 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 vehicle demands propagate downstream instanteously, subject of course to capacity constraints.
4. Capacities of subsections, including weaving sections and merging points, are estimated using the Highway Capacity Manual methods.
5. No weaving will be allowed between priority lanes and nonpriority 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 to 30 mph. Thus, throughout PRIFRE (the priority-lane model), the priority sections are treated as an isloated roadway with no entry or exit except at the beginning and end of the section.
6. The freeway model, FREEQ, is indeed an accurate model of a freeway under nonpriority operations. It has been validated against actual freeway operations in several cities.
7. No queuing 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 changed to nonpriority status.

Major Improvements to the Model's Realism

Significant improvements over the earlier EXCBUS model are as follows:

1. The introduction of time slices to the study period and subsections to the study section to allow for the handling of a wider range of possible demand patterns, off- and on-ramp traffic, and changes in the capacity of the study section over time and location;
2. The introduction of a varying demand pattern for buses rather than the previously assumed uniform or constant proportion demand pattern;
3. The introduction of both automobile and bus vehicle-occupancy distributions that are a function of time and not constant as currently assumed;
4. The use of three speed-flow relations—one for normal traffic, one for traffic in the reserved lanes, and one for traffic in the unreserved lanes; and
5. The introduction of truck equivalency factors to compensate for the effects of truck traffic on traffic flow.

It is felt that the PRIFRE model as it now exists represents the most comprehensive analytical tool available for evaluating priority operations on freeways.

Manual Checking of Program

An extensive program check was performed on the PRIFRE model to ensure that the computer simulation of freeway situations encountered was as prescribed in the mathematical model formulation and was an accurate representation of actual operations. All possible effort was made to include those features in the model program that facilitate the evaluation of priority-lane operations on freeways. The final assumptions and limitations of the model are documented in the PRIFRE report (20).

Input to the PRIFRE Model

In order to make a reasonable estimation of the travel time on a freeway, we must know the physical and operational characteristics of the freeway and 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 relation 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 that exhibit the properties of constant capacity and demand over their lengths. It is also necessary to itemize the features that affect the capacity of each subsection, such as design speed, number of lanes, lane width, volume of buses, percentage of grade, grade length, number of priority lanes, and location of on- and off-ramps. Traffic factors, such as percentage of trucks, that affect subsection capacities and are hypothesized to be constant over the peak period should also be given in the same table. It is convenient for later analysis to list all of these elements in the format given in Table 1. These elements are used to calculate the capacity of each subsection.

Traffic demands are introduced in 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 are considered as destinations. The origins and destinations are numbered consecutively from upstream to downstream.

Because 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-min time interval should be used because 15 min 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 other vehicles (Tables 2 and 3).

Although this method of treating traffic demand is complex, it yields the following desirable characteristics:

1. Actual demand patterns are more realistically simulated,
2. Travel times for individual O-D movements can be readily obtained and are essential for evaluating the effectiveness of improvements such as ramp control,
3. The resultant freeway priority-lane model exhibits a flexibility that will facilitate considerations of network traffic movements and patterns, and
4. It facilitates future growth forecasts because each O-D movement can be multiplied by a common factor.

Output From the PRIFRE Model

The PRIFRE computer program conveys many useful results to the user. The format of Table 4 includes the number of freeway lanes, reserved and unreserved, and their original and actual volumes, capacity, volume-capacity ratio, density, average speed, and individual subsection travel times. The number of vehicles in queue is listed for all on-ramps and merge points that have delays for that time slice. Table 4 gives output under normal operations only, and Table 5 gives output under priority operations. Tables 6 and 7 give the single trip time for priority and nonpriority trips respectively for each O-D movement. Under normal operations, Tables 6 and 7 are the simple product of the single trip time matrix multiplied by the O-D table, giving the total travel time in hundredths of vehicle-hours for each O-D movement. When a priority-lane situation exists, only single trip times will be printed out. 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 nonpriority vehicles (Table 8).

METHODOLOGY FOR USING THE MODEL

For the evaluation of priority-lane operation schemes, it is first necessary to obtain a satisfactory simulation of the existing freeway operations. The procedure for the evaluation of priority-lane operations using the PRIFRE model is shown in Figure 1. Basically, a satisfactory simulation of the existing freeway operation is first obtained as the basis for comparing alternative priority-lane operation schemes as well as for

Table 1. Freewav subsection parameters.

Sub-section	No. of Lanes	Capacity	Reserved Capacity	Length (ft)	Speed-Flow/Capacity (curve no.) Normal	Unre-served	Re-served	Truck Factor	Subsection Description
1	4	10,000		200	3	3	3	0.97	Tollbooth
2P	4	7,200	1,500	400	4	4	4	0.97	Acceleration area, start reserved lanes
3P	4	7,200	1,500	5,400	5	5	5	0.97	Golden Gate Bridge
4P	4	6,890	1,500	600	5	5	5	0.97	
5P	4	6,751	1,500	200	5	5	5	0.97	Wrong-way bus crossover
6P	4	6,752	1,500	600	5	5	5	0.97	Neglect Vista Point on-off ramp
7P	4	6,500	1,500	600	5	5	5	0.72	Alexander (formerly Sausalito)
8P	4	6,500	1,500	3,000	5	5	5	0.72	
9P	4	6,400	1,500	1,050	5	5	5	0.72	Waldo Tunnel
10P	4	6,500	1,500	1,600	5	5	5	0.72	
11P	4	6,961	1,500	2,320	5	5	5	0.97	Spencer
12P	4	7,294	1,500	2,500	5	5	5	0.97	
13P	4	7,294	1,500	550	5	5	5	0.97	Rodeo
14P	4	7,294	1,500	4,850.	5	5	5	0.97	
15P	4	7,294	1,500	1,800	5	5	5	0.97	Marin City
16P	4	7,470	1,500	1,000	5	5	5	0.97	Capacity adjusted, large weave effect
17P	4	7,294	1,500	1,400	5	5	5	0.97	Bus crossover
18	4	7,294		3,000	5	5	5	0.97	Main line, Richardson Bay Bridge
19	3	5,820		800	5	5	5	0.97	
20	3	5,820		3,600	5	5	5	0.97	Main line, south of Tiburon

Table 2. Bus O-D matrix (in buses per hour).

On-Ramp	Off-Ramp 1	2	3	4	5	6	7	8	9	10
1	0	0	0	32	0	0	0	16	0	4
2			8	0	0	16	0	0	0	0
3				6	0	0	0	4	0	0
4					0	0	0	0	0	0
5						12	0	8	0	20
6							0	0	0	0
7							0	16	0	4
8							0	16	0	0
9								8	20	8
10								8	0	4
11									0	40
12										

Table 3. Automobile O-D matrix (in persons per hour).

On-Ramp	Off-Ramp 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	326	286	192	194
3		49	154	207	68	43	154	136	91	52
4			65	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 4. Output for normal freeway operations.

Sub-section	Adjusted On-Ramp Volume	Adjusted Off-Ramp Volume	Original Demand	Volume	Freeway Capacity	Weave Effect	Volume-Capacity Ratio	Density (vehicle/mile/lane)	Speed (mph)	Travel Time (min)	Length (ft)	Queue (ft)	Rate of Flow of Excess Removal (vph)
1	5,966	0	5,966	5,966	10,000	0	0.60	39	38	0.06	200	0	0
2	0	0	5,966	5,966	7,200	0	0.83	32	47	0.10	400	0	0
3	0	0	5,966	5,824	7,200	0	0.81	33	44	1.42	5,400	731	142
4	0	0	5,966	5,824	6,890	0	0.85	63	23	0.30	600	600	142
5	0	0	5,966	5,824	6,751	0	0.86	67	22	0.16	300	300	142
6	0	194	5,966	5,824	6,752	0	0.86	67	22	0.31	600	600	142
7	0	0	5,772	5,630	6,500	0	0.87	64	22	0.31	600	600	142
8	40	0	5,812	5,670	6,500	0	0.87	64	22	1.54	3,000	3,000	142
9	0	0	5,812	5,670	6,400	0	0.89	63	23	0.53	1,050	1,050	142
10	0	491	5,812	5,670	6,500	0	0.87	64	22	0.82	1,600	1,600	142
11	0	0	5,321	5,179	6,961	0	0.74	72	18	1.47	2,320	2,320	142
12	291	19	5,612	5,470	5,470	0	1.00	61	30	0.95	2,500	0	0
13	0	0	5,592	5,441	5,470	0	1.00	61	30	0.21	550	0	0
14	0	63	5,592	5,451	5,470	0	1.00	61	30	1.84	4,850	0	0
15	0	0	5,528	5,388	5,470	0	0.98	55	32	0.46	1,300	0	0
16	511	831	6,039	5,809	6,500	910	0.89	42	46	0.25	1,000	0	0
17	0	0	5,175	4,979	5,470	0	0.91	37	44	0.36	1,400	0	0
18	180	379	5,355	5,159	5,470	0	0.94	44	39	0.87	3,000	0	0
19	0	0	4,953	4,700	5,820	0	0.82	34	47	0.19	800	0	0
20	120	4,900	5,083	4,900	5,820	0	0.84	35	47	0.88	3,600	0	0

calibrating model parameter values. The traffic performance measures of alternative schemes output by the PRIFRE model are then compared manually, and the best schemes are selected through a search process. The major steps of the evaluation procedure are described as follows.

Preparation of Input Data

Freeway Design Characteristics—The freeway design parameters that are necessary to evaluate freeway operations in the PRIFRE model are given in Table 1. The data shown are always for one side of a freeway only; data are input on eight separate card formats, as shown in chapter 3 of the PRIFRE report (20). Up to 50 subsections may be used, and the freeway section studied is usually limited to less than 10 miles, the distance a vehicle is able to travel in one 15-min time slice. The capacities for the freeway subsections can be determined by using the Highway Capacity Manual method or from actual volume measurements. The traffic flow data are usually not available to determine the capacity of the reserved lane on a freeway section under priority operations and must be assumed based on traffic experience and judgment (for the Marin 101 example in the PRIFRE report it was assumed that the capacity of the reserved lane approximates the conditions of tunnel traffic behavior).

The computer program contains five speed-flow/capacity curves—three from the Highway Capacity Manual for design speeds of 50, 60, and 70 mph; one from San Francisco-Oakland Bay Bridge (design speed of 55 mph); and one from I-80 Eastshore Freeway (design speed of 65 mph). The user may also input his own special speed-flow/capacity relation by supplying the appropriate data.

Traffic Characteristics—A study time period of sufficient duration is first selected, and O-D tables for both buses and other vehicles are then prepared. Three kinds of traffic data help in preparing a complete set of O-D tables for the input data to the model: volume counts, aerial photographs, and O-D surveys. The user then selects the appropriate values for bus-equivalency factor and bus-occupancy and automobile-occupancy distributions for each time slice.

Selection of Priority Strategies—The user selects the type of priority-lane strategy he wants to analyze; i.e., number of priority lanes, "wrong-way" lanes, separate busways, and so forth. Next he decides the location, beginning, and end of the priority lane. Then he selects the minimum vehicle-occupancy level for priority qualification status. This priority cutoff might be for buses only, or buses plus car pools with specified minimum-occupancy level. Next, the user considers occupancy shifts from nonpriority automobiles into priority car pools, e.g., 3, 6, and 9 percent shifts are chosen for evaluation and data input on the proper cards. Similarly, modal split shifts, i.e., automobile passenger to bus passenger, may also be chosen, but new O-D tables must be prepared to accomplish this. Finally, growth periods for anticipated traffic demands in future years may also be considered by choosing an appropriate factor by which all O-D table entries are multiplied uniformly.

Interpretation of Output

The PRIFRE program simulates various operation strategies and gives several traffic performance measures to the user including the following.

Single Trip Times—Single trip times for priority vehicles in the reserved lane should always be less than the corresponding single trip time for nonpriority vehicles—otherwise there will be little or no incentive to use the reserved lane. Occupancy shifts can be assumed to occur in direct proportion to the number of minutes saved in the reserved lane. If any single trip times are greater than 15 min, the length of one time slice, the model's limiting assumption concerning total travel time has been exceeded and results should be qualified.

Queuing—The traffic performance output should be examined for excessive queuing lengths and duration. If queuing extends out of the first freeway subsection or past the last time slice at the end of simulation, results should be qualified. The user may also have operation constraints of his own that may not be exceeded without interfering critically with the operation of the freeway. All queues should be checked to see if they are reasonable, using queuing contour maps if available.

Total Travel Times—The program automatically compares the total travel time under priority operations with the total travel time under the corresponding normal operation and gives the total travel time saved (+) or lost (-). A saving in travel time usually indicates a corresponding saving in all other categories selected as measures of effectiveness. Therefore, this output has been selected as the major measure of effectiveness for comparing priority-lane strategies under the search process shown in Figure 2.

Total Travel Distance—This output can be used to calculate vehicle operating cost savings, accident savings, and pollution savings, which are based on the number of vehicle-miles.

Messages—There are several warning messages built in the PRIFRE program that can signal the user of critical or unusual freeway performances, such as an overloaded off-ramp, ramp queuing delays, excessive queue lengths, queue collisions, or excess demand for the reserved lane.

Search Procedure

Generally, results from the many possible priority strategies can best be displayed by tabulating them in some graphical form. Total travel-time saving can be used as the basis of comparison for selecting the more promising strategies for further evaluation. In the search process, one returns to the original assumptions made for the freeway design characteristics, the traffic demand characteristics, and the selection of the priority strategy and adjusts these to suit his particular needs (dashed lines, Fig. 1).

Selection of Best Strategy

The user analyzes the model results, compares them with previous runs, and decides if further strategies or refinements are needed until he is satisfied that the most promising options have been reached. He can then prepare an evaluation summary table showing the best strategies by their benefits and costs. This table can then be presented to those policy-makers who will make the final decision regarding the selection and implementation of the "best" priority-lane operating strategy.

FUTURE RESEARCH

The experience gained during the development and application of the model makes it possible to suggest a number of ways in which further realism and operational ease could be added to the model. Some of these are as follows:

1. Improve the method of inputting raw data into the program. Present formats require much manual manipulation of field data.
2. Make provisions for weaving analyses at the beginning and end of the priority lane. Currently, no adjustments are made for weaving conflicts.
3. Allow lane changing to take place between the priority lanes and the nonpriority lanes. Currently, the program does not allow vehicles to freely enter or leave the priority lane except at the beginning and end of the priority section.
4. Improve the queuing subroutines and capacity analysis in the program in order to make them more efficient and better understood by the user.
5. Include a provision for automatic modal split shifts, i.e., a passenger shift to buses, similar to automobile occupancy shifts to car pools. Now one must manually create new O-D tables reflecting new modal splits, a time-consuming task.
6. Improve the model so as to allow a full network to be modeled. Now parallel facilities are ignored, although they might be potential alternate routes.
7. Improve the model so as to better handle special reserved-lane strategies, such as wrong-way bus lanes, separate busways, and special ramp entries. Some manual manipulation is now required to accomplish this.
8. Enlarge the measures of effectiveness, or objective functions, to include safety, operational costs, pollution costs, parking and congestion costs in CBD's, etc., besides the present travel time and distance.

Table 5. Output for priority-lane operations.

Sub-section	Adj. On-Ramp Vol.	Adj. Off-Ramp Vol.	Original Demand	Reserved Priority Operations: No. of Priority Lanes	Vol.	Capacity	v/c	Density[a]	Speed (mph)	Travel Time	Unreserved or Normal Operations: Section[b]	No. of Lanes	Vol.	Capacity	Weave Effect	v/c	Density[a]	Speed (mph)	Travel Time	Length (ft)	Queue (ft)	Rate of Flow of Excess Demand (vph)
1	3,845	0	3,865								N	2	3,845	10,000	0	0.38	39	24	0.09	200	0	0
2	0	0	3,845	2	804	3,000	0.27	9	44	0.10	U	2	3,040	3,600	0	0.84	46	33	0.14	400	0	0
3	0	0	3,845	2	804	3,000	0.27	8	52	1.17	U	2	3,040	3,600	0	0.84	33	47	1.32	5,400	0	0
4	0	0	3,845	2	804	3,000	0.27	8	52	0.13	U	2	3,040	3,445	0	0.88	33	45	0.15	600	0	0
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14	0	100	3,716	2	804	3,000	0.27	8	52	1.05	U	2	2,347	3,647	0	0.64	50	24	2.60	4,850	4,850	564
15	0	0	3,616	2	804	3,000	0.27	8	52	0.23	U	2	2,247	3,647	0	0.62	75	15	1.01	1,300	1,300	564
16	522	495	4,138	2	804	3,000	0.27	8	52	0.22	U	2	2,760	2,769	966	1.00	46	30	0.38	1,000	0	0
17	0	0	3,554	2	804	3,000	0.27	8	52	0.30	U	2	2,274	3,647	0	0.62	23	49	0.33	1,400	0	0
18	220	236	3,179								N	4	3,299	7,294	0	0.45	18	50	0.68	3,000	0	0
19	0	0	3,505								N	3	3,063	5,820	0	0.53	21	50	0.18	800	0	0
20	119	3,182	3,624								N	3	3,182	5,820	0	0.55	21	50	0.83	3,600	0	0

[a]Vehicle per mile per lane. [b]N = normal and U = reserved.

Table 6. Travel time for one priority trip (in tenths of a minute).

On-Ramp	Off-Ramp 1	2	3	4	5	6	7
1	168	392	405	521	570	668	769
2		121	226	340	389	487	588
3			54	169	218	316	417
4				104	153	251	352
5					21	119	220
6						68	169
7							83

Table 7. Travel time for one nonpriority trip (in tenths of a minute).

On-Ramp	Off-Ramp 1	2	3	4	5	6	7
1	496	870	1,234	1,640	1,782	1,883	1,983
2		365	700	1,106	1,247	1,349	1,449
3			188	594	735	836	937
4				364	506	607	708
5					38	139	240
6						68	169
7							83

Table 8. Summary of travel times.

Factor	Current Time Interval: Vehicle-Hours[a]	Current Time Interval: Passenger-Hours[b]	Cumulative Values: Vehicle-Hours[c]	Cumulative Values: Passenger-Hours[d]
Freeway travel time (normal)	24	34	362	524
Freeway travel time (unreserved)	165	188	2,263	2,316
Freeway travel time (reserved)	14	35	370	934
Input delay (normal)	1,201	1,690	7,102	9,890
Input delay (unreserved)	110	158	1,874	2,694
Total travel time under priority operations	1,535	2,106	11,972	16,458
Total travel time under nonpriority operations	–	–	2,190	3,175
Travel time savings over nonpriority operations	–	–	-9,781.5	-13,283.0

[a]Total travel distance = 5,168 vehicle-miles.
[b]Total travel distance = 6,816 passenger-miles.
[c]Total travel distance = 87,707 vehicle-miles.
[d]Total travel distance = 125,301 passenger-miles.

Figure 1. Priority-lane operations evaluation procedure.

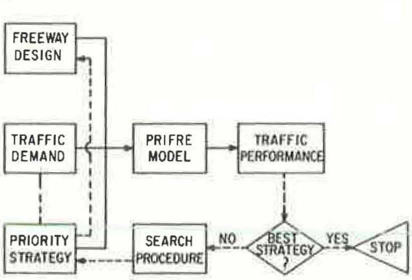
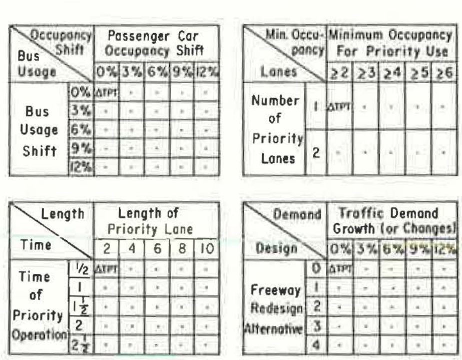


Figure 2. Measures of effectiveness data.



ΔTPT = Total Passenger Travel Time Difference

Along with these model refinements, extensive field research is needed to investigate priority-lane operations. Much can be learned from factual evaluations of existing and planned priority-lane demonstrations around the country. Also in the areas of education, safety, and law enforcement, research is needed to overcome the many present objections to priority-lane operations. Much information is needed on forecasting possible or probable occupancy shifts based on the user's perceived value of time and cost savings.

With more than 15 priority-lane projects now in operation around the country, it seems certain that much emphasis will be placed on evaluating these and other possible priority-lane operations in the next few years. Many new and diverse strategies will probably emerge. Traffic engineers and policy-makers will be called on to analyze and evaluate the strategy that best fits their particular area's needs. By using flexible, realistic computer simulation models, many more strategies and variations can be analyzed than would be possible if they were done by manual calculations. This diversity and sensitivity can only lead to a better insight and knowledge of possible priority strategies, and hopefully to sounder solutions, because more options can be considered for possible adoption and implementation.

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