EFFECTIVENESS OF PRIORITY ENTRY RAMPS IN TEXAS

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ABSTRACT

Priority entry ramps have been operational in Dallas and Houston for approximately five years. An evaluation of these installations indicated three of the four sites exhibited positive benefits in terms of delay savings to high-occupancy vehicle patrons authorized to use the priority entry ramp. Significant cost-effectiveness was found to be associated with priority entry bypassing ramp metering signalization. Violations of priority entry ramps decreased as the relationship between non-priority vehicle delay and priority vehicle demand increased. A benefit-cost methodology for assessing priority entry ramp effectiveness was formulated and recommended guidelines for implementation of priority entry ramps given.

Key Words: Priority Entry, Bypass Ramps, High-Occupancy Vehicles (HOV), Preferential Lanes, Ramp Metering, Ramp Meter Bypass.

SUMMARY

In Texas, priority entry ramps were opened approximately five years ago in Dallas and Houston. Conditions under which these sites were first established, both physically and operationally, have changed dramatically. No detailed evaluation of the effectiveness of these priority entry ramps has been made, nor do guidelines exist for implementation of future sites. The objectives of this study were: 1) to collect the required evaluation data at existing entry sites in Dallas and Houston under various operating conditions; 2) summarize and analyze the effectiveness of existing priority entry ramps in Texas; 3) develop the benefit-cost methodology for application in determining the effectiveness of future priority entry ramp locations; and 4) finally, to recommend guidelines for the implementation and operation of priority entry ramps in Texas.

Both operational performance data and physical inventory data were collected at each of four existing priority entry ramp sites in Dallas and Houston. The sites studied in Dallas were on North Central Expressway (I-45) at Mockingbird Lane and on R.L. Thornton Freeway (I-30) at Ferguson Road. The sites in Houston were both on Southwest Freeway (US 59) at Bellaire Boulevard and at Hillcroft Avenue. A summary of operational results is given in Table S-1 for volume, occupancy, and travel time for both priority and non-priority vehicles. Table S-2 summarizes results for ramp compliance and violations.

For the three operational study sites in Texas, excluding Mockingbird in Dallas, an assessment of the impact of implementing priority entry ramps may be summarized as follows.

(1) Priority entry ramp vehicular volume constitutes 2-4% of total ramp volume.

(2) Priority entry ramp passenger volume constitutes 35-50% of total ramp person usage.

Table S-1. Summary of Operational Results

Site	Average Non-Priority Volume (vehicles/hour)	Average Priority Volume (vehicles/hour)			Average Total Passenger Volume (persons/hour)	Average Occupancy Non-Priority (passengers/vehicles)	Average Total Combined Occupancy (passengers/vehicles)	Average Delay Savings (minutes/vehicle)
		Bus	Van	3+ Carpools				
Mockingbird (Dallas)	1445	12	---	---	2550	1.25	1.75	*
Ferguson (Dallas)	1014	18	5	21	2478	1.26	2.34	0.75
Bellaire (Houston)	875	9	12	---	1734	1.20	1.94 All Vehicles	4.03
Hillcroft (Houston)	1019	15	41	---	2495	1.17	2.32 All Vehicles	4.92

*Due to excessive violations and inappropriate ramp operations it was not possible to measure priority and non-priority travel time and delay savings.

Table S-2. Summary of Operational Results

Site	Total Average # Non-priority vehicles utilizing Non-priority ramp (vehicles/hour) (1)	Total Average # Non-priority vehicles (vehicles/hour) (2)	Compliance Ratio (1) ÷ (2) %	Total Average # Unauthorized for priority entry (vehicles/hour) (3)	Total Average # Vehicle utilizing priority entry ramp (vehicles/hour) (4)	Violation Ratio (3) ÷ (4) %
Mockingbird* (Dallas)	782	1445	54.1*	663	675	98.2*
Ferguson (Dallas)	1000	1014	98.6	14	58	24.1
Bellaire (Houston)	852	875	97.4	23	42 All Vehicles	54.8
Hillcroft (Houston)	1010	1019	99.1**	9	65 All Vehicles	13.8**

*Not meaningful　　**Random enforcement presence

(3) Priority entry ramps increased total ramp vehicular occupancy level.

(4) Priority entry ramps were responsible for delay savings to high-occupancy vehicle patrons of between 0.75-5.00 minutes per person.

(5) The average compliance rate was approximately 98%, while the average violation rate was 31%.

(6) Random enforcement appears to reduce (40%) violation rate as evidenced by the limited comparative data within this study.

(7) Violations appear to decrease as priority entry exposure ratio increases.

A relationship was found to exist between violation rate (dependent variable) and non-priority service time divided by priority arrival time, defined as Priority Entry Exposure Ratio (independent variable). The linear regression equation was given as:

Violation Ratio = 0.55 - 0.08 Exposure Ratio $R^2 = 0.67$

Benefit-cost methodology was formulated to assess priority entry ramps. Assumptions for design life, discount rate, improvement costs, occupancy levels, and time value of delay savings were incorporated and calculations made on an annual basis. Figure S-1 graphically illustrates general curves for benefit-cost ratios of 1:1, 10:1, and 100:1 for priority entry ramp improvement projects.

General guidelines resulting from this study are recommended in evaluating the feasible implementation of priority entry ramps.

(1) Travel time delay to non-priority motorists should be equal to or greater than 2.0 minutes per person. This implies the existence of a ramp meter signal or extreme freeway congestion.

(2) Total travel time delay savings to priority ramp authorized users should be in the range of 4.0-6.0 passenger hours during the peak hour, or equivalent to 1500-2500 passenger hours per year.

(3) Construction and/or maintenance costs for priority entry ramp improve-provements are site specific and require individual project estimation.

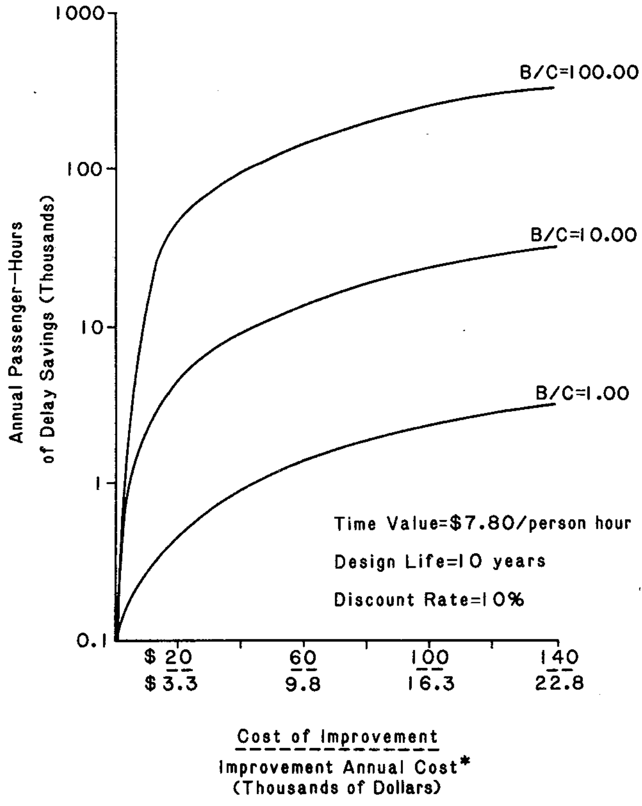

Figure S-1: Benefit/Cost, Priority Entrance Ramps

(4) The presence of enforcement initially is necessary for reinforcement of priority authorization and ramp operations; randomly maintained enforcement presence assures an acceptable violation rate.

(5) Advance operational signing and definitive delineation are critical to minimize motorist confusion and unintentional violations on priority entry ramps.

(6) No significant impact on freeway occupancy level can be anticipated from the modal shift resulting from an individual priority entry ramp.

(7) Priority entry ramps can serve an important function in concert with freeway control and/or transitway system access.

(8) From a public relations standpoint, priority entry ramps are perceived as a positive transportation improvement action.

IMPLEMENTATION STATEMENT

This project is oriented to assist the Texas State Department of Highways and Public Transportation in planning and implementing priority treatment techniques for high-occupancy vehicles. Several major highway transit projects are in various stages of construction, design, and planning in the major metropolitan areas of Texas. Potential sites for priority entry ramps exist not only within the limits of these projects, but also at locations of ramp metering necessitated by increasing freeway congestion. This report was specifically directed to evaluate the effectiveness of existing priority entry ramp installations and to extend that experience to the production of benefit-cost methodology and guidelines for implementation of additional priority ramps.

DISCLAIMER

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INTRODUCTION

Background

Priority entry ramps are specially designated (signing, marking) or physically separated preferential lanes which allow high-occupancy vehicles (HOV's) to bypass single-occupancy vehicles delayed in access to freeway mainlanes due to congestion. This Transportation Systems Management (TSM) technique is implemented to produce travel time savings as an incentive for motorists to utilize an HOV mode of travel and, therefore, increase the person capacity of freeway corridors.

National statistics on priority entry ramps report approximately two hundred installations either operational or planned (1). The State of California Department of Transportation (Caltrans) has over ten years experience with these facilities, predominantly with HOV authorization for carpools (2). One recent evaluation by Caltrans (3) of thirteen metered priority entry ramps (buses and 2+ carpools) reported a small time-savings (1.0 minute average) and a nonsignificant increase in carpool formation due to the priority bypass lanes. However, the priority entry ramp was assessed to be a useful and effective means to promote usage of transit modes. An earlier study in 1975 (4) indicated that time savings associated with the installation of bypass ramps was responsible for an average 50% increase in carpools and an increase in vehicle occupancy from 1.24 to 1.33.

The City of Minneapolis, Minnesota, has established a number of priority entry ramps, primarily for buses but also for 3+ carpools. Findings from one study (5) of two downtown ramps indicate that time savings of 1.5 minutes or less was not sufficient to induce a significant modal shift. However, a recent national survey (6) of priority bypass ramps states that average observed time savings of 1.5 minutes or greater (5.0 minutes maximum) has been correlated with an increase in carpools of 40-50%.

In Texas, priority entry ramps were opened approximately five years ago in Dallas, followed by Houston. Conditions under which these sites were first established, both physically and operationally, have changed dramatically. No detailed evaluation of the effectiveness of priority entry ramps in Texas has been made, nor do guidelines exist for the application of this TSM technique at other sites within several freeway corridors. The intent of this study was to address these issues.

Objectives

The objectives of this research investigation were as follows.

- Collect required data at existing priority entry sites in Dallas and Houston under various operating conditions.
- Summarize and analyze the results to assess the effectiveness of existing priority entry ramps in Texas.
- Develop the benefit-cost methodology for application in evaluating the effectiveness of future priority entry ramp locations.
- Recommend guidelines for the implementation and operation of priority entry ramps in Texas.

STUDY SITES

Data Collection

Both operational performance data and physical inventory data were collected at each of four priority entry ramp sites existing in Dallas and Houston. Each location was monitored for a minimum of four typical weekdays during the a.m. peak period in clear and dry weather with no accidents. Distinction was made within the data set as to the presence or absence of enforcement.

Operational performance data were separated by measured conditions on the priority ramp versus the non-priority ramp. Traffic parameters recorded were:

(1) Total volume for both the priority and non-priority ramps;

(2) Vehicle type and occupancy for both priority and non-priority ramps;

(3) Travel time (delay) to non-priority vehicles due to freeway congestion or ramp metering;

(4) Violations by unauthorized vehicles on the priority ramp; and

(5) Presence of enforcement.

Physical ramp data were taken on-site, photographically, and from design plans. This information consisted of:

(1) Ramp alignment, horizontal and vertical, with respect to both frontage road and freeway connections;

(2) Ramp pavement cross section, type, and condition;

(3) All signing, pavement marking, and delineation associated with both priority and non-priority ramps; and

(4) Existence of ramp signalization control and operating details.

The majority of the data was collected during a three-month period from October-December 1982. Subsequent collection of additional violation data was made in March-April 1982. All data were measured manually from an inconspicious observation setting so as not to be perceived as enforcement personnel and influence violations.

Each priority entry ramp site is distinct in itself, although the two sites in Houston are located within the same freeway corridor. A detailed discussion of each site is given below.

Dallas

Two priority entry ramp sites were studied in Dallas (Figure 1). The locations are:

(1) North Central Expressway (I-45) at Mockingbird Lane, and

(2) R.L. Thornton Freeway (I-30) at Ferguson Road.

The priority entry ramp (for buses only) on North Central Expressway at Mockingbird was constructed and made operational in 1977 at a cost of approximately $20,000. Original installation was in conjunction with ramp metering to the non-priority traffic. At that time, one study (7) estimated the delay savings to priority vehicles at approximately 2.5 minutes per vehicle, or approximately 10,000 person-hours per year. Under current study, no ramp signal was present and, therefore, delay savings were minimal. In addition, a very high violation rate existed at this site due to apparent motorist confusion as to the appropriate priority/non-priority vehicle path and no observed enforcement. Motorist confusion seems to occur from a combination of restricted visibility due to vertical alignment on the ramp, horizontal curvature associated with delineation treatment necessary to separate priority and non-priority vehicles, and inadequate advance signing designating ramp authorization. Figure 2 presents a schematic layout of this site. Figure 3 is a photograph of the site.

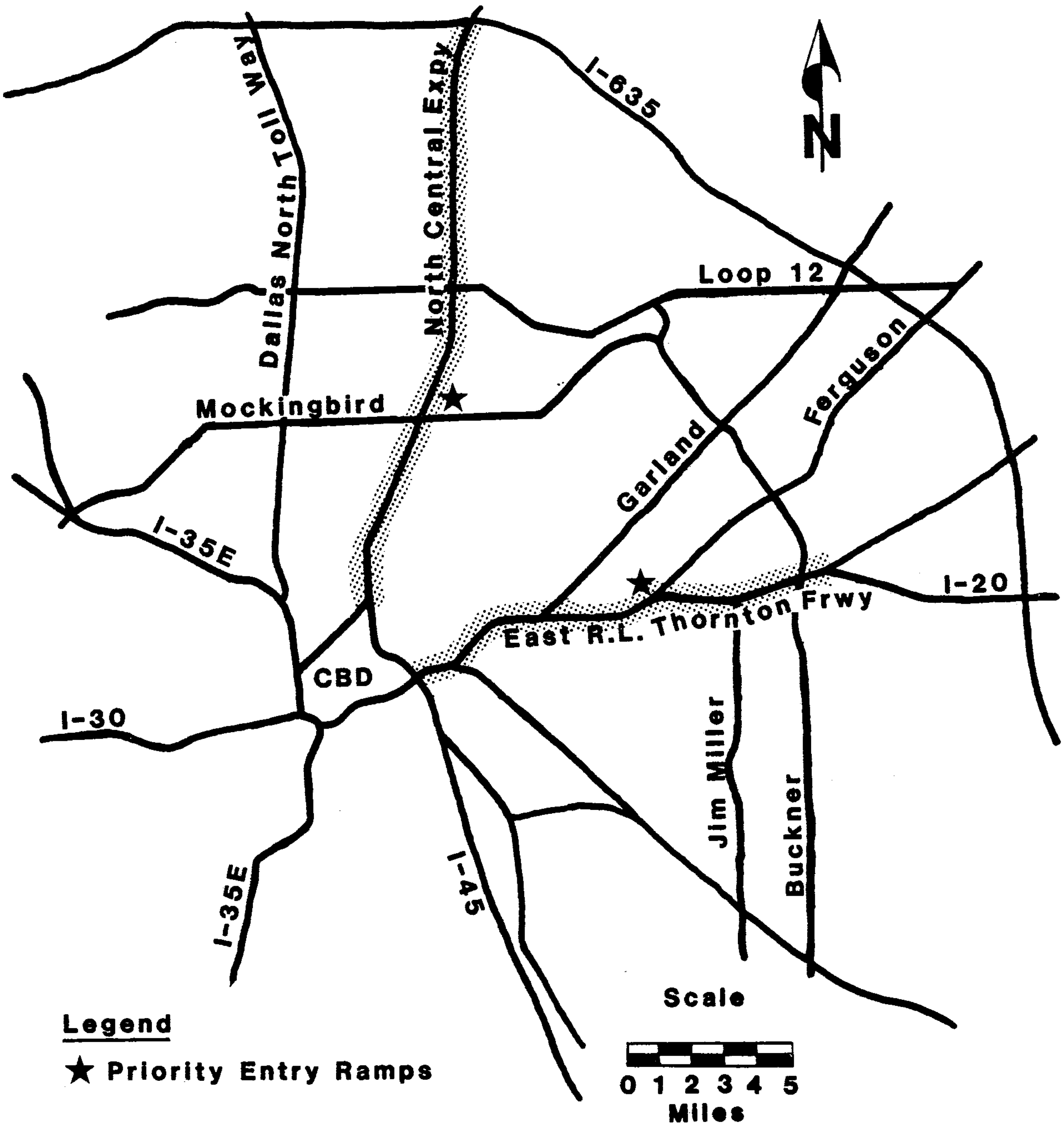


Figure 1. Dallas Priority Entry Ramp Sites

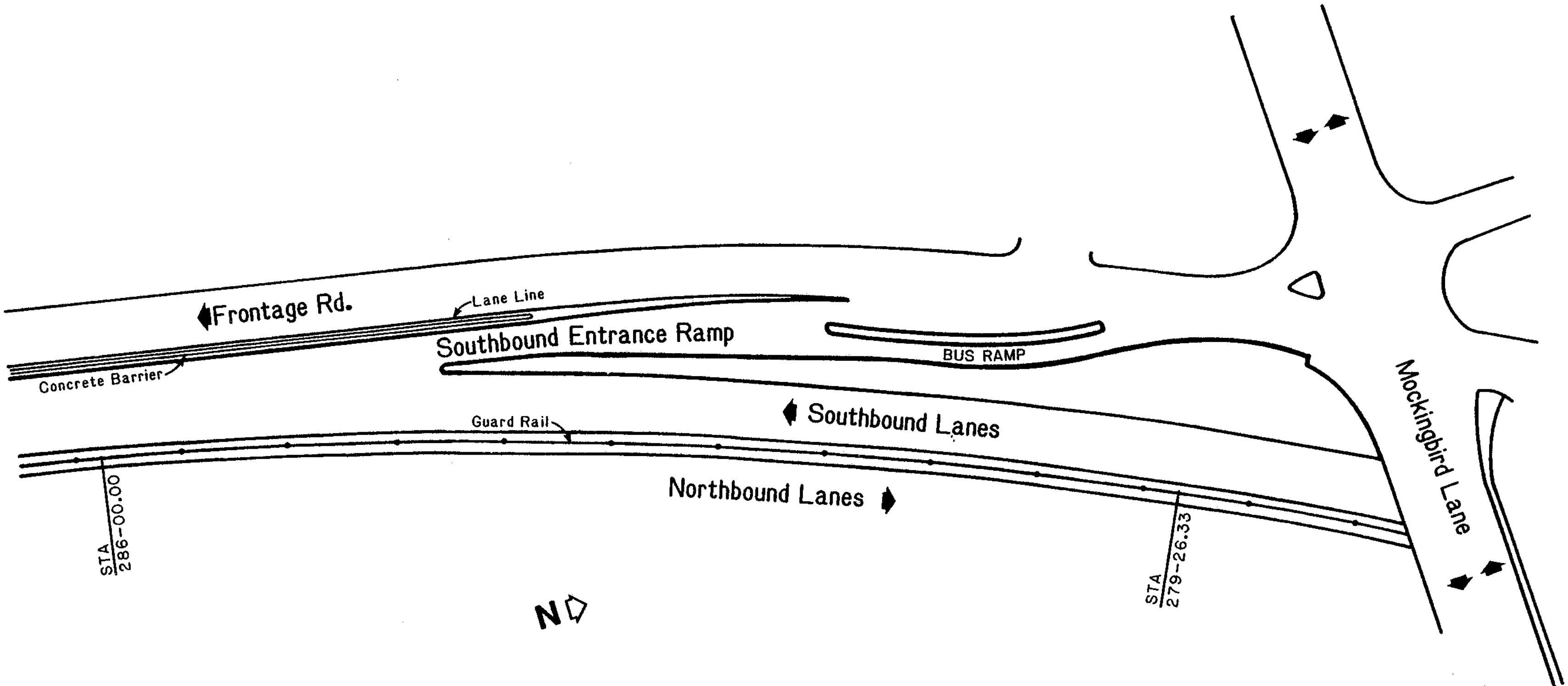


Figure 2. Priority Entry Ramp, North Central Expressway At Mockingbird, Dallas

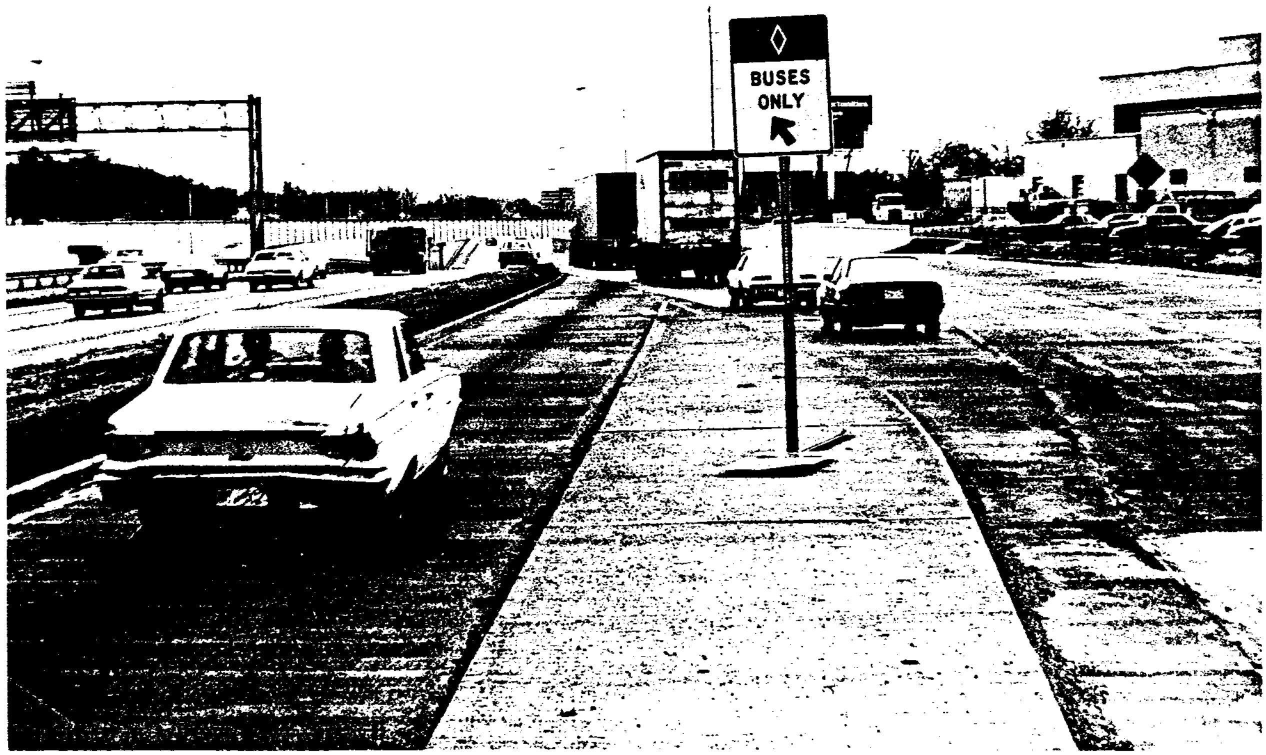


Figure 3. Priority Entry Ramp Operations, North Central Expressway At Mockingbird, Dallas

The priority entry ramp on R.L. Thornton freeway at Ferguson was implemented in May 1979 at a cost of approximately $50,000. Vehicles authorized to use the priority entry ramp were buses and carpools with three or more occupants. This facility operates only between 6:00 a.m. to 9:00 a.m., with no ramp meter installation controlling non-priority vehicle access to the freeway.

Under current study, the site exhibited good alignment transition in connecting with the freeway and merging of the priority and non-priority vehicles prior to entering the freeway. No operational problems were observed during the study period. Pavement markings and delineation were well-maintained and adequately visible. Both degree and placement of signing was operationally correct. Figure 4 presents a schematic layout of the ramp site. Figure 5 illustrates the operation of the ramp.

Houston

Two priority entry ramp sites were studied in Houston (Figure 6). The locations are:

(1) Southwest Freeway (US 59) at Bellaire Boulevard, and

(2) Southwest Freeway (US 59) at Hillcroft Avenue.

Each of these sites has signalization control for the non-priority traffic. The priority and non-priority ramps are physically separated at both the connections to the frontage road and the freeway merge points.

The priority entry ramp on Southwest Freeway at Bellaire Boulevard was constructed and made operational in 1978 at an estimated cost of approximately $10,000. Buses and vanpools are authorized to use the priority entry ramp with access at all times. Significant travel time savings are realized by priority vehicles due to the queueing of non-priority vehicles at the ramp signal.

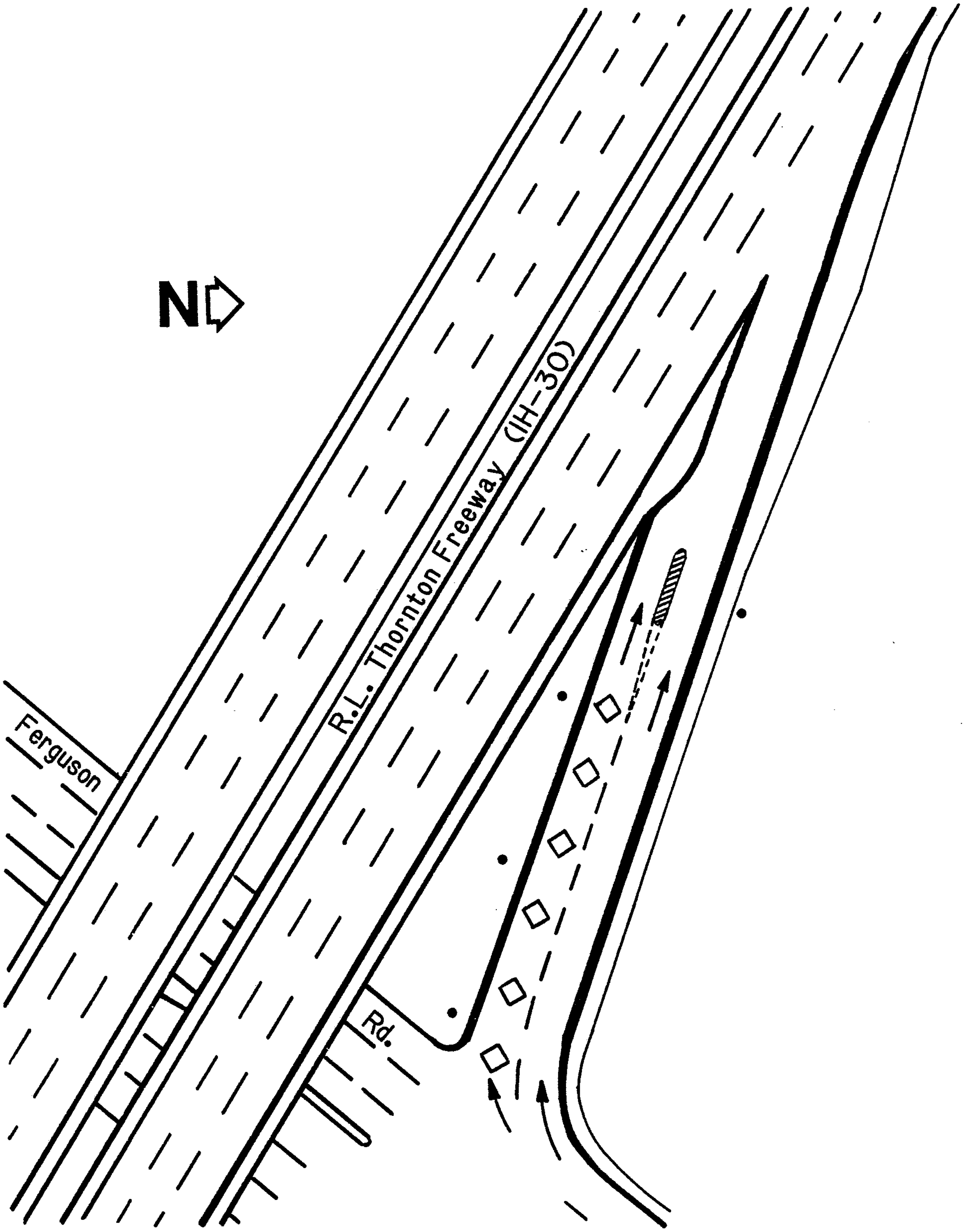


Figure 4. Priority Entrance Ramp, R.L. Thornton At Ferguson Road, Dallas

Figure 5. Priority Entry Ramp Operations, R.L. Thornton at Ferguson Road Operations

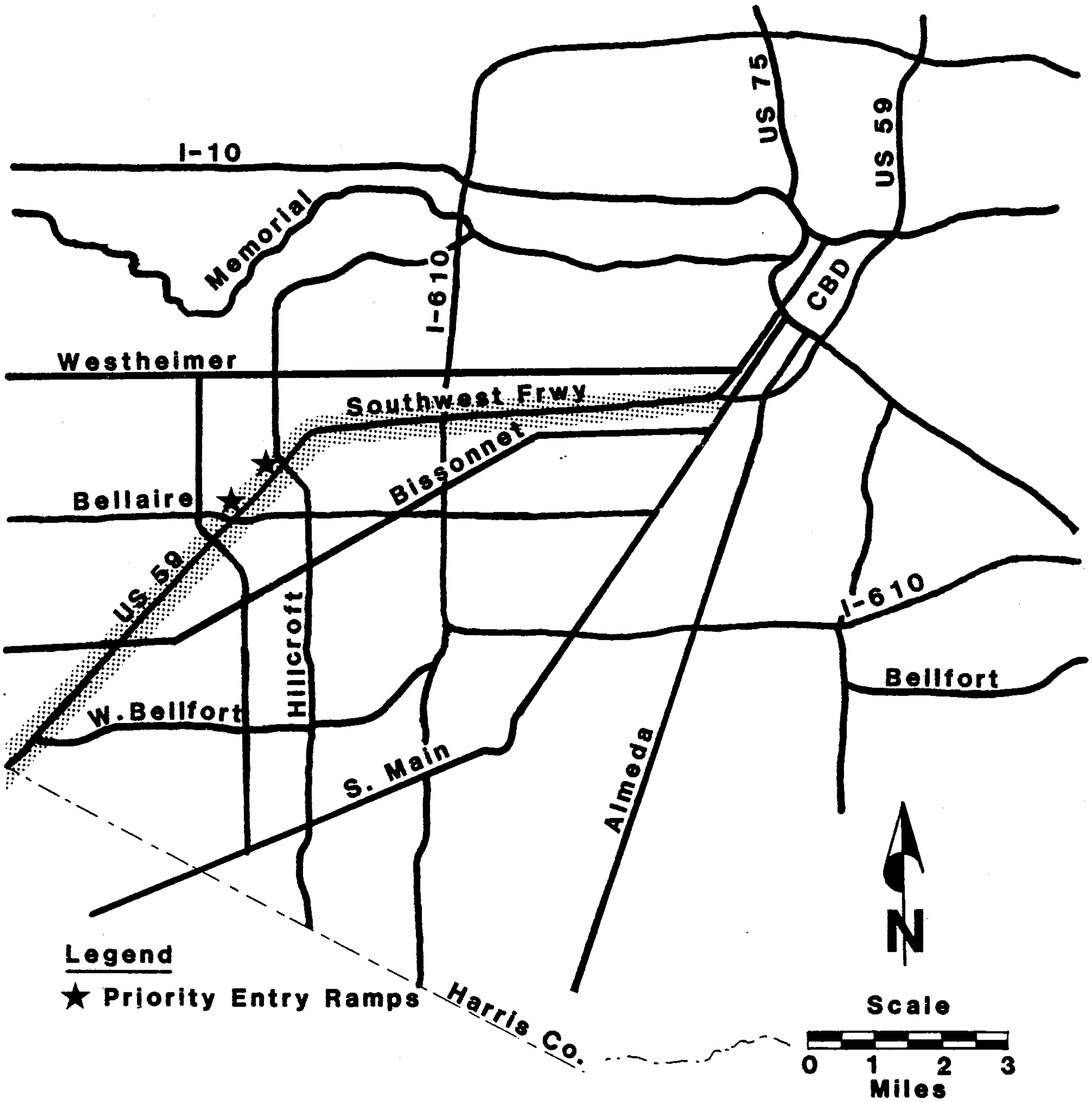


Figure 6. Houston Priority Entry Ramp Sites

Enforcement is applied on a random basis to control both signal and priority ramp use violations.

Signing and delineation are minimal yet adequate for this site, as the physical separation of ramps provides sufficient positive guidance to both priority and non-priority vehicles. Violations are more likely deliberate, rather than due to confusion from lack of sufficient information. Based on this, enforcement was indicated to be more readily justified for violations and more easily applied. Figure 7 illustrates a schematic layout of the Bellaire priority entry ramp. Figure 8 presents an aerial view of the ramp in operation.

The priority entry ramp on Southwest Freeway at Hillcroft Avenue for buses and vanpools was also implemented in 1978. Estimated cost of construction was approximately equal to the cost at the Bellaire site ($10,000). This ramp exhibited both the highest peak-hour, non-priority vehicle and priority vehicle volumes. The ramp site is in a highly congested section of the Southwest Freeway corridor. Access to the freeway on this ramp is metered by signalization; a considerable queue is present daily. Delay to the non-priority traffic is significant.

Ramp alignment is similar to that at the Bellaire site. Observed operations were acceptable, and there were no reports or information obtainable to indicate merging problems between the priority and non-priority vehicles. A schematic layout of this site is shown in Figure 9. Operations in the merge area are photographically illustrated in Figure 10.

Priority volume was substantially higher at the Hillcroft ramp than at the other sites due to the proximity of a park-and-ride lot. This seems to be a successful pairing of incentives for high-occupancy vehicle utilization.

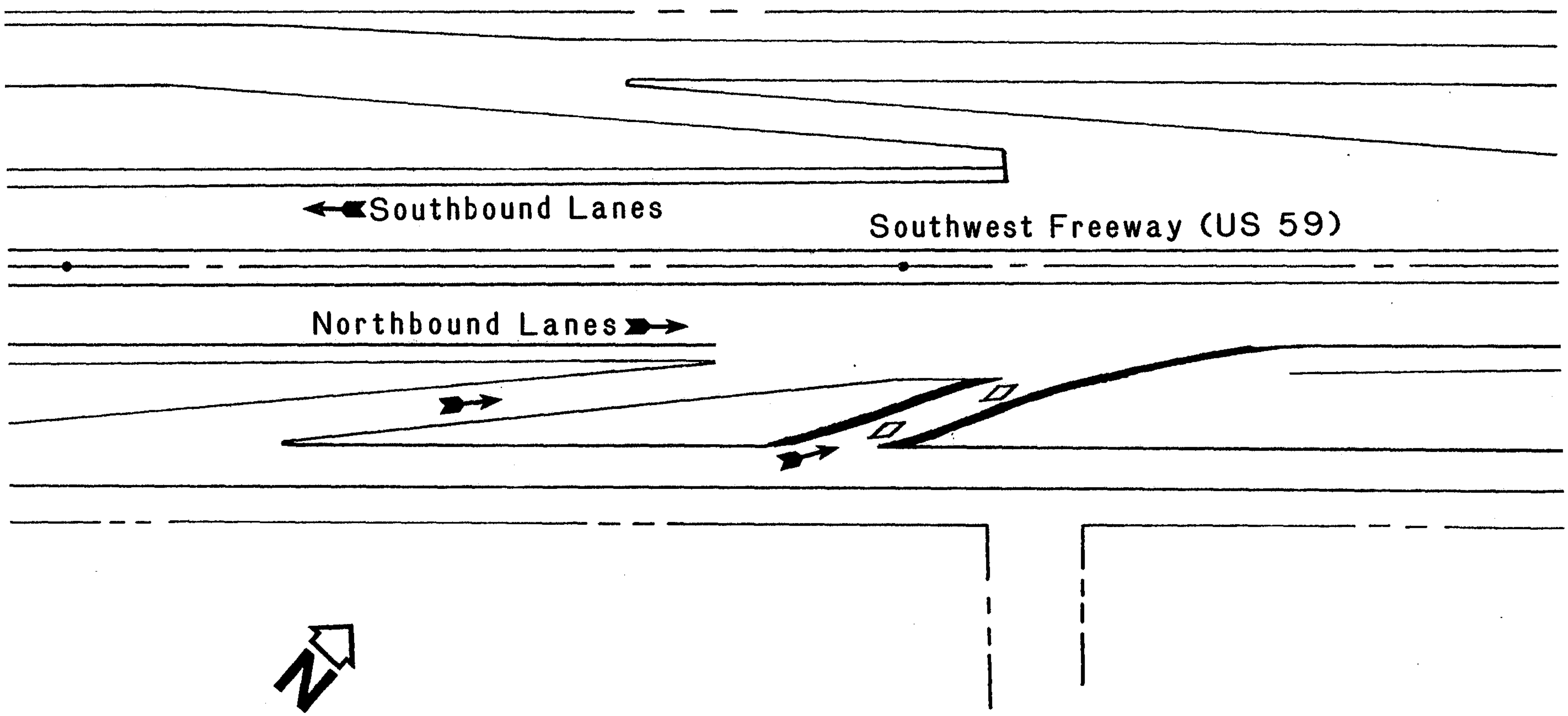


Figure 7. Priority Entry Ramp, Southwest Freeway At Bellaire Blvd, Houston

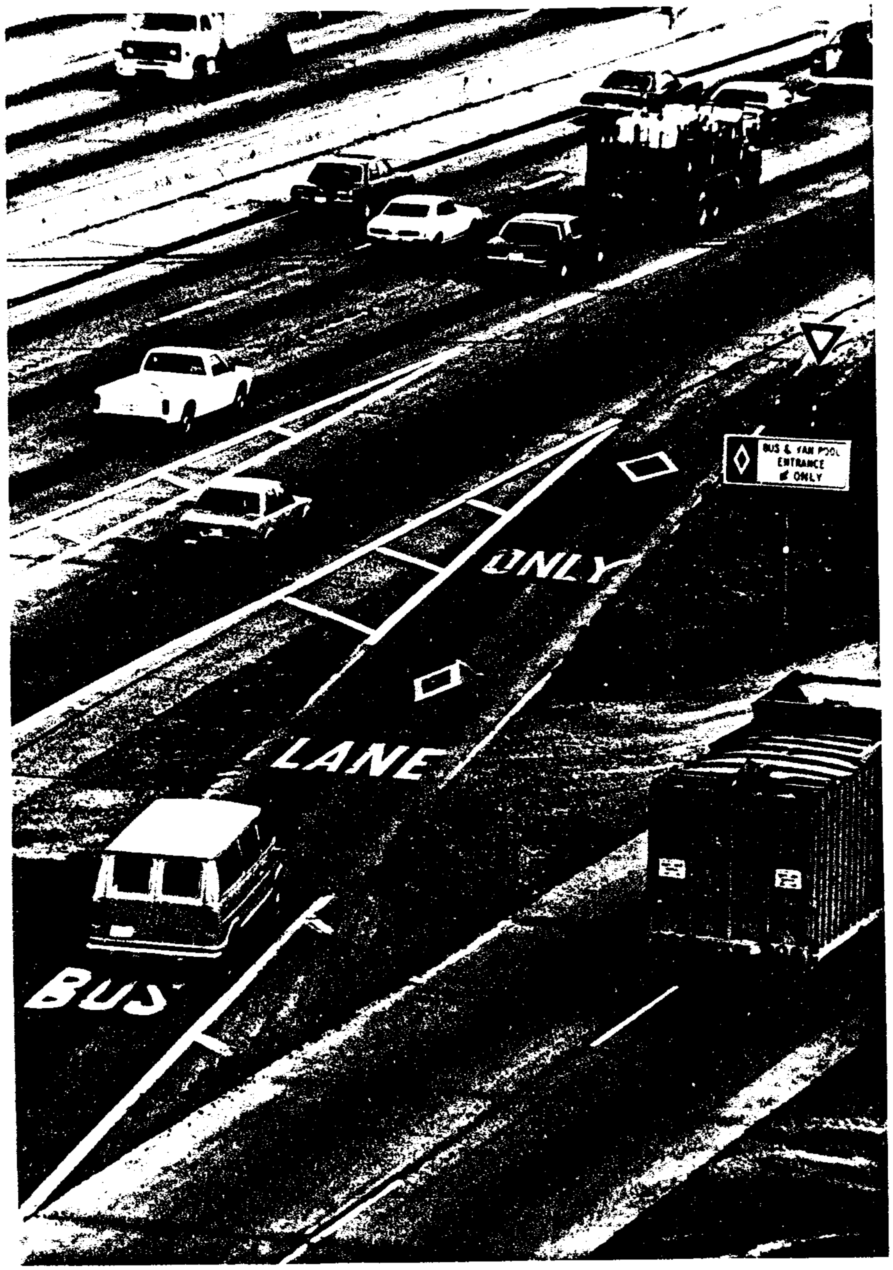


Figure 8. Priority Entry Ramp Operations, Southwest Freeway at Bellaire Blvd., Houston

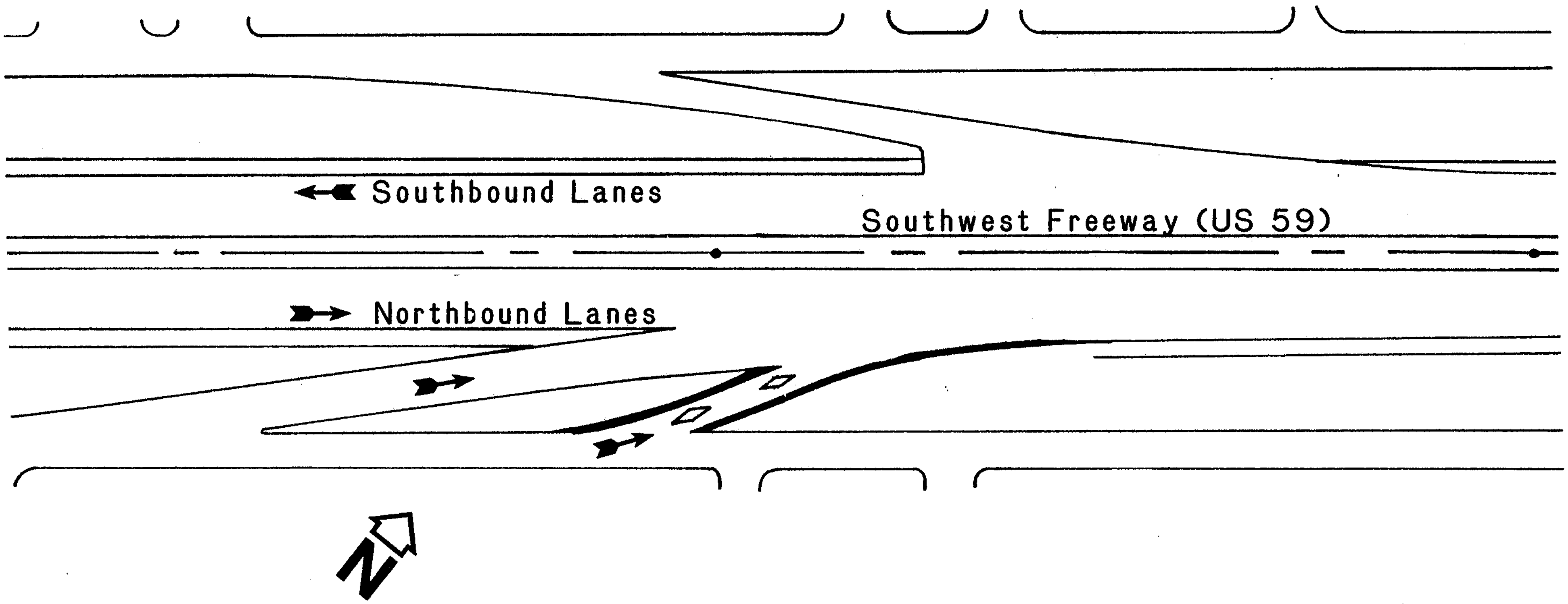


Figure 9. Priority Entrance Ramp, Southwest Freeway At Hillcroft Avenue, Houston

Figure 10. Houston Priority Entry Ramp Southwest Freeway at Hillcroft

RESULTS

Operations

Ramp volumes for both priority and non-priority vehicle use at each site are summarized and averages shown in Table 1 for the a.m. peak hour.

Table 1. Ramp Volume Summary, A.M. Peak Hour

Site	Average Non-Priority Volume (vehicles/hour)	Average Priority Volume (vehicles/hour)			Average Total Passenger Volume (persons/hour)
		Bus	Van	3+ Carpools	
Mockingbird (Dallas)	1445	12	---	---	2550
Ferguson (Dallas)	1014	18	5	21	2478
Bellaire (Houston)	875	9	12	---	1734
Hillcroft (Houston)	1019	15	41	---	2495

The Mockingbird ramp exhibited the highest total vehicular hourly volume (1457); however, as previously discussed, this volume was divided between non-priority vehicles in compliance with designated ramp use and non-priority vehicles in violation of priority authorization. This site also had the lowest priority vehicle usage (12) of all sites.

Both the Ferguson and Hillcroft sites had an average of approximately 1000 non-priority vehicles per hour in a.m. peak hour and 44 and 56 priority vehicles, respectively, during this same time period; total ramp passenger volume was approximately 2500 persons per hour. The Bellaire ramp site, as can be seen in Table 1, was much lower in non-priority and priority usage. This may be the result of the proximity to the Hillcroft site which is also more strategically located to a park-and-ride facility.

A summary of average occupancy levels of both priority and non-priority vehicles at all sites are shown in Table 2. While the average occupancy level of non-priority vehicles at all sites was 1.22 passengers per vehicle, in combination with priority vehicle occupancy, the overall average ramp occupancy level for all vehicles at all sites was 2.09. Although this is a significant change on an individual ramp volume basis, it may have little influence on a total freeway volume basis.

Table 2. Ramp Occupancy Summary, A.M. Peak Hour

Site	Average Occupancy Non-Priority (passengers/vehicle)	Average Occupancy Priority (passengers/vehicle)	Average Total Combined Occupancy (passengers/vehicle)
Mockingbird (Dallas)	1.25	62.00 Buses Only	1.75 All Vehicles
Ferguson (Dallas)	1.26	27.30 Buses, vans, carpools	2.34 All Vehicles
Bellaire (Houston)	1.20	32.57 Buses/vans	1.94 All Vehicles
Hillcroft (Houston)	1.17	23.27 Buses/vans	2.32 All Vehicles

Measurement of average ramp travel time and delay savings for three of the four sites are presented in Table 3. The Mockingbird site was not considered, due to excessive priority ramp violations and confusion by motorists as to appropriate ramp operations. As can be seen, average delay savings per person are minimal at the Ferguson site (no ramp meter), while ranging from 4-5

Table 3. Ramp Delay Summary A.M. Peak Hour

Site	Average Priority Travel Time (Seconds/vehicle)	Average Non-Priority Travel Time (Seconds/vehicle)	Average Delay Savings (Minutes/person)
Mockingbird* (Dallas) No ramp meter	---	---	---
Ferguson (Dallas) No ramp meter	13.0	58.0	0.75
Bellaire (Houston) Ramp meter	15.0	257.0	4.03
Hillcroft (Houston) Ramp meter	15.0	310.0	4.92

*Due to excessive violations and inappropriate ramp operations it was not possible to measure priority and non-priority travel time and delay savings.

minutes per person at the Bellaire and Hillcroft sites (with ramp meter). Delay savings of this magnitude are cost-effective as demonstrated subsequently in this report.

Compliance/Violations

Compliance with priority entry ramp designation has been calculated by the following equation.

$$\text{Compliance (\%)} = \frac{\text{Non-Priority Vehicles Utilizing Non-Priority Ramp}}{\text{Total Non-Priority Vehicles}} \times 100$$

Table 4 presents a summary of average compliance data for the a.m. peak hour at all four sites. Again, the data collected at the Mockingbird site are not meaningful. Note the influence of random enforcement at the Hillcroft site.

Table 4. Ramp Compliance Summary, A.M. Peak Hour

Site	Total Average # Non-priority vehicles Utilizing Non-priority Ramp (vehicles/hour) (1)	Total Average # Non-priority vehicles vehicles (vehicles/hour) (2)	Compliance Ratio (1) ÷ (2)X100 %
Mockingbird* (Dallas)	782	1445	54.1*
Ferguson (Dallas)	1000	1014	98.6
Bellaire (Houston)	852	875	97.4
Hillcroft** (Houston)	1010	1019	99.1**

*Not meaningful
**Random enforcement presence

While seemingly inconsequential relative to compliance, enforcement is more significant influencing violations.

Violation ratio is defined as follows (9).

$$\text{Violation (\%)} = \frac{\text{Unauthorized vehicles using the priority entry ramp}}{\text{vehicles utilizing the priority entry ramp}} \text{X100}$$

Generally, as the compliance ratio is increased, the violation ratio is decreased. Table 5 summarizes average violation data at all four sites for the a.m. peak-hour time period.

Again, the violation data at the Mockingbird site was not meaningful. The violation ratio at the Ferguson site was acceptably low due to the advance motorist information signing and definitive delineation as well as the minimal delay time incurred by non-priority traffic. There was no need for violation of the priority entry ramp, based on travel time savings.

Table 5. Ramp Violation Summary, A.M. Peak Hour

Site	Total Average # Unauthorized for priority entry (vehicles/hour) (1)	Total Average # Vehicle utilizing priority entry ramp (vehicles/hour) (2)	Violation Ratio (1) ÷ (2)X100 %
Mockingbird* (Dallas)	663	675	98.2*
Ferguson (Dallas)	14	58	24.1
Bellaire (Houston)	23	42	54.8
Hillcroft** (Houston)	9	65	13.8**

*Not meaningful
**Random enforcement presence

The most demonstrative example of enforcement influence may be seen in a comparison of the violation rate between the two adjacent Houston sites, Bellaire and Hillcroft. Here, a 40 percent difference in average violation ratio exists between Bellaire and Hillcroft where random enforcement was observed. It should also be noted that a high violation ratio exists at Bellaire where the non-priority traffic is experiencing travel time delays exceeding 4.0 minutes.

Examination of an apparent relationship between non-priority service rate (time waiting in queue), priority vehicle arrival rate (time between vehicles based on priority volume), and violation rate (as previously defined) led to subsequent data collection over a one-month period at the Houston priority entry sites. Data collected were as follows.

(1) Service time of non-priority vehicles

(2) Time headway between arrival of priority vehicles

(3) Volume of priority entry ramp authorized vehicles

(4) Number of priority entry ramp violations

The service time of non-priority vehicles and time headway between arrival of priority vehicles was used to calculate the factor of "Priority Entry Exposure Ratio." This factor is defined as the ratio of the time a non-priority vehicle is exposed to a confirmed usage of the priority entry ramp by a high occupancy vehicle. The associated calculation is as follows.

$$\text{Priority Entry Exposure Ratio} = \frac{\text{Service Time of Non-Priority Vehicles (minutes)}}{\text{Arrival Time Headway of Priority Vehicle (minutes)}}$$

The hypothesis which follows is that as the exposure ratio increases the violation ratio will decrease. The exposure ratio is influenced by both delay time to non-priority vehicles and usage (volume) of the priority entry ramp which confirms the worth of the priority entry ramp and acts as incentive for modal shift.

All additional data were collected during the a.m. peak hour, Tuesday-Thursday, clear-dry weather conditions, and with no enforcement present. Table 6 summarizes this data for each day of collection. The average of these results, with regards to priority volume, non-priority delay, and violation ratio, are consistent with the previously discussed results in Tables 1-3.

A linear regression model was applied to this data set to test significance with the exposure ratio established as the independent variable and the violation ratio as the dependent variable. A summary of statistics employing the Statistical Analysis System (SAS) is shown in Table 7. As indicated, the R^2 value equals 0.6659 for acceptable significance. The linear equation is given as follows.

$$\text{Violation Ratio} = 0.55 - 0.08 \text{ Exposure Ratio}$$

Table 6. Exposure Ratio Summary, A.M. Peak Hour

Site	Time of Collection (a.m.)	Service Time of Non-Priority Vehicles (minutes) (1)	Arrival Time Headway of Priority vehicles (minutes) (2)	Exposure Ratio (1)÷ (2)	Violation Ratio
Hillcroft	6:30-7:30	3.98	0.79	5.03	0.183
Bellaire	7:30-8:30	6.67	3.38	1.97	0.438
Bellaire	7:30-8:30	6.00	3.49	1.72	0.375
Hillcroft	7:30-8:30	4.08	3.53	1.16	0.393
Bellaire	7:00-8:00	3.21	5.45	0.59	0.593
Bellaire	7:00-8:00	3.31	5.45	0.61	0.500
Hillcroft	7:00-8:00	3.25	1.88	1.73	0.238
Bellaire	6:30-7:30	2.96	3.53	0.84	0.553
Bellaire	6:30-7:30	3.15	2.16	1.46	0.457
Hillcroft	6:30-7:30	4.58	1.68	2.73	0.285
Average		4.12	3.13	1.78	0.40

Table 7. Summary of Linear Regression Statistics, Exposure Ratio vs. Violation Rate

Source	DF	Sum of Squares	Mean Square	F Value	Prob F
Model	1	0.108255	0.108255	15.948	0.0040
Error	8	0.054305	0.006788147		
C Total	9	0.162561			
Root MSE		0.082390	R-Square	0.6659	
Dependent Mean		0.401500			
Coefficient of Variance		20.5206			
Variable	DF	Parameter Estimate	Standard Error	T for H0:	Prob (T)
Intercep	1	0.549817	0.045367	12.119	0.0001
Expose	1	-0.83137	0.020818	-3.993	0.0040

Figure 11 graphically illustrates a plot of the actual and predicted data. A reasonable correlation appears evident. It should be noted, that even with the calculated significance of these results, the study sample size is limited.

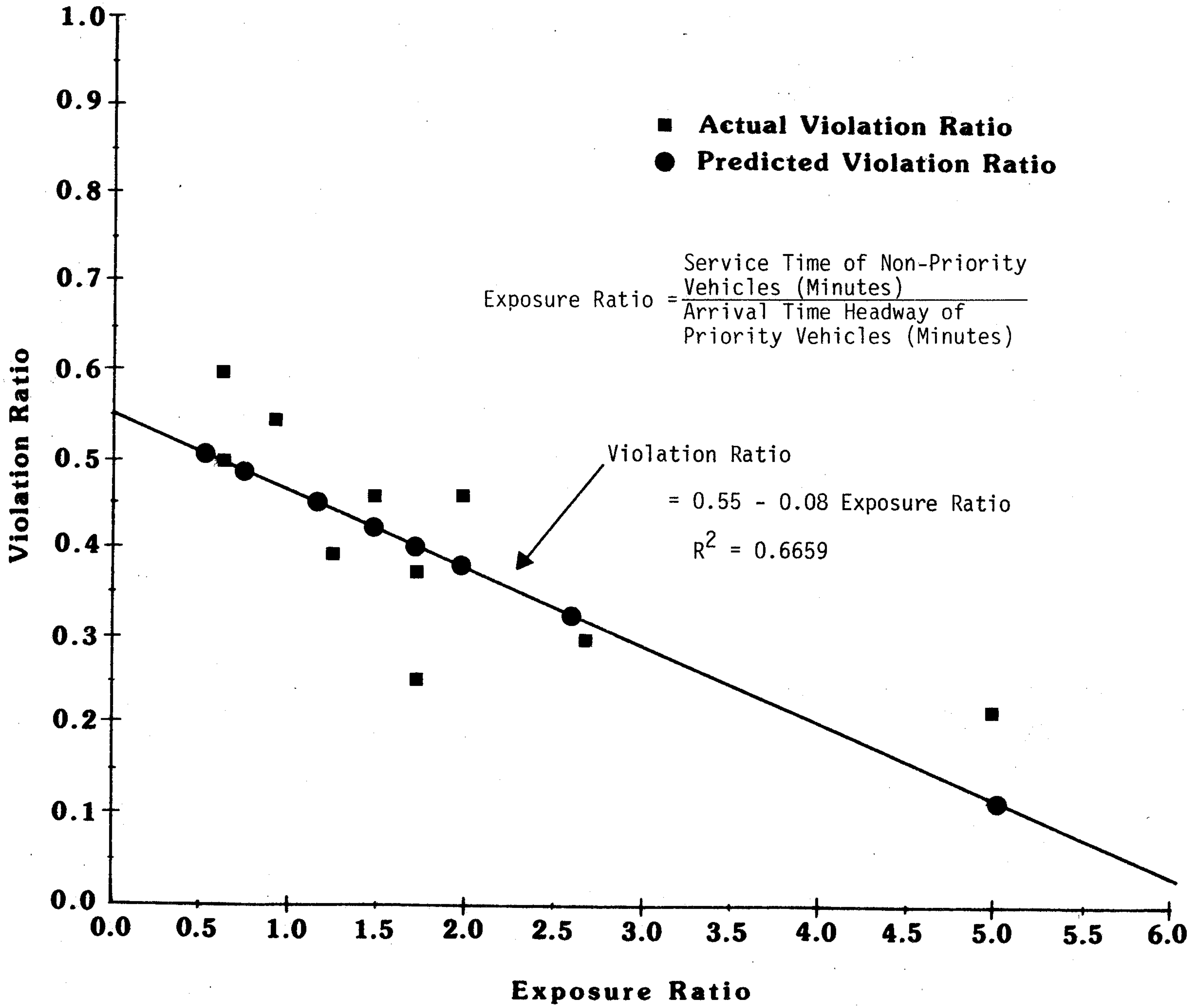


Figure 11. Violation Ratio VS. Exposure Ratio

Summary

For the three operational study sites in Texas, excluding Mockingbird in Dallas, an assessment of the impact of implementing priority entry ramps may be summarized as follows.

- Priority entry ramp vehicular volume constitutes 2-4% of total ramp volume.
- Priority entry ramp passenger volume constitutes 35-50% of total ramp person usage.
- Priority entry ramps increased total ramp vehicular occupancy levels by 0.75-1.10 passengers per vehicle.
- Priority entry ramps were responsible for delay savings to high-occupancy vehicle patrons of between 0.75-5.00 minutes per person.
- The average compliance rate was approximately 98%, while the average violation rate was 31%.
- Random enforcement appears to reduce violation rate by perhaps 40% as evidenced by the limited comparative data within this study.
- Violations appear to decrease as priority entry exposure ratio increases. Exposure ratio defined as average service time of non-priority vehicles divided by average time headways of priority vehicle arrivals.

BENEFIT-COST UTILITY

Assumptions

Based on the previously obtained data regarding each individual priority entry site installation and operation, a methodology was formulated to assess the benefit-cost utility of these existing sites and also to assess the feasibility of implementation at future locations. Within this methodology, several assumptions were made. These are as follows.

(1) The design life of a priority entry ramp improvement is established as 10 years.

(2) The discount rate determined as reasonable for economic analysis is 10%.

(3) Priority entry improvement initial capital expenditure will vary from $20,000-$120,000 as these are site specific. A portion of this total cost ($10,000) will be assumed to represent the cost of ramp signalization.

(4) Annual operating cost was assumed to average $2500 per year divided between maintenance ($500) and random enforcement ($2000). An initial regular enforcement cost of $5,000 was also assumed as necessary.

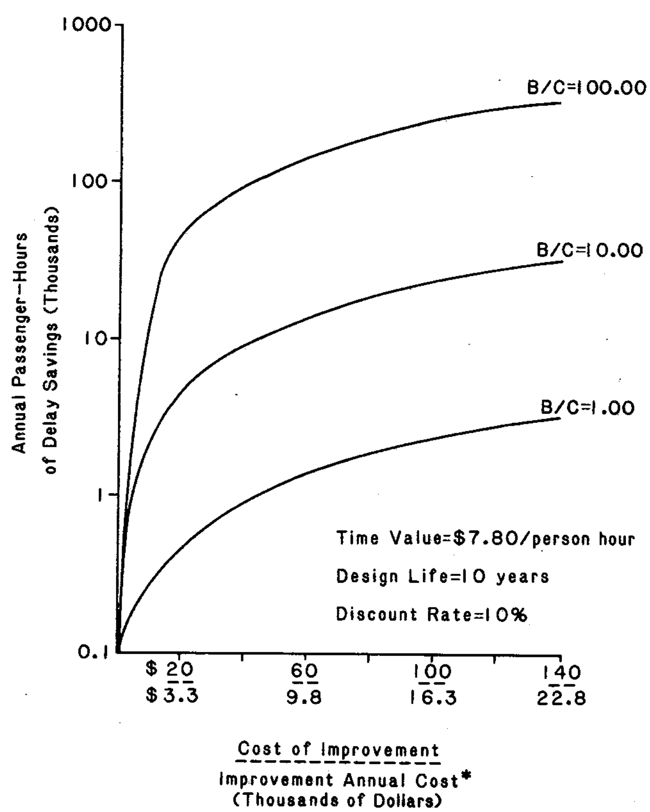
(5) Time value of delay savings was taken as $7.80 per person-hour (1.25 persons per vehicle) which is an accepted 1982 state and national standard (10).

(6) Average vehicle occupancy levels were assumed to be 60 persons per bus, 9 persons per van and 3 persons per carpool.

(7) For calculation purposes, there was assumed to be 250 operational days per year and a peak-hour factor representing a proportionate level of peak-period demand of 0.60 (i.e., 60% of total peak period demand occurs in the peak hour).

Using these assumptions, calculations may be performed for a range of priority demand levels and translated into annual delay savings. Priority entry improvement capital costs may also be annualized using a 6.144 factor (10 year, 10%) along the previously mentioned expenditure levels. Graphical comparison between annual benefits and costs allows the plotted representation of a family of curves for ratios of 1:1, 10:1, and 100:1. Figure 12 illustrates the general graph of benefit-cost ratios for priority entry ramps.

Three operational study sites in Texas--Ferguson, Bellaire and Hillcroft--were all evaluated for cost-effectiveness under these assumptions and the stated calculation methodology. Table 8 presents the benefit-cost results for each site.



* Annualized Factor = 6.144

Figure 12. Benefit/Cost, Priority Entrance Ramps

Table 8. Benefit-Cost Calculations Priority Entry Ramp Sites

Site	Ferguson (Dallas)	Bellaire (Houston)	Hillcroft (Houston)
Peak Hour Priority Demand	1,200 Persons	650 Persons	1,200 Persons
Average Delay Savings per Person	45 Seconds	240 Seconds	300 Seconds
Total Delay Savings per Day	24.2 Hours	72.0 Hours	176.1 Hours
Total Annual Delay Savings	6,050 Hours	18,000 Hours	44,025 Hours
Annual Cost of Delay (Benefits)	$47,190	$140,400	$343,393
Total Life Improvement Cost	$90,000	50,000	50,000
Annual Cost of Improvement	$14,648	8,138	8,138
Benefit-Cost Ratio	3.22	17.25	42.20

RECOMMENDATIONS

The following general guidelines are recommended in evaluating the feasible implementation of priority entry ramps at potential future sites.

(1) Travel time delay to non-priority motorists should be equal to or greater than 2.0 minutes per person. This implies the existence of a ramp meter signal or extreme freeway congestion.

(2) Travel time delay savings to priority ramp authorized users should be in the range of 4.0-6.0 passenger hours during the peak hour, equivalent to 1500-2500 passenger hours per year.

(3) Construction and/or maintenance costs for priority entry ramp improvements are site specific and require individual project estimation.

(4) Initial regular enforcement presence is necessary for reinforcement of priority authorization and ramp operations; randomly maintained enforcement presence assures that an acceptable violation rate will result.

(5) Advance operational signing and definitive delineation are critical to minimize motorist confusion and unintentional violations of priority entry ramps.

(6) No significant impact on freeway occupancy level can be anticipated from the successful modal shift resulting from an individual priority entry ramp site.

(7) Priority entry ramps can serve an important function in concert with freeway control and/or transitway system access.

(8) From a public relations standpoint, priority entry ramp treatments are perceived as a positive transportation improvement action.

Figure 13 represents a graphical interpretation of these recommendations and the previously outlined methodology. A feasible and infeasible zone of implementation is established between the two parameters of priority vehicle patrons utilizing a ramp and potential delay savings to these patrons due to ramp delay.

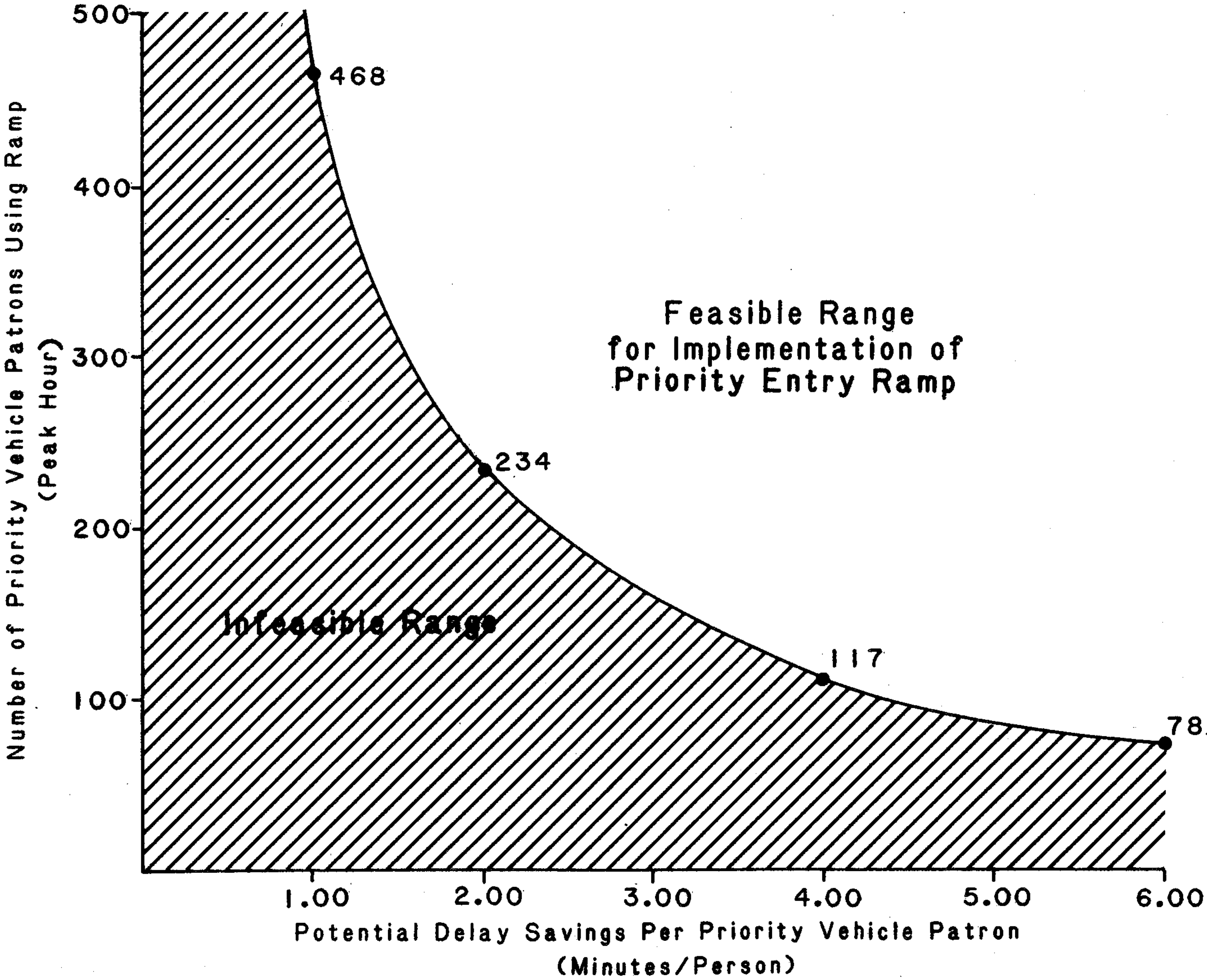


Figure 13. Feasibility of Priority Entry Ramp Implementation

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