Uses of the FREQ8PL Model To Evaluate an Exclusive Bus-High-Occupancy-Vehicle Lane on New Jersey Route 495

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The FREQ8PL freeway simulation model was used to aid in the evaluation of the feasibility of a proposed exclusive bus-high-occupancy-vehicle priority lane treatment on New Jersey Route 495 between the New Jersey Turnpike and the Lincoln Tunnel. The input data, assumptions, and usefulness of the model in assessing impacts of alternative treatments are described. The model was used as an aid in the evaluation of three possible configurations of an exclusive lane. The simulation results indicated the importance of maximum utilization of bottleneck sections. They also indicated the importance of beginning the priority lane before the start of queues of nonpriority vehicles. The simulations revealed a significant limitation of the FREQ8PL model: it cannot account for reduced processing capability at on ramps blocked by standing mainline queues. To remedy this, an external spreadsheet-based procedure for adjusting ramp volumes was developed. This external procedure was also needed to supplement the queue length and travel time information reported by FREQ8PL to obtain estimates of queue lengths and delay times on blocked ramps. Probable shifts in route of travel in response to the priority lane implementation were also estimated external to the FREQ8PL model, because of limitations in the model's ability to estimate such shifts. A lower level-of-service F speed-flow curve than that presented in the current *Highway Capacity Manual* was developed to replicate the dense, slow-moving queues observed on this freeway during peak periods. The spreadsheet program was also used to create several useful graphics displaying projected travel times and queue lengths.

New Jersey Route 495 is a 2.5-mi-long, six-lane freeway (three lanes per direction) running in an east-west orientation between the New Jersey Turnpike and the Lincoln Tunnel (see Figure 1). With the George Washington Bridge to the north and the Holland Tunnel to the south, the Lincoln Tunnel is one of the three Hudson River vehicular crossings providing access to Manhattan. As the only expressway-type facility feeding the Lincoln Tunnel, the Route 495 mainline carries some 15,000 vehicles, including automobiles, buses, and trucks heading toward Manhattan (eastbound) in a typical morning peak period (7:00-10:00 a.m.). The capacity of Route 495, together with two local street approaches that also feed the Lincoln Tunnel, significantly exceeds the a.m. peak-period three-lane eastbound capacity of the tunnel itself (estimated at 3,900 vehicles per hour). Extensive backups occur at the tunnel during peak traffic periods.

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In December 1970, one of the westbound lanes of Route 495 was officially opened as a contraflow lane exclusively for the use of eastbound buses during weekday morning rush hours. This became the first reverse-flow exclusive bus lane in the country, allowing commuter buses to bypass automobile and truck traffic backed up from the tunnel.

During a year's testing the exclusive bus lane (XBL) carried thousands of commuters daily at a time saving varying from 10 to 25 min. In 1971 more than 206,000 buses and 8.7 million riders used the lane. Because of the favorable indications at the end of the trial year, the XBL became a permanent part of the Lincoln Tunnel operation. Since this time, the XBL has progressed in terms of increased volume and physical or operational improvements.

XBL travel time has varied as its use has increased. The free-flow travel time at a recommended speed of 30-35 mph is about 5 min or slightly less, a figure that was achieved regularly until the early 1980s. With the implementation of a nonstop toll program for buses in March 1985, average XBL travel times have been maintained in the range of 5.5 to 6 min, in spite of peak-hour bus volumes approaching the capacity of the lane.

Since this time, however, XBL use has grown rapidly and peak-hour demand has exceeded the lane's capacity. This has caused bus backups at the entrance to the lane, where bus flows from the New Jersey Turnpike and New Jersey Route 3 merge. Delays of 4 to 5 min or more regularly occur at this location during the peak hour (7:30-8:30 a.m.). As a result, alternative improvements have been discussed, including conversion of the leftmost eastbound lane, designated "Lane 3," of Route 495 to exclusive bus and carpool use.

This paper describes the use of the FREQ8PL freeway simulation model, which was selected as the most applicable existing off-the-shelf computer program, for evaluating the proposed priority bus-high-occupancy-vehicle treatment for Lane 3.

BACKGROUND ON FREQ8PL

FREQ8PL is the latest in a series of freeway simulation models developed at the Institute for Transportation Studies (ITS), University of California, Berkeley (*1*). Released in 1985, FREQ8PL was designed for the evaluation of normal-flow (as opposed to contraflow) exclusive lanes (also called "priority lanes") on urban freeways.

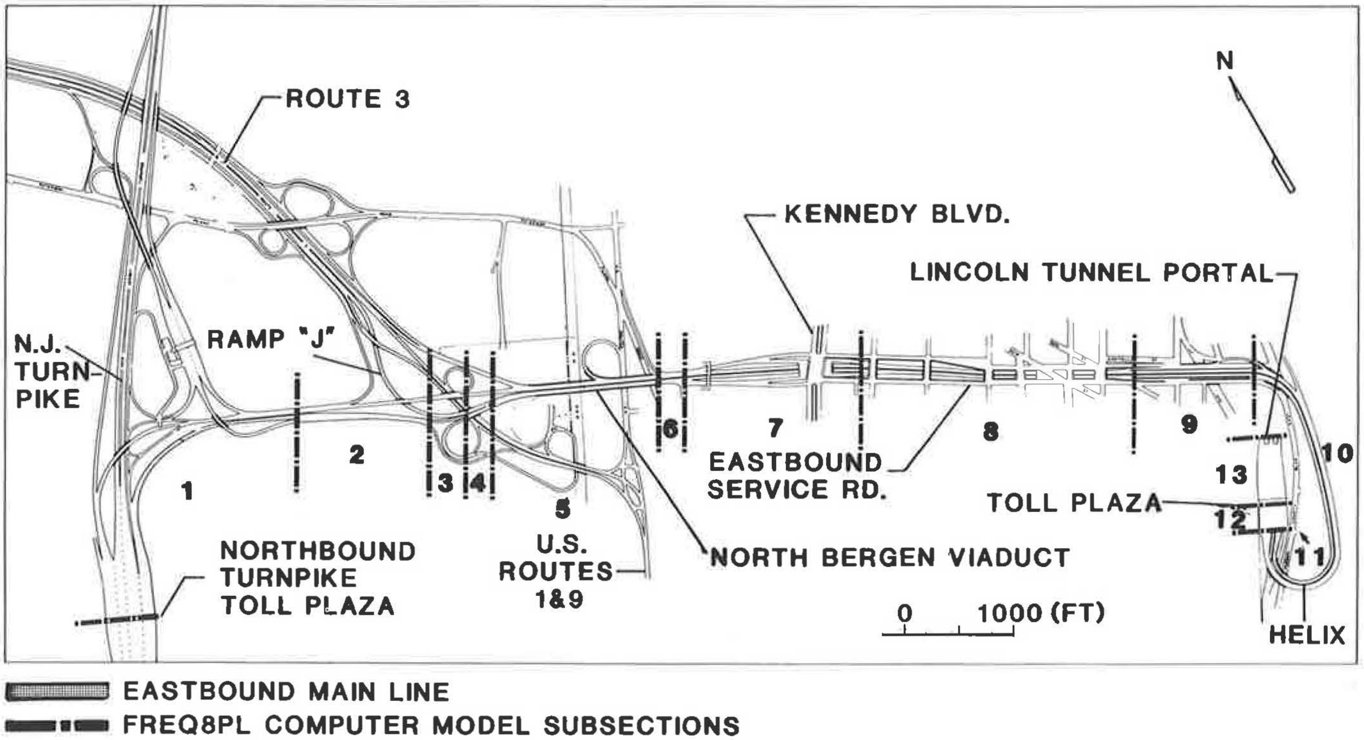

FIGURE 1 New Jersey Route 495 showing simulation subsections.

As described in detail earlier (*1*), FREQ8PL simulates the performance of a mainline freeway section divided into subsections reflecting major changes in demand or capacity. Inputs to the model include

- Ramp counts, reflecting the number of vehicles entering and exiting at each freeway ramp by time slice;
- Vehicle occupancy distributions (percent of vehicles by one-, two-, or three-plus-person occupancy) for each on ramp;
- A description of each subsection, including number of lanes, capacity, length, and whether the subsection has an origin (on ramp) or a destination (off ramp) or both; and
- Speed-flow curves, reflecting the relationships between speed and volume-to-capacity ratio, for each subsection type.

A submodel within FREQ8PL (called SYNPD2) estimates origin-destination trip tables by time slice (typically a 15-min period) based on the ramp counts. [A recently published article (*2*) discussed the effectiveness of using synthetic origin-destination data in freeway simulation models.] The inclusion of this submodel is one of the features that distinguishes FREQ8PL from its predecessors. FREQ8PL then performs a demand-capacity analysis for each time slice. Bottleneck locations where demand exceeds capacity are identified. The model then uses queueing theory and shock-wave theory (*3*) to calculate the extent of queueing upstream of the bottleneck locations. The speed-flow curves are used to calculate travel time in each subsection by time slice. Reports are generated showing the simulated travel times and queue locations, as well as other evaluation measures such as aggregate vehicle miles traveled, fuel consumption, and vehicle emissions.

FREQ8PL is capable of performing simulations for the following conditions:

- Before implementation of a priority lane,
- Short-term conditions after implementation of a priority lane (before route or mode shifts, or both, occur), and
- Longer-term conditions after implementation of a priority lane (after route or mode shifts, or both, occur).

FREQ8PL assumes that the priority lane is in operation during the entire time period being simulated. It also assumes that priority vehicles are free to enter and leave the exclusive lane at any point.

Additional information on the algorithms and assumptions used by the model is available in documents published by ITS (*4,5*).

For this analysis, the FREQ8PL model was installed on the Prime 550-II minicomputer located in the New York City office of URS Company, Inc.

DESCRIPTION OF MODELED STUDY SECTION

The mainline freeway section to be modeled was defined as eastbound New Jersey Route 495 beginning at the New Jersey Turnpike's eastern spur exits (16E and 17E) to the Lincoln Tunnel and continuing through the Lincoln Tunnel to New York. The modeled section includes the toll plaza for the Lincoln Tunnel, as well as the Lincoln Tunnel itself, which are operated by the Port Authority of New York and New Jersey. The Lincoln Tunnel toll plaza is made up of 14 toll lanes operated during morning peak periods, of which the leftmost two are almost entirely dedicated to the XBL and local buses.

The Lincoln Tunnel comprises three separate tubes: North, Center, and South, each carrying two lanes of traffic. The

North Tube is always westbound, the South Tube always eastbound, and the Center Tube lanes are reversed during peak periods to accommodate the peak direction flow. Thus, in the morning peak period, four tunnel lanes are available for eastbound (toward Manhattan) traffic. One of these lanes (the left lane of the Center Tube) is used almost exclusively by buses using the contraflow XBL, as well as buses entering from the local street system. The system modeled for this analysis did not include the XBL or the tunnel bus lane.

New Jersey Route 495 was divided into 16 subsections (subsections 1-13 are shown in Figure 1). A new subsection was started at each freeway entrance and exit. An additional subsection (6) was provided at the east end of the North Bergen viaduct, where it was initially assumed that the exclusive Lane 3 operation would begin.

Additional subsections were provided at the Lincoln Tunnel toll plaza, at the tunnel portal in New Jersey, at the beginning of the upgrade section in the tunnel, and at the tunnel portal in New York. Each of these represented a point where roadway capacity changes significantly.

Three possible exclusive lane configurations were tested: in the first a continuous exclusive bus-HOV lane was provided in the leftmost eastbound lane (Lane 3) of Route 495 beginning at the eastern end of the North Bergen viaduct and continuing through the Lincoln Tunnel toll plaza and into the right lane of the Center Tube (which would be entiredly dedicated to buses and HOVs). In the second configuration the exclusive Lane 3 operation ended at the Lincoln Tunnel toll plaza. In a third configuration the exclusive lane started in the left-hand lane of Route 3 (a major east-west six-lane freeway feeding Route 495), continued via the left lane of an existing left-hand ramp (Ramp J) from Route 3 to eastbound Route 495, and ended at the tunnel toll plaza.

DATA COLLECTION AND INPUT ASSUMPTIONS

Ramp classification counts and occupancy distributions were available from surveys conducted on four typical weekdays during 1984 and 1985. The period surveyed was 6:00 to 9:30 a.m. By averaging the data collected on these dates, a total eastbound demand of 13,800 cars and trucks was obtained, of which 65 percent were single-occupant passenger cars, 19 percent were two-occupant cars, 6 percent were three-or-more occupant cars, and 10 percent were trucks. Aerial photography was also used to identify times, locations, and densities of current queueing along the mainline roadway. Observations of mainline travel times at various time points throughout the peak period were also made to complete the volume-density-speed data base.

The number of lanes and length of each subsection were readily identifiable. Capacities for the freeway subsections were computed by using the conventional *Highway Capacity Manual* (HCM) [*Circular 212 (6)*] techniques. Subsection capacities were first computed in vehicles per hour by using the computed average percentage of trucks in each subsection over the 6:00-9:30 a.m. period to determine the adjustment factors for heavy vehicles. It was then decided that the wide fluctuation in truck percentages over this period made it inappropriate to use a single vehicle-per-hour figure to represent the capacity of each subsection over the entire morning peak period. Because FREQ8PL does not allow for the use of different capacities by time period for a given subsection, it was necessary to express all subsection capacities in equivalent passenger-car units (pcu). All freeway demand information was correspondingly converted from vehicles to pcu. A truck was taken to be the equivalent of two passenger cars.

Considerable care was taken in estimating the hourly capacity of the Lincoln Tunnel Toll Plaza. XBL and local buses were excluded, because it was not necessary to consider these vehicles for the simulation of existing conditions on the Route 495 main roadway approach to the toll plaza. "Audit sheets" showing the vehicles processed on November 31, 1984, at each toll lane at 14- or 16-min intervals were provided by the Port Authority. Excluding Lanes 7 and 9, in which the XBL and local buses predominate, the maximum observed processing rate for the entire toll plaza on this date was about 80 vehicles per minute, or 4,800 vehicles per hour. This value was tested as the capacity of the toll plaza in the simulation of existing conditions and was adjusted downward in order to produce simulated queue lengths that replicated observed queues and delay times as closely as possible. A final capacity estimate of 4,550 pcu/hr was obtained for the toll plaza, exclusive of Lanes 7 and 9.

The combined car and truck capacity of the three eastbound tunnel lanes during the morning peak period was estimated, using the HCM, at about 5,200 pcu/hr. This value was too high for use in the simulations, however, because the demand numbers took each truck to be the equivalent of two passenger cars, whereas in the upgrade section of the tunnel, an equivalency of 5 or 6 is more appropriate. Because the demand numbers could not be increased midstream, the tunnel capacity value had to be reduced to compensate. A capacity value of 4,400 pcu/hr for the three tunnel lanes was found to yield simulated queue lengths and delay times that were in close agreement with observed conditions.

The final hourly capacities used for each freeway subsection are given in Table 1.

TABLE 1 EASTBOUND ROUTE 495 SUBSECTION CHARACTERISTICS

Subsection No.	Length (ft)	Capacity (pcu/hr)	No. of Lanes
1	2,830	4,000	2
2	1,180	6,000	3
3	340	4,000	2
4	210	3,200	2
5	1,620	8,000	4
6	180	8,000	4
7	1,600	6,000	3
8	2,520	6,000	3
9	1,020	6,000	3
10	2,940	5,700	3
11	10	10,000	5
12	250	14,000	7
13	570	4,550	4
14	3,740	5,200	3
15	4,400	4,400	3
16	10	6,000	3

Four speed-flow curves (Figure 2) were input to FREQ8PL. Curve 1 was used to represent all sections of Route 495 from the New Jersey Turnpike to the beginning of the helix approach to the Lincoln Tunnel. Curve 2 was used for the helix and for the downgrade section in the Lincoln Tunnel. Curve 3 was used for the upgrade section of the tunnel, and Curve 4 was used for the 260 ft immedicately before the Lincoln Tunnel toll booths. The upper limits of these curves were based on speed runs performed on a Saturday morning, when traffic was very light. The remainder of each curve was adapted from the speed-flow curves in the HCM. The lower limbs of the curves (used for queued traffic, level-of-service F) are lower than those in the HCM. This results in denser, slower-moving queues, which more closely match the observed queue densities and speeds on Route 495.

SIMULATION OF EXISTING CONDITIONS AND CALIBRATION OF INPUTS

A series of simulations was performed in order to calibrate some of the key inputs to the FREQ8PL model. In particular, the capacities of three critical subsections, including the Lincoln Tunnel toll plaza and the upgrade section in the tunnel, were adjusted on the basis of the simulation outputs. The goal was to obtain capacity values that would yield simulated queue lengths and delay times in reasonable agreement with observed queues and delays.

Simulated queue lengths were compared with the queue lengths observed in aerial photographs taken on the mornings of October 16 and 17, 1985. Simulated travel times were compared with observed travel times from Port Authority runs conducted on various dates in 1985. As a result of adjusting the capacities of the critical subsections, close agreement was obtained between the simulated and observed queue lengths for specific time points during the peak period.

Simulated and observed travel times are shown in Figure 3 (produced using Lotus 1-2-3). It can be seen that the simulated times are generally in close agreement with the observed times.

SIMULATION OF SHORT-TERM CONDITIONS AFTER IMPLEMENTATION OF PRIORITY LANE

Assumptions

Short-term (or Day 1) simulations were performed for three configurations of a Lane 3 exclusive bus-HOV lane on Route 495. HOVs were defined as passenger vehicles with three or more occupants, because initial analyses indicated that a two-or-more HOV definition would overload the lane. The first configuration (called Long Lane) starts immediately east of the North Bergen viaduct and continues through the Lincoln Tunnel (with the right lane of the Center Tube being dedicated to buses and HOVs). For this configuration, it was assumed that four toll lanes at the tunnel would be dedicated to the buses and HOVs from Lane 3 and the local streets. Nine toll lanes would be available for the remaining two lanes of the Route 495 roadway and the local non-HOV traffic.

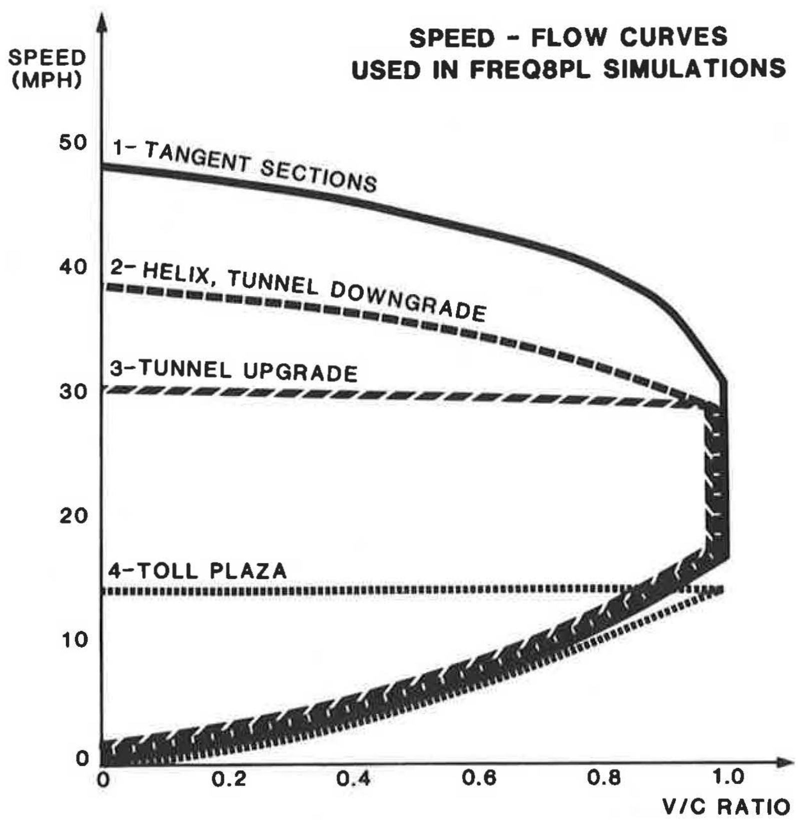

FIGURE 2 Speed-flow curves used in FREQ8PL simulations.

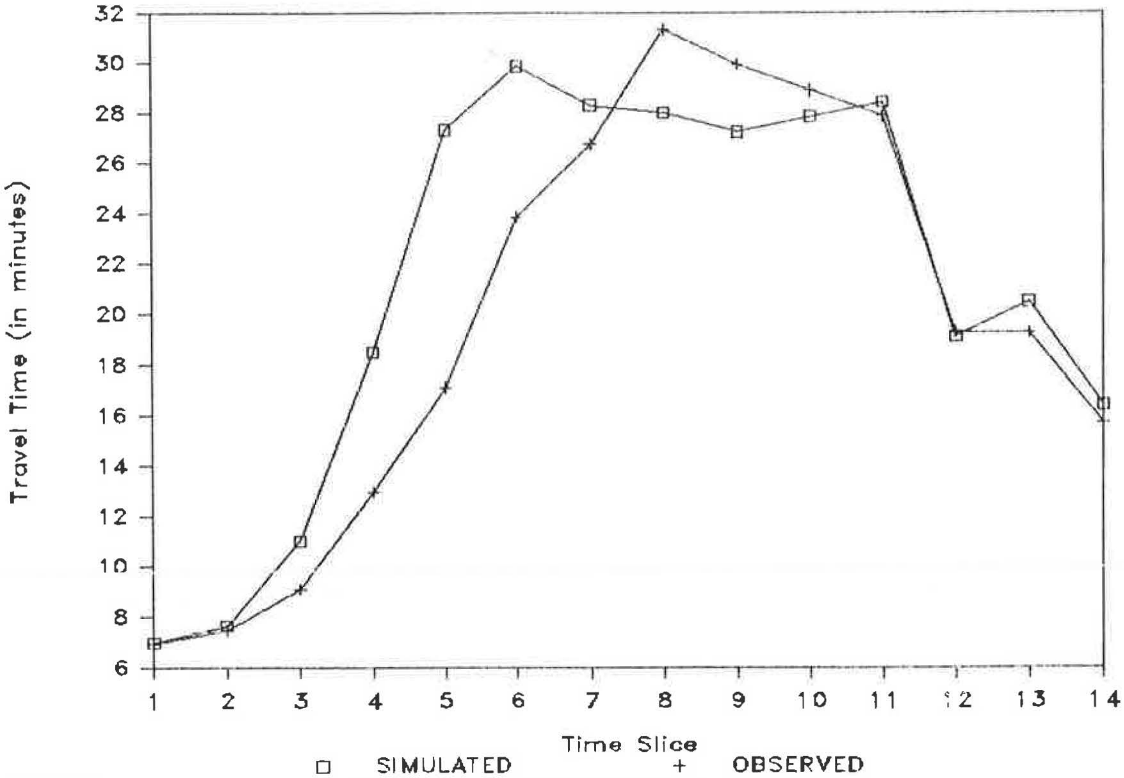

FIGURE 3 Route 495 mainline travel times: simulated versus observed.

In the second configuration (called Short Lane), the exclusive Lane 3 operation would end at the Lincoln Tunnel toll booths. Buses from Lane 3 would then be directed into either the left or right lane of the Center Tube, and HOVs would mix back in with the general traffic. The right lane of the Center Tube would be open to all traffic in order to achieve maximum use of the tunnel. For this configuration, it was assumed that only three toll lanes would be dedicated to the non-XBL buses and HOVs, whereas 10 lanes would be available to all other traffic.

A third configuration (called Short Lane 2) was based on the assumption that the exclusive lane would begin in the left-hand lane of Route 3, allowing buses and HOVs from Route 3 to bypass backups on Route 495. The lane would continue via the left-hand ramp onto eastbound Route 495 and into Lane 3, ending at the Lincoln Tunnel toll booths.

The assumed capacities of the various sections of the exclusive lane were as follows:

Tangent sections of Routes 3 and 495: 2,000 pcu/hr
Helix: 1,900 pcu/hr
Toll plaza: 1,520 pcu/hr for Long Lane; 1,140 pcu/hr for Short Lane and Short Lane 2 (380 pcu/hr/toll lane)
Downgrade section of tunnel: 1,730 pcu/hr (Long Lane only—as per HCM)
Upgrade section of tunnel: 1,470 pcu/hr (Long Lane only—one-third of 4,400 pcu/hr for three tunnel lanes)

For the short-term simulations it was assumed that no changes would occur in travel mode, route, or time period. The one exception was the assumption that some of the non-HOV traffic currently using the local street approaches to the tunnel would have to shift to the main Route 495 approach because of the need to close one of the local approaches to non-HOV traffic. This was logical insofar as this non-HOV traffic represents those vehicles currently diverting from the Route 495 mainline to the local street system for alternative routes to the Lincoln Tunnel entrances. For this analysis, these vehicles were shifted back to the Route 495 mainline by reducing the non-HOV off-ramp counts at the exits to the parallel local street.

It was assumed that the exclusive lane would be used by express buses from Route 3 (currently about 380 buses between 6:30 and 9:30 a.m. and peaking at about 190 buses from 7:30 to 8:30) as well as passenger vehicles carrying three or more occupants.

Ramp Volume Adjustments

When the short-term simulations were initially performed, a problem with the simulation algorithm was identified. The simulated queue in the non-priority lanes of Route 495 extended back beyond the northbound New Jersey Turnpike exit to the Lincoln Tunnel, blocking the other major input points to Route 495 from the southbound turnpike and from Route 3. The model assumes, however, that whatever volume is given for an on ramp is able to enter the freeway regardless of whether the entrance is blocked by a standing queue. The simulated mainline throughput is correspondingly reduced, causing the model to project unrealistically long backups.

The only way to rectify this situation was to reduce the ramp counts at the blocked ramps. Adjusted ramp volumes were calculated for each time slice during which the ramps are blocked by assuming that the maximum volume on a blocked ramp is a certain percentage of the volume on the freeway subsection into which the ramp feeds. The percentage varied by ramp depending on the configuration of the merge.

A spreadsheet-based model was constructed to calculate the adjusted ramp volumes and to keep track of the resulting queue on each ramp. When the simulation was rerun with the adjusted volumes, the mainline queue was reduced, causing some of the ramps to be blocked for a shorter period of time. This required the ramp volumes to be readjusted. This iteration was repeated several times.

Ramp queue delay times were estimated in the spreadsheet by dividing the estimated number of vehicles in the queue in each time slice by the assumed processing rate of the ramp. Ramp queue lengths were estimated by multiplying the estimated number of queued vehicles by 20 lane-ft per queued vehicle. This figure is based on the level-of-service F speed-flow curve adopted for the simulations with an assumed v/c of 0.25.

Results

The short-term simulations indicated the importance of maximum utilization of the eastbound lanes of the Lincoln Tunnel. This was demonstrated by the extent of queueing of nonpriority vehicles projected by the model. The extent of queueing on Route 495 projected by the model for the Short-Lane configuration, which achieves maximum tunnel traffic utilization, is shown in Figure 4.

Under the Long-Lane configuration, in which there are currently not enough buses and HOVs to fill the capacity of two completely dedicated tunnel lanes, the simulated queues of nonpriority vehicles grew more rapidly and extended further back along the approach roadways to Route 495.

Under the Short-Lane 2 configuration, in which the exclusive lane would begin on Route 3 itself, buses and HOVs from Route 3 would be able to completely bypass the Route 495 queue. However, the capacity of Ramp J to process non-HOVs onto Route 495 is reduced, because its left lane would be totally dedicated to buses and carpools. The spreadsheet model described earlier was used to estimate that the impact of this reduced non-HOV capacity on Route 3 would be a non-HOV backup extending up to 1.5 mi back from Route 495 onto Route 3.

In order to compare projected travel times for the various Lane 3 configurations, the origin-to-destination travel times reported by FREQ8PL had to be supplemented with the ramp queue delay times estimated by the spreadsheet procedure for the major approaches to Route 495. Projected maximum travel times from each of the major approaches to the Lincoln Tunnel's New York portal are shown before Lane 3 and for Day 1 after implementation of Lane 3 (Short-Lane 2 configuration) in Figures 5 and 6.

The FREQ8PL model computes total system passenger hours both before and after the implementation of a priority lane. However, these estimates do no include the delays that occur at on ramps that are blocked by standing traffic queues. Therefore, the ramp delay times estimated by time slice using the spreadsheet were used to supplement the mainline travel times reported by FREQ8PL in order to develop projected travel times by approach for buses, carpools, non-HOVs, and trucks. These travel times were multiplied by the 15-min volumes at each approach and again by vehicle occupancies (3.6 was used as the average occupancy of a carpool and 41.5 for a bus, based on observed conditions).

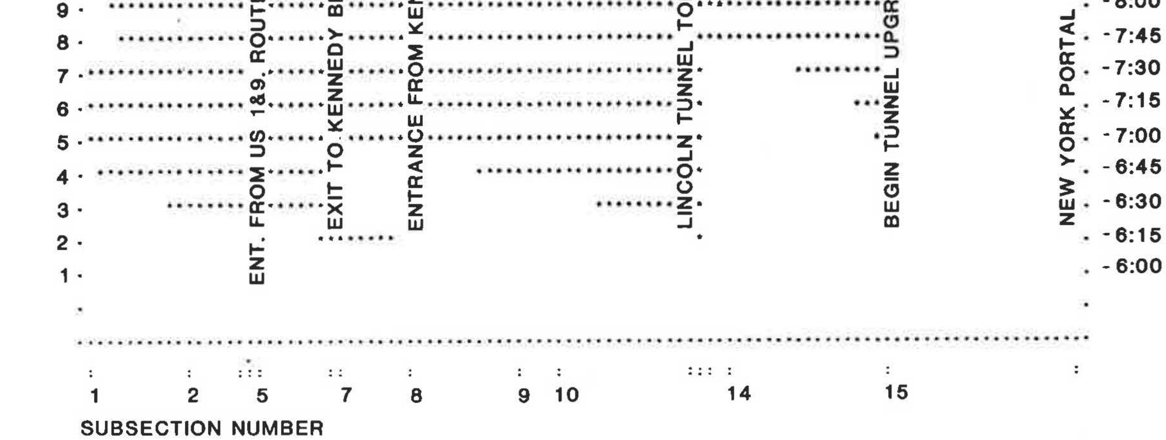

FIGURE 4 Simulation of queueing in nonpriority lanes: short-term condition after implementation of Short Lane 3 exclusive lane.

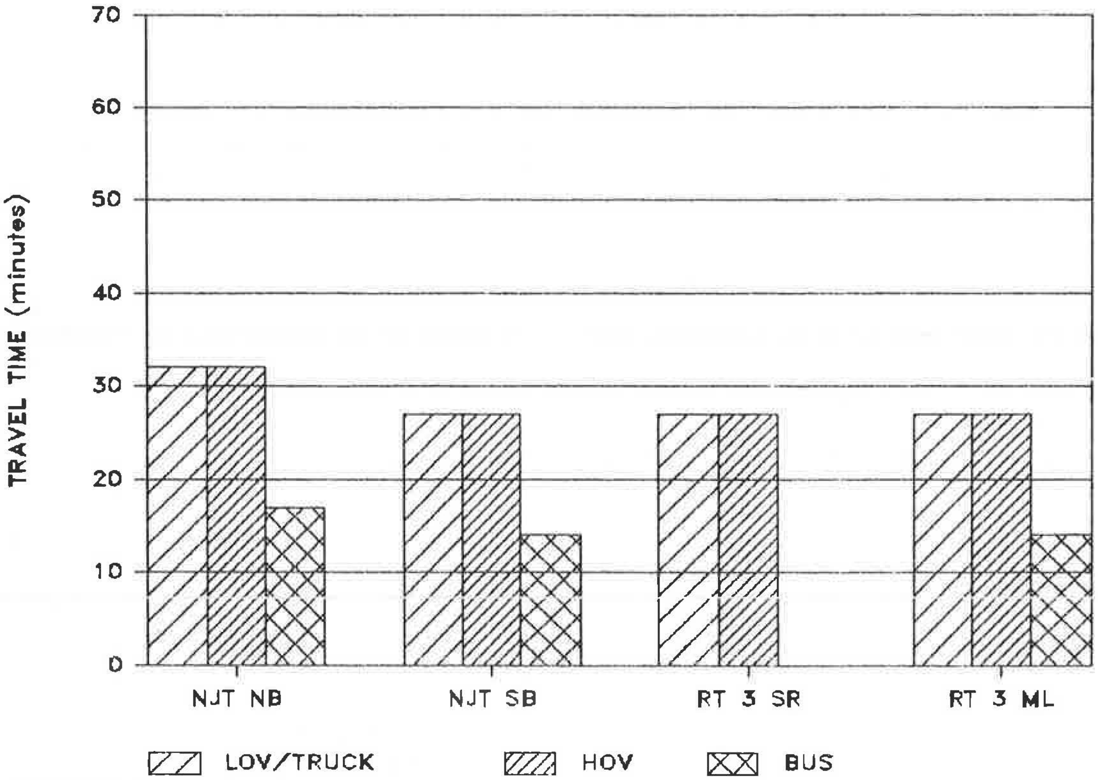

FIGURE 5 Projected maximum times to N.Y. portal before Lane 3.

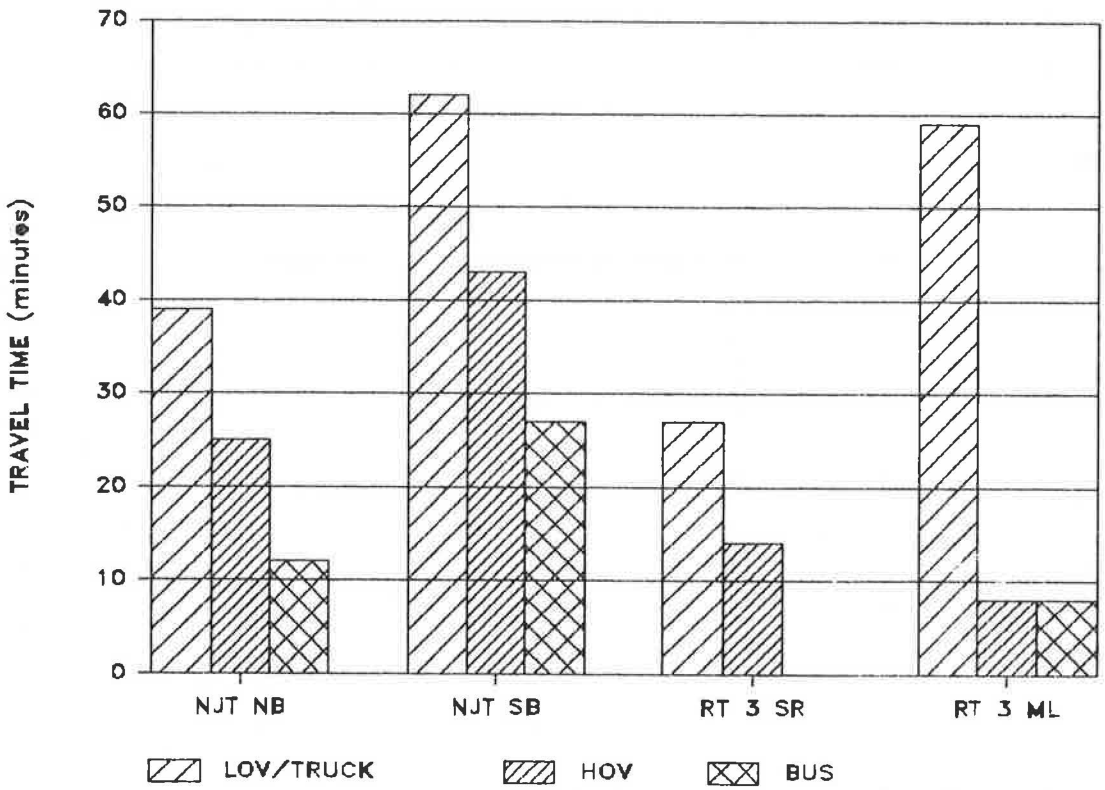

FIGURE 6 Projected maximum times to N.Y. portal, Day 1 after Lane 3.

SIMULATION OF LONGER-TERM CONDITIONS AFTER IMPLEMENTATION OF PRIORITY LANE

The Short-Lane 2 option was analyzed further to assess possible longer-term impacts after travel route shifting occurs. It was assumed that no shifts in time of travel or in travel mode would occur, even though bus and HOV travel times would be reduced relative to non-HOV travel times. At the time of the study, there was no demonstrable evidence available for the New Jersey-New York travel market, indicating that mode shifts have actually occurred in response to other HOV priority strategies that have been implemented. Accordingly, the estimation of mode shifts using theoretical models was not considered.

Assumptions as to probable diversions in route of travel were made, however. The FREQ8PL model contains a procedure for estimating diversions to a parallel alternative route. These shifts are based on a comparison of freeway mainline speeds and assumed alternative route speeds. The model does not, however, take into account on-ramp delays caused by queues blocking freeway entrances, because these delays are not calculated within the model. It was therefore necessary to estimate route diversions externally and then rerun the FREQ8PL and spreadsheet models through ramp volume adjustments to estimate the corresponding impacts on Route 495 and its approach roadways.

Two types of travel route shifts were estimated: first between the various approach routes to Route 495 and second, diversions to other Hudson River vehicular crossings.

Shifts between approach routes were estimated for each time slice by manipulating the spreadsheet model to determine the volume changes that would produce, to the extent possible, balanced travel times on the major approach roadways to Route 495.

Diversions of non-HOV vehicles to other crossings were then estimated. For lack of a more sophisticated procedure, these were calculated to produce travel times about halfway between current travel times without the priority lane and the travel times that were simulated under Day 1 conditions immediately after priority lane implementation. A total diversion of about 800 vehicles was estimated to occur during the 6:30-9:30 a.m. period under this assumption.

The model-simulated non-HOV queue lengths for each of the four priority lane conditions and major approaches (measured back from the merge point of each approach to Route 495), as estimated by the spreadsheet-based procedure, are shown in Figures 7 through 10. The lane conditions were before Lane 3, Day 1 after Lane 3, after approach-route shifts only, and after approach-route and crossing shifts.

The simulated maximum travel times from each of the major approaches after route shifts are shown in Figure 11.

CONCLUSIONS AND DIRECTIONS FOR FURTHER RESEARCH

FREQ8PL was found to be an extremely useful tool in the evaluation of the alternative priority lane treatments proposed for Route 495. As this is being written, the model is being prepared to simulate the section of Route 3 west of Route 495 to obtain more detailed information on the extent of queueing for various alternative bus and HOV priority treatments along this roadway.

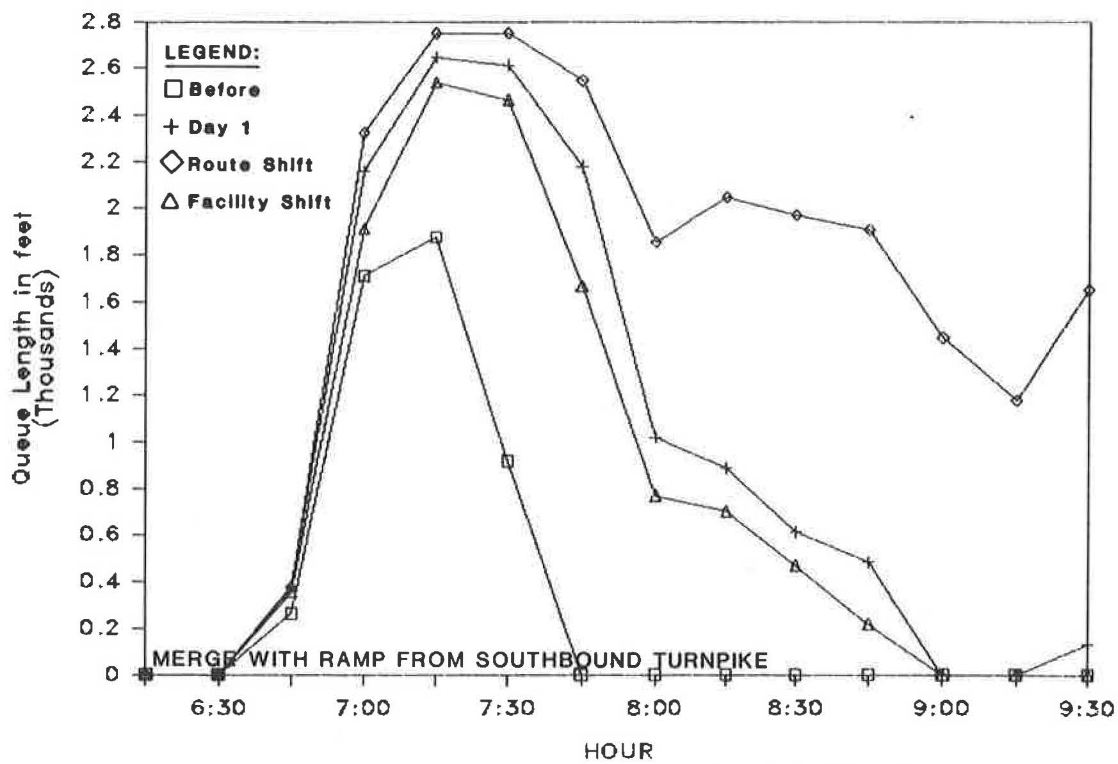

FIGURE 7 Projected queue length: northbound N.J. Turnpike approach to Route 495.

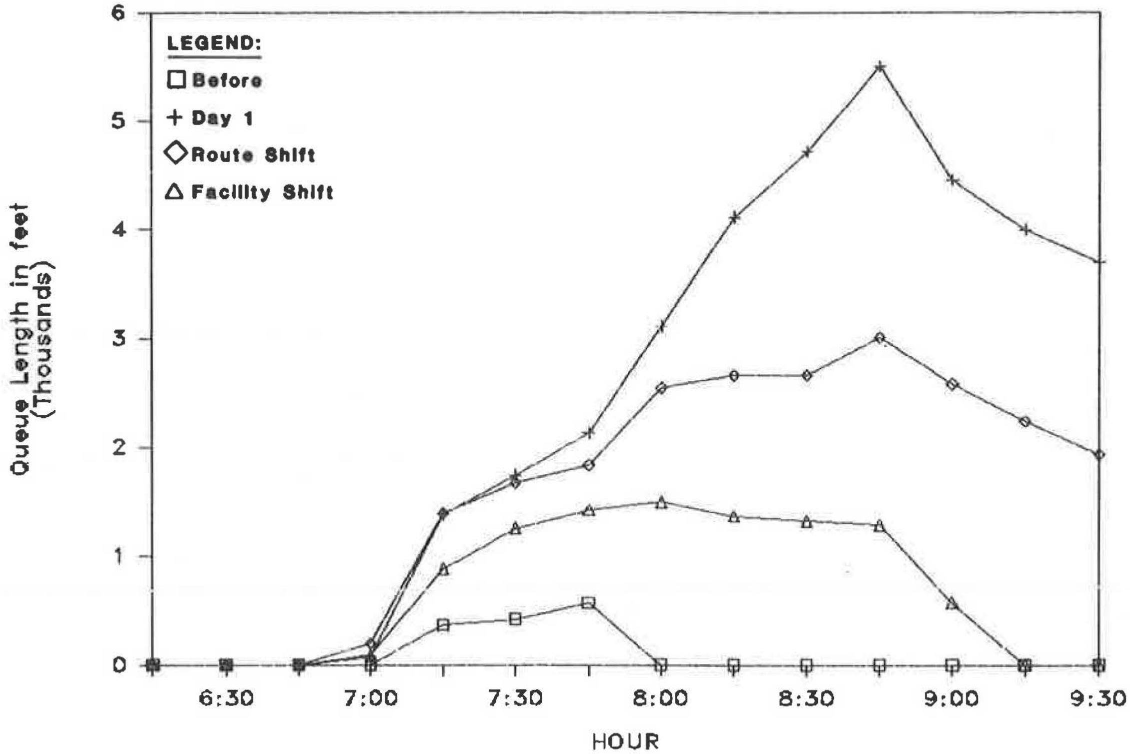

FIGURE 8 Projected queue length: southbound N.J. Turnpike approach to Route 495.

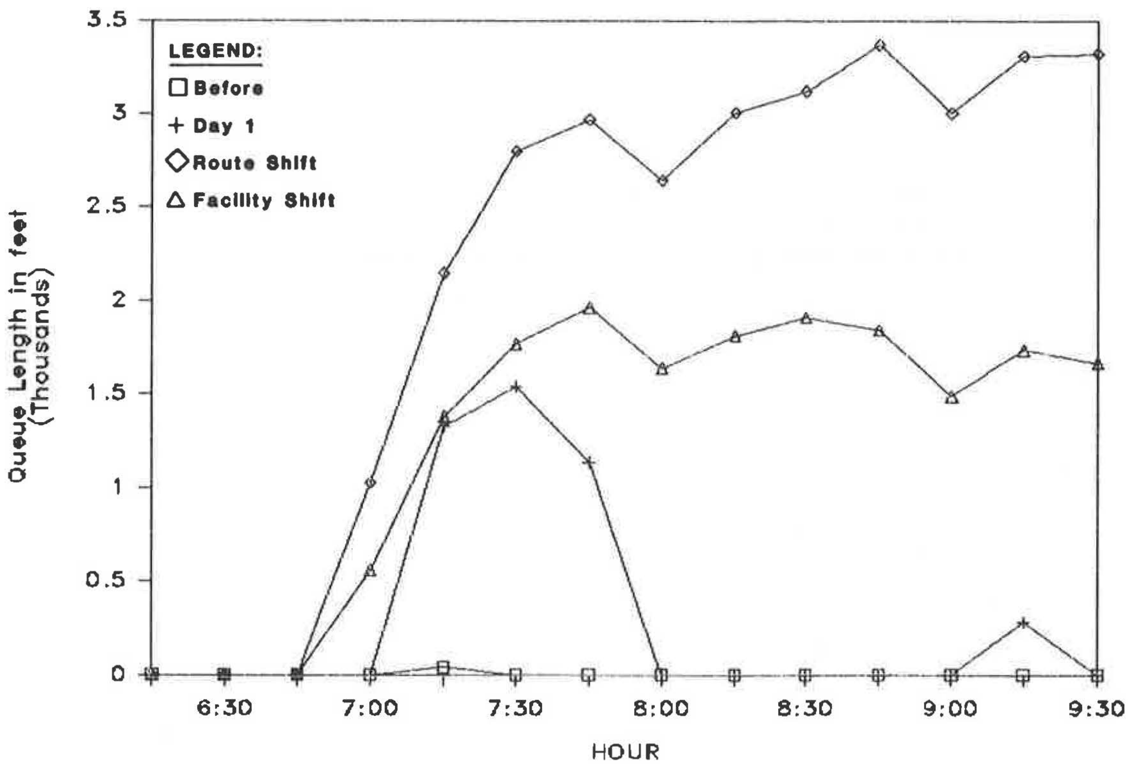

FIGURE 9 Projected queue length: Route 3 service-road approach to Route 495.

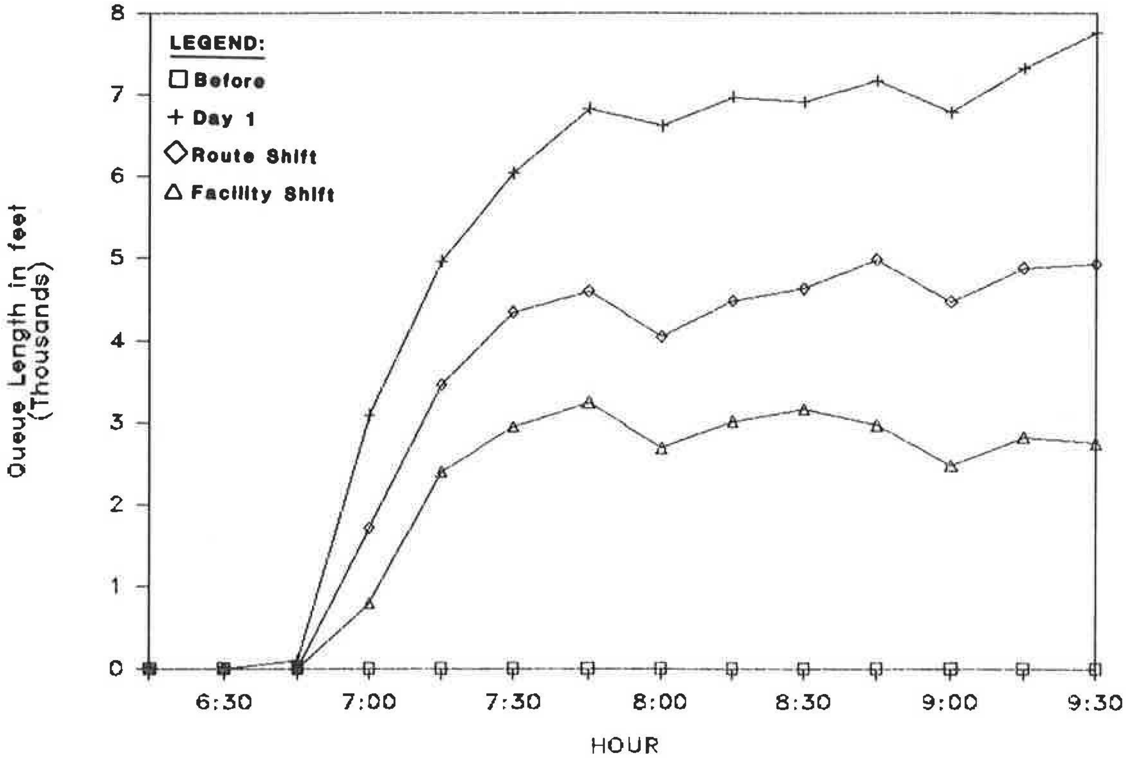

FIGURE 10 Projected queue length: Route 3 mainline approach to Route 495.

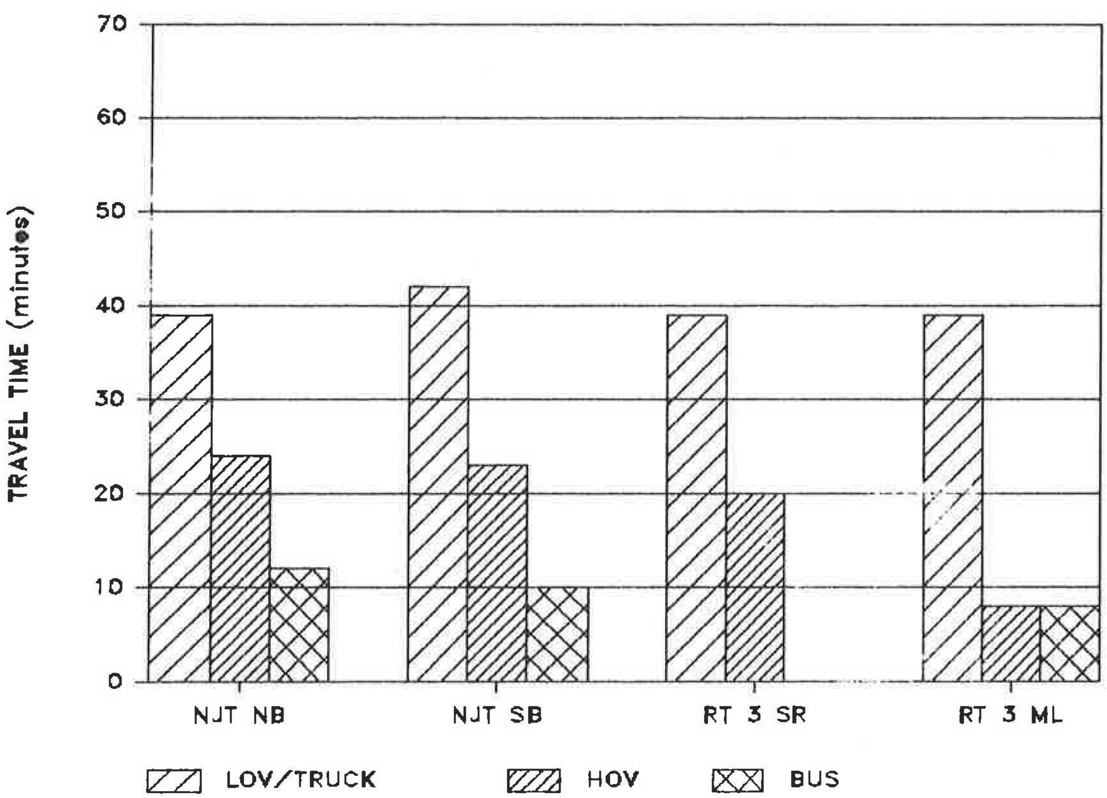

FIGURE 11 Projected maximum times to N.Y. portal: after route and facility shifts.

It should be noted that certain limitations of the model exist. In its current form, the model has no way of accounting for the reduced processing capacity of on ramps that are blocked by mainline queues. For this analysis, an external spreadsheet-based procedure for adjusting ramp volumes and estimating ramp queues was developed. This external procedure had to be relied on to supplement the queue-length and travel-time estimates reported by FREQ8PL. It is recommended that FREQ8PL itself be enhanced so that these computations can be made internally.

It would also be desirable if FREQ8PL had a more appropriate means to reflect the impact of heavy vehicles on roadway capacity. Ramp counts could be classified into automobiles, trucks, and buses, instead of only automobiles and buses as at present. Pce factors for trucks and buses could be input for each subsection. Capacities would then be expressed in passenger-car units, and the model would internally convert the demand on each subsection into these units using the equivalency factors.

Furthermore, FREQ8PL's route-shift estimation capabilities are limited, so that for a given application, route shifts have to be estimated externally.

Finally, it would be useful if FREQ8PL's reporting capabilities were enhanced to include graphic displays of travel times between specified points.

ACKNOWLEDGMENT

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