Figure 1. Marginal shifts in modal demands.

ALTERNATIVE	AUTO	BUS/CARPOOL	HIGH-SPEED LINE
CONTRA-FLOW	(651) →	1,240 ←	(589)
	651 Net Loss	1,240 Net Gain	589 Net Loss
PEAK-FLOW	(239) → (675) →	 1,264 ←	239 (589)
	914 Net Loss	1,264 Net Gain	350 Net Loss

Although these net modal gains and losses are of primary interest to this study, isolating the various intermodal marginal shifts that resulted in these net changes is also important. Figure 1 reveals that the high-speed line loses an equal number of persons to the exclusive lane under either alternative. The automobile mode also loses nearly an equal number of persons to the exclusive lane under either alternative. The major difference between the two alternatives is that the peak-flow alternative causes an additional loss of 239 persons from automobile to high-speed line. This additional marginal shift is a direct result of the decreased vehicle capacity on the boulevard.

This study indicates that a car pool is the least significant travel mode in the corridor. Even the implementation of an exclusive bus and car-pool lane on a congested, but vital, arterial highway seems to have little real effect on boosting the market sharing of car pooling.

CONCLUSIONS

1. The implementation of an exclusive bus and car-pool lane on Admiral Wilson Boulevard and on the Ben Franklin Bridge would yield nearly identical use whether the lane is contraflow or peak flow.
2. If an exclusive lane is implemented, regardless of its configuration, it could result in a reduction of 1 to 2 percent of the Lindenwold High-Speed Line share of the total market.
3. Excluding car pooling, the automobile is the least significant mode in the market and would sustain the greatest intrusion into its share of the market (2.3 to 3.2 percent).
4. Implementation of an exclusive lane in the peak-flow direction would result in a loss of nearly three times as many riders from automobile as from high-speed line. The contraflow lane would result in a loss of almost equal numbers from both automobile and high-speed line.
5. The peak-flow alternative would cause a 40 percent greater shift from automobile than would occur in the contraflow alternative. However, this additional loss would be attracted to the high-speed line rather than to the exclusive bus and car-pool lane.
6. Car pool would be the least significant mode in the market area. The implementation of an exclusive lane might have little real effect in improving the market share of this mode.

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Abridgment

Simulation of a Bus-Priority Lane

R. J. Salter, University of Bradford, England
A. A. Memon, Mehran University, Pakistan

The use of bus-priority measures to increase to optimum highway flow of passengers, as opposed to highway flow of vehicles, is being applied in many developed countries. A review of the application of bus-priority measures has been made in the United States by the National Cooperative Highway Research Program (1) and in the United Kingdom by the Transport and Road Research Laboratory (2). This paper describes a simulation model of bus priority developed at the University of Bradford, England.

To assist the peak-hour tidal traffic flow into and out of the city of Bradford, West Yorkshire, England, a bus-only lane has been established on a section of the A-65 Bradford to Keighley highway.

The section of the Bradford to Keighley highway studied is a two-way, four-lane highway 1.1 km (0.7 mile) long and has three signal-controlled junctions. The highway carries bus flows in excess of 50 buses/h inbound in the morning peak period and in excess of 60 buses/h outbound in the evening peak period.

SIMULATION MODELS

In an investigation into the overall travel effects of this bus-priority scheme, two digital computer simulation models have been developed. The first simulates inbound traffic flow on the highway in the morning peak hour under normal nonpriority conditions; the second simulates traffic flow when bus-priority lanes are in operation.

In the nonpriority model the rules of operation of the model assign vehicles traveling straight ahead to the in-

Figure 1. Distributions of non-bus-vehicle travel times with and without priority scheme.

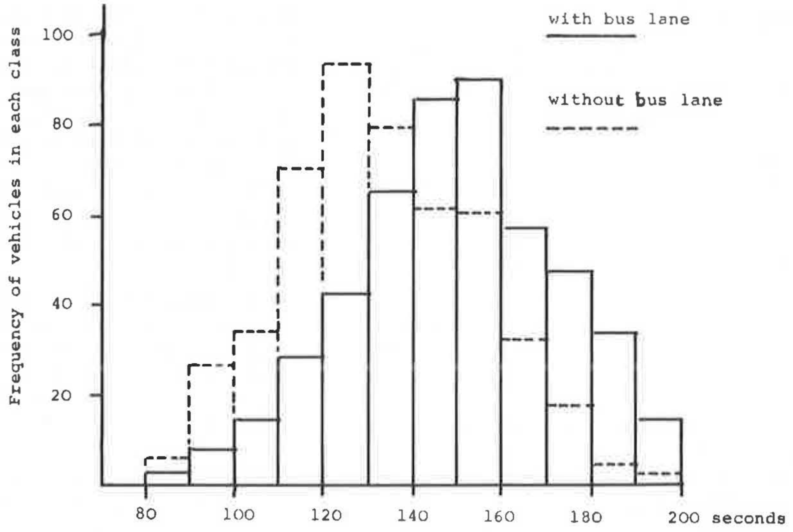
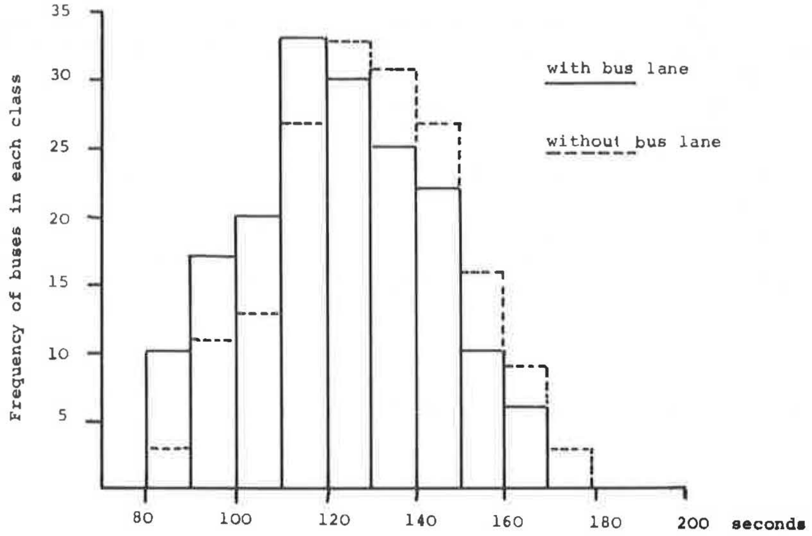


Figure 2. Distribution of bus travel times with and without priority scheme.



side lane of the two traffic-signal-approach lanes and vehicles turning right (left rule of the road) or traveling straight ahead to the outer lane. In the priority model, nonbus vehicles traveling straight ahead or turning right are confined to the outer lane and only buses travel on the inner lane. Vehicles turning left are not considered in the models because the number of these vehicles in the traffic flow is small.

At the traffic-signal approach, the bus-priority lane terminates 60 m (196.8 ft) from the stop line to allow vehicles traveling straight ahead to bypass vehicles turning right, which are prevented from completing their traffic movement by opposing vehicles, and also to allow the use of the full approach width to all vehicle types.

Observations of traffic flow on the highway were carried out to determine the characteristics of the speed and headway distributions. We noted that the displaced negative exponential distribution was an adequate description of the cumulative headway distribution on the highway and that the normal distribution described the observed velocity distribution.

A microscopic Monte Carlo simulation model was used that assigned each vehicle entering the section of the highway under study to a lane and to a vehicle type. A vehicle-following procedure was used; the performance of the vehicle following was determined from a consideration of the characteristics of the vehicle leading. The system was scanned at a uniform time increment of 0.5 s and commenced with the scanning of the vehicle nearest to the exit of the section under study. A vehicle assigned to a lane at the entry of the section was not allowed to change lanes or to overtake vehicles in its own lane. All vehicles were assumed to have similar characteristics.

1. Minimum space between vehicles in a queuing condition was 7 m (23 ft).
2. Maximum speed was 14 m/s (45.9 ft/s).
3. Acceleration and deceleration rates were 1.5 m/s^2 (4.9 ft/s^2) and 2 m/s^2 (6.6 ft/s^2) respectively.

The use of similar operating characteristics for buses and nonbus vehicles in congested flow conditions was justified by field observations. No provision was made for the time lost when passengers get on or get off buses because this time was considered to be similar for both non-bus-priority and bus-priority conditions. The traffic signals along the route operated on a fixed-time basis without coordination because real-life conditions were represented.

To validate the operation of the simulation model, we made a comparison between the delays at the signal-controlled intersections along the route given by the models and those delays obtained by using the expression derived by Webster (3). Close agreement between simulated and calculated delays was noted.

EFFECT OF BUS PRIORITY ON TRAVEL TIMES

A comparison was made between the travel times of buses and nonbus vehicles by running the priority and nonpriority models under identical traffic flows and signal settings. Figure 1 shows the variation in the distribution of nonbus travel times with and without the bus-priority schemes in operation when total vehicular flow was 1100 vehicles/h and the proportion of bus to nonbus vehicles was 20 percent. Because nonbus traffic is confined to a single lane under bus-priority conditions, there is an increase in journey time and a decrease in overall speed for nonbus vehicles compared to nonpriority conditions. These changes in journey times were caused by the interaction of vehicles throughout the length of the simulated section rather than by increases in delay at the junction alone. Similar distributions of journey times for buses are shown in Figure 2, on which journey time is a decrease in mean journey time from 129.9 to 122.6 s under bus-priority conditions.

The small changes in travel times due to the introduction of the bus-priority scheme are caused by the inelasticity of speed. The simulated flow was within the range of 600 to 1400 vehicles/h in one direction. At lower traffic volumes there is no justification for affording priority to buses, and at higher traffic volumes

Figure 3. Travel time and flow relationship for buses in priority lane, non-bus vehicles under priority conditions, and all vehicles under non-priority conditions.

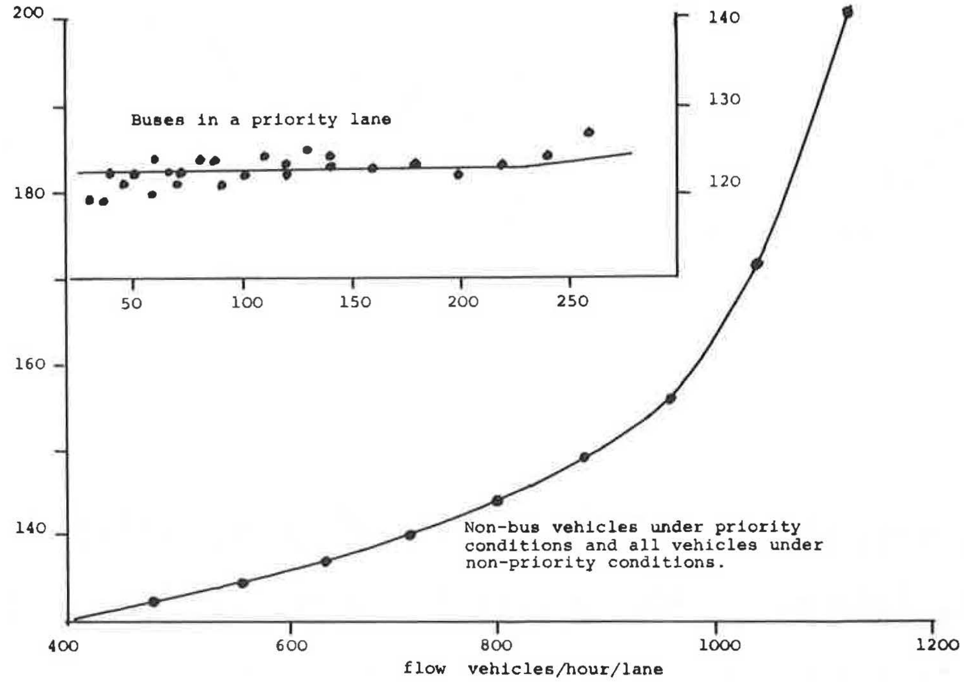
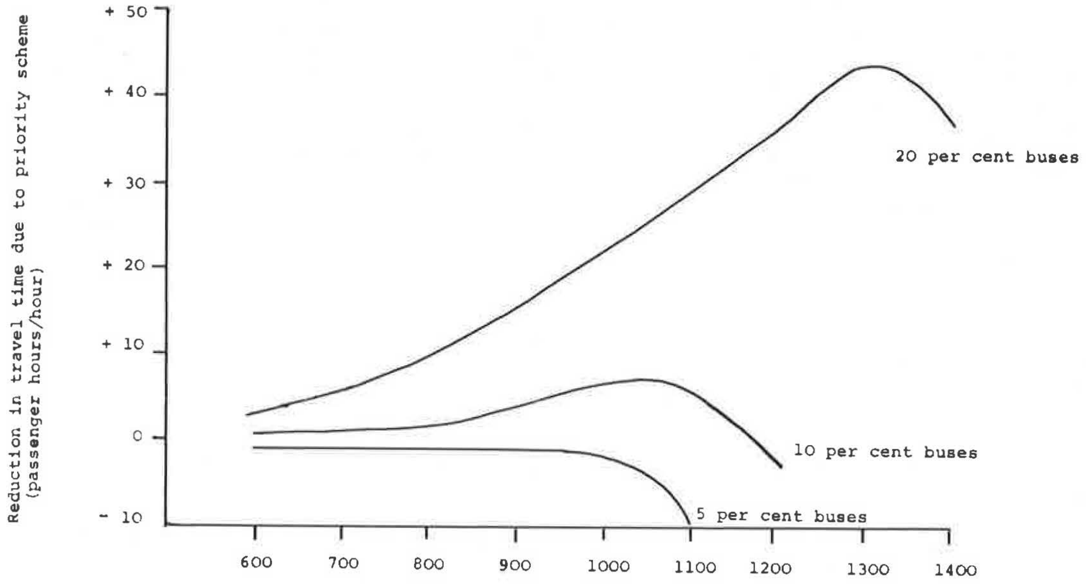


Figure 4. Reductions in passenger travel time due to priority scheme.



the signal-controlled intersections have inadequate capacity to pass the traffic.

Speed and flow relationships for bus and nonbus traffic under priority and nonpriority conditions obtained by the use of the simulation model are shown in Figure 3. Figure 3 shows that (a) for a wide range of bus flows the travel time on the simulated section of highway may be regarded as constant with no interaction between vehicles and (b) for nonbus vehicles interaction occurs as the traffic volume increases because there is a marked increase in travel time as the traffic flow increases beyond 1000 vehicles/lane/h.

CONCLUSIONS

Use of these two speed and flow relationships allows overall passenger travel time savings to be calculated for various proportions of buses in the traffic flow as illustrated in Figure 4, in which we assumed a bus occupancy of 50 persons and a nonbus vehicle occupancy of 1.5 persons. When only 5 percent of the traffic is buses, the installation of a bus-priority scheme results in increases in passenger journey time at the traffic volumes studied. When the proportion of buses in the traffic flow is 10 percent, then the saving in passenger delay reaches a maximum at a total traffic flow of approximately 1050 vehicles/h. As would be expected when there is a high proportion of buses in the flow, then substantial reductions in passenger journey time can be expected; at a 20 percent proportion, a maximum saving of 43 passenger·h/h is reached when 1300 vehicles/h enter the section.

Since the introduction of the bus-priority scheme, field observations have verified, as far as possible, the validity of the model. The highway under consideration has, however, pronounced peaking characteristics, and the recent establishment of signal-controlled, pedestrian-crossing facilities has prevented the determination of comprehensive speed-flow relationships. Observations have shown, however, that the travel times of buses in the priority lane are in the region of 120 to 130 s when the flow is 50 to 60 buses/h. Travel times of nonbus vehicles are very variable, as would be expected, at flows producing such low levels of service.

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Abridgment

Evaluation of Bus-Priority Strategies on Northwest Seventh Avenue in Miami

Joseph A. Wattleworth, Kenneth G. Courage, and Charles E. Wallace, Transportation Research Center, University of Florida

A 3½-year demonstration project was established in Miami in 1973 to develop more efficient people-moving capabilities in the I-95 and Northwest Seventh Avenue corridor that extends 16 km (10 miles) from the Golden Glades Interchange in north Dade County to Miami to the south. The basic transit concept was to provide fast, directional, line-haul, peak-period service by express buses that operated between a major residential area and four specific areas of major employment along Northwest Seventh Avenue (US-441), a major arterial street.

A park-and-ride facility located in the Golden Glades Interchange contained a bus terminal and a 967-space parking lot to accommodate the park-and-ride patrons. Some of the express buses were used to provide feeder route service in the residential market area. Provisions were made for kiss-and-ride and local bus interchanges. In addition, some car pools were formed and used the facility.

Various combinations of the following three bus-priority treatments were evaluated:

1. A reversible, exclusive bus lane;
2. A traffic signal preemption system that allowed express-bus drivers to preempt traffic signals to give themselves the green signal; and
3. A coordinated signal system designed to favor the movement of express buses in the peak-period direction.

Combinations of the three priority treatments were examined in the following five evaluation stages:

1. Stage 0—before condition, no priority treatment;
2. Stage 1—bus preemption of traffic signals, buses in mixed mode;
3. Stage 2—bus preemption of traffic signals, buses in reserved bus lane;
4. Stage 3—signal progression, buses in reserved bus lane; and
5. Stage 4—signal progression with bus preemption of traffic signals, buses in reserved lane.

The express-bus service was named the Orange Streaker and was operated by the Metropolitan Dade County Transit Agency (MTA). The bus-priority treatments were evaluated by considering their effects on bus operations, traffic signal performance, traffic stream,