Feasibility Study Of Advanced Technology Hov Systems: Volume 3: Benefit Implications Of Alternative Policies For Including Hov Lanes In Route Guidance Networks

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Feasibility Study of Advanced Technology HOV Systems

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FEASIBILITY STUDY OF ADVANCED-TECHNOLOGY HOV SYSTEMS

Volume 3:

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by

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Contents

EXECUTIVE SUMMARY

Vehicle delays on urban freeways in the U.S. have totalled over 2 billion vehicle-hours annually. By 2020, these delays could exceed 10 billion vehicle-hours. Just as important, urban traffic congestion has lost its directional bias and, in seriously congested areas, spilled outside rush hours. Effective traffic management is therefore needed as travel demand continues to grow. Emerging route-guidance technologies could help drivers to avoid routes that are congested, by giving them alternative less-congested routes. In this way, available system capacity could be more efficiently utilized and urban mobility enhanced.

To date, plans for testing or implementing dynamic route-guidance systems have focussed on route-guidance networks comprised of freeway mainline and arterial streets. Prior studies have reported that "real-time" motorist information could reduce travel time for guided vehicles by 6-15 percent depending on the study, and possibly some smaller travel-time savings for unguided vehicles. However, prior studies generally did not include high-occupancy-vehicle (HOV) lanes in route guidance networks, when HOV lanes existed on the corridors. When there is an HOV lane on a corridor, the inclusion of the HOV lane in the route guidance network means that route guidance information will also be provided to vehicles eligible to use HOV lanes (i.e, HOV's), in addition to the general traffic (i.e., single-occupancy vehicles, or SOV's).

This study aims to investigate whether it would be beneficial to include HOV lanes in route guidance networks when HOV lanes exist on the corridors. This is an important policy issue for a number of reasons. First, HOV lanes are integral parts of many urban corridors in the U.S., and there is no compelling reason at this time to exclude them from route-guidance networks. Second, HOV's share same roadways with SOV's outside HOV lanes, thus congestion outside HOV lanes also affects HOV's. Therefore, HOV's can conceivably benefit from having route guidance information to guide their journey. Third, evidence suggests that HOV lanes are a good public policy, thus it appears desirable to continue to provide travel-time advantages to HOV's over SOV's even when advanced route guidance technologies become available.

Study Objective

The objectives of this study are to:

- Identify policy scenarios for including HOV lanes (in addition to freeway mainline and surface streets) in dynamic route-guidance networks, when HOV lanes exist on the corridors.
- Determine the feasibility of these policy scenarios, by assessing travel-time impacts of these scenarios on various vehicle classes (e.g., guided HOV's, guided SOV's, unguided HOV's, and unguided SOV's).

Alternative Policy Scenarios

In order to assess travel-time merits of including HOV lanes in route guidance networks (in addition to freeway mainline and surface streets), two policy scenarios for including HOV lanes in route guidance networks are defined. Travel-time characteristics under these two scenarios will be compared with those under a base-case scenario in which route guidance networks only include freeways and surface streets but not HOV lanes, when all scenarios are implemented in identical corridors and traffic conditions. The scenario in which HOV lanes are not included in route guidance networks is chosen as the base-case scenario because it represents a scenario for which travel-time benefits have been extensively reported in the literature. This base-case scenario is described first, followed by the description of the two new policy scenarios (Scenarios II and III).

Base-Case Scenario: HOV Lanes Not Included in Route-Guidance Networks

Under the base-case scenario, it is assumed that HOV lanes would not be included in route-guidance networks; only freeway mainline and surface streets are included. Therefore, route guidance information would essentially not be meaningful for vehicles using HOV lanes.

Scenario II: HOV Lanes are Included in Route Guidance Networks

Under Scenario II, HOV lanes would be included in route networks. Therefore, HOV's and SOV's equipped with route guidance devices could receive information on "best" routes to guide their respective journey. Under Scenario II, there is a need to distinguish between equipped HOV's and equipped SOV's. Available shortest paths within the network would be assigned to equipped HOV's and SOV's simultaneously, without preferential treatments for one group over the other.

Scenario *III: HOV* lanes are Included *in* Route Guidance *Networks and Equipped HOV's are Given Priorities in Route Selection Over Equipped SOV's*

Scenario III is an extension of Scenario II in that it is aimed at minimizing travel time for guided HOV's, by giving available shortest paths to guided HOV's first while routes assigned to guided SOV's would be subject to having minimized travel time for guided HOV's. The rationale for wanting to give preferential route selections to guided HOV's over guided SOV's is based on a general perception that HOV's (relative to drive-alone) are a good public policy. Therefore, when advanced route guidance technologies become available, it would still be desirable to give travel-time advantage to HOV's over SOV's as far as possible, so that HOV's could still have the same or greater travel-time advantage over SOV's than they currently do now.

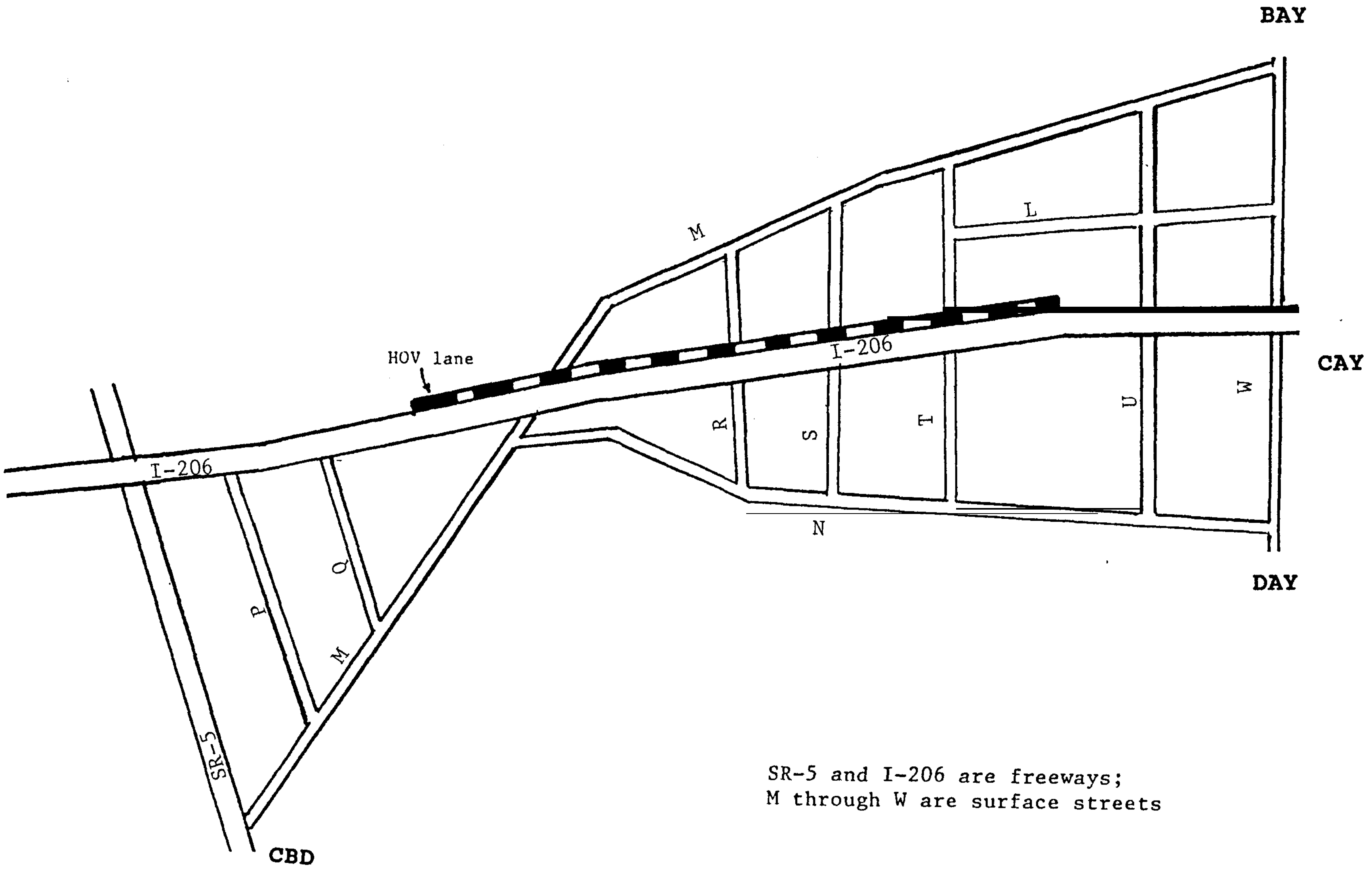
Methodology

The assessments of routes used and travel time characteristics under Scenarios II and III, relative to the base-case scenario, are based on a hypothetical corridor consisting of two freeways, 10 surface streets, and one HOV lane (Figure S1). These assessments are performed for two levels of existing freeway congestion -- "serious" and "slight" freeway congestion. In this way, the sensitivity of the merits of Scenarios II and III to variations in the freeway congestion level may also be evaluated.

Route Selection Process for Unguided Vehicles

Unguided vehicles do not receive route guidance information to guide their journey. For analysis purposes, it is assumed that unguided vehicles choose routes based on some personal preference and route familiarity. Based on results of a survey reported by a prior study, this study assumes that 89 percent of unguided HOV's choose "freeway-biased" routes (i.e., routes that include the HOV lane, which maximize the length of available freeways and minimize the use of surface streets); and the other 11 percent choose "other" routes (i.e., routes including the HOV lane, with various combinations of freeways and surface streets). Unguided HOV's do not use surface streets exclusively (i.e., "arterial-biased" routes) to complete their trips because such routes preclude the use of the HOV lane.

The analysis assumes that 76 percent of unguided SOV's choose "freeway-biased" routes (routes that maximize the use of freeways), 14 percent "arterial-biased" routes (surface streets exclusively), and 10 percent "other" routes (various combinations of freeways and surface streets).



SR-5 and I-206 are freeways;
M through W are surface streets

Figure S1: Hypothetical Corridor

Route Selection Process for Guided Vehicles

Guided vehicles can receive information on "best" routes. Because the extent to which the received information is used by motorists is still a subject of continuing research, this study simply assumes that all drivers of guided vehicles follow the information given to them. Route selections for guided vehicles are determined from route assignment simulation that seeks to minimize "user" (as opposed to "systems") travel time.

Route Assignment Simulation Procedure

To improve the reliability of route assignment results for the hypothetical corridor (which consists of freeways, surface streets, and numerous intersections), the route assignment simulation procedure makes use of two traffic simulation models (FREQ8PC and TRANSYT-7F), in conjunction with the ASSIGN module of MINUTP. FREQ8PC and TRANSYT-7F are used to compute travel time and delays on freeways and surface streets, respectively. The ASSIGN module of MINUTP is then used to determine the shortest paths within the network, based on the travel-time impedance obtained from FREQ8PC and TRANSYT-7F.

Summary of Principal Findings

1. Ease of implementation and system-design flexibility are likely to favor the base-case scenario over Scenario II or Scenario III. If the base-case scenario is implemented on the hypothetical corridor, average travel time for HOV's, guided SOV's, and unguided

SOV's (averaged across all three O-D pairs) could be 17.1, 25.8, and 29.8 minutes, respectively, when the freeways are severely congested. These relative travel-time values suggest that if a motorist who currently drives alone wishes to reduce his travel time, he' may choose to either buy route guidance devices or rideshare. The latter option would permit the use of HOV lanes. Between these two options, the motorist is likely to achieve greater travel-time savings from ridesharing than from driving alone with route guidance devices (i.e., travel-time savings of 43 percent with ridesharing versus 13 percent with drive-alone using route guidance devices, when the freeways are severely congested). Given that high-occupancy vehicles (as opposed to single-occupancy vehicles) are perceived to be a good public policy, this finding suggests that driving-alone using route guidance devices would still be less attractive than ridesharing.

2. There could be some travel time advantage due to Scenario II or Scenario III relative to the base-case scenario. That is, Scenario II or Scenario III could reduce the range of travel time on routes used by guided vehicles and, to a smaller extent, the range of travel time on routes used by unguided vehicles. This implies that both Scenario II and III can improve travel time dependability within the network, relative to the base-case scenario.

3. Percent changes in average travel time per vehicle for Scenario II or Scenario III relative to the base-case scenario are shown in Tables S1 through S4, by the O-D pair. Table S5 shows a

Table S1

Percent Changes in Average Travel Time for Guided Vehicles
for Scenarios II and III Relative to Base-Case Scenario
("Serious" Freeway Congestion)

- means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Guided HOV	Guided sov	Guided HOV	Guided sov	Guided HOV	Guided sov
Scenario II	-8.6	0	+3.0	-7.4	+5.9	-5.5
Scenario III	-17.1	-4.3	-6.0	-9.3	-5.9	-9.1

Table S2

Percent Changes in Average Travel Time for Unguided Vehicles
for Scenarios II and III Relative to Base-Case Scenario
("Serious" Freeway Congestion)

- means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov
Scenario II	0	0	0	0	-1.7	0
Scenario III	-5.7	-3.0	-3.0	-3.3	-5.1	-1.7

Table 83

Percent Changes in Average Travel Time for Guided Vehicles for Scenarios II and III Relative to Base-Case Scenario ("Slight" Freeway Congestion)

- means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Guided HOV	Guided sov	Guided HOV	Guided sov	Guided HOV	Guided sov
Scenario II	-1.9	-2.7	-2.5	-3.1	+4.9	+2.9
Scenario III	-5.1	0	-6.1	+3.1	-1.9	+5.7

Table 84

Percent Changes in Average Travel Time for Unguided Vehicles for Scenarios II and III Relative to Base-Case Scenario ("Slight" Freeway Congestion)

- means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov
Scenario II	-0.7	-4.5	+5.2	-2.2	-2.1	+3.7
Scenario III	-1.4	-5.3	-1.5	-0.8	-1.3	+0.9

Table S5

Selected Travel-Time Statistics for the Three Scenarios

Statistic	"Serious" Freeway Congestion			"Slight" Freeway Congestion		
	Base-Case	Scenario II	Scenario III	Base-Case	Scenario II	Scenario III
Aver. travel time per guided HOV (mins.)	N/A*	17.0	15.3	N/A*	14.6	14.0
Aver. travel time per guided SOV (mins.)	25.8	24.6	23.8	17.4	17.2	17.8
Aver. travel time per unguided HOV (mins.)	17.1	17.3	16.8	14.6	14.6	14.3
Aver. travel time per unguided SOV (mins.)	29.8	29.9	29.3	17.8	17.8	17.8
Ratio of travel time for all HOV's to guided SOV's	0.66	0.70	0.64	0.84	0.85	0.80
Ratio of travel time for all HOV's to unguided SOV's	0.57	0.58	0.52	0.82	0.82	0.82
Ratio of travel time for guided HOV's to unguided HOV's	NA*	0.98	0.91	NA*	1.0	0.98
Total vehicle-hours	1,116	1,100	1,065	753	751	750

*For the base-case scenario, all HOV's are unguided by design summary of selected travel-time statistics for Scenarios II and III, relative to the base-case scenario. Values shown in Table 5 are averaged across all three O-D pairs.

4. When comparing Scenario III with the base-case scenario, Table S5 indicates that Scenario III could reduce average travel time for both guided HOV's and guided SOV's, particularly in "serious" freeway congestion. This suggests that Scenario III warrants consideration and in-depth investigations when planning route guidance projects on urban corridors that have HOV lanes.

5. When comparing Scenario II with Scenario III, Table S5 shows that Scenario III could yield lower average travel time for guided HOV's than Scenario II, without adversely affecting average travel time of guided SOV's. Further, under Scenario III, guided HOV's could have almost 10 percent lower travel time than unguided HOV's. All these imply that Scenario III particularly favors guided HOV's, and that the use of route guidance technologies under Scenario III might help to encourage the use of HOV's.

6. Table S5 suggests that as freeways become more congested, potential travel-time advantages of Scenarios III and II over the base-case scenario are expected to become more pronounced. On the other hand, if freeways rarely reach a "serious" congestion state, Scenario III or II are not likely to be necessary and the base-case scenario ought to suffice.

Conclusion

Similar to reported travel-time savings due to the use of motorist information in the literature, findings from this study concerning travel-time merits of including HOV lanes in route guidance networks (Scenarios III and II) relative to excluding HOV lanes (the base-case scenario) are also likely to be corridor specific; Because this study is the first to address the feasibility of providing route-guidance information to both HOV's and SOV's, generalization of the findings to any corridor anywhere is likely to be premature, without investigating many more real-world corridors.

BACKGROUND

The public has ranked urban traffic congestion among the top problems affecting quality of life in large metropolitan areas (ITE, 1986). Between now and the year 2020, travel by automobiles could grow at the rate of 1.7 percent annually (TRB, 1988). Evidence indicates that there were over 2 billion vehicle-hours of delay on urban freeways in the U.S. in 1987 (Lindley, 1989). By 2020, this delay can exceed 10 billion vehicle-hours. More important, the nature of urban traffic congestion in major metropolitan areas is becoming more complicated, with congestion in seriously congested urban areas spilling outside rush hours (Underwood, 1990).

Dynamic route-guidance technologies, by providing drivers with information about alternative less-congested routes, could help drivers to avoid routes that are severely congested. In this way, available road capacity could be more efficiently utilized and urban mobility could be enhanced. Dynamic route guidance systems making use of real-time traffic information are not new concepts, and several system variations have been reported in the literature. First-generation systems include ERGS in the U.S. (Rosen et al, 1970), CACS in Japan (Yumoto et al, 1979), and AL1 in Europe (Chen, 1992); all of which use low-rate inductive loops for communication. Second-generation systems include ALI-SCOUT (von Tomkewitsch, 1991) and EURO-SCOUT (Chen, 1992), which use beacons for short-distance communication. Third-generation systems include CARMINAT (Renault, 1990) which uses one-way wide-area communication into the vehicle via RDS; SOCRATES (Catling, 1990) and ADVANCE (Kirson, 1991) which use two-way communication via a digital cellular radio link; and TRAVTEK in the U.S. (Rillings, 1991). These third-generation systems are capable of transmitting informati'on continuously and at a high rate (Chen, 1992). The first two generations of route guidance systems are generally "centralized" systems (or infrastructure-based), in which the "best" routes are determined by some centralized facilities. On the other hand, the third-generation systems are generally "distributed" systems, in which the "best" routes are determined by computers on board the vehicles.

Dynamic route-guidance systems could be designed to provide information on shortest paths for intended journey, thereby minimizing unnecessary excess travel and/or delays. Excess travel and delays have adverse economic consequences (e.g., King et al, 1987). Heretofore, efforts for testing and implementing dynamic route-guidance systems have usually focused on networks comprised of freeways (i.e., the freeway mainline) and surface streets. Prior studies investigating potential travel-time benefits of such plans have generally agreed that advanced motorist information could reduce travel time, and that route guidance systems are feasible technologies. For example, Yumoto et al (1979) reported that route guidance systems could provide travel time savings of 9-15 percent in Tokyo. Kobayashi (1979) estimated potential travel-time savings in Tokyo of 6 percent. JMP (1987) reported reductions in vehicle delays due to the use of dynamic route guidance systems of 7-15 percent in London. Al-Deek et al (1988) reported travel-time savings of over 10 percent for vehicle equipped with route guidance devices in California. In addition, most prior studies have also agreed that advanced motorist information could yield greater travel-time benefits when there are incidents on the roadway than under recurring congestion. Besides direct travel-time benefits for guided vehicles, route guidance systems may also result in indirect travel-time benefits for unguided vehicles. For example, Smith et al (1989) reported that potential benefits to unguided traffic in London could be as much as 3 percent. However, Koutsopoulos et al (1989) reported essentially no benefits to unguided vehicles under recurring congestion.

The literature has not systematically evaluated whether it would be beneficial to include high-occupancy-vehicle (HOV) lanes in route guidance networks, when HOV lanes exist on the corridors, to provide route-guidance information to vehicles eligible to use HOV lanes (to be called HOV's) in addition to the general traffic (to be called single-occupancy vehicles or SOV's). This study aims to perform analyses to address this question, which is an important policy issue for a number of reasons. First, HOV lanes are an integral part of many urban corridors in the U.S., and there is no compelling reason at this time to exclude them from route-guidance networks. Second, outside HOV lanes, vehicles eligible to use HOV lanes share same roadways with vehicles not eligible to use HOV lanes (or SOV's). Therefore, congestion outside HOV lanes also affects HOV's, and they are likely to benefit from having route guidance information to guide their journey. Third, evidence suggests that HOV lanes are good public policies, thus it appears desirable to continue to provide travel-time advantages to HOV's over SOV's even when advanced route guidance technologies become available.

STUDY OBJECTIVE

The objective of this study is to assess the feasibility of including HOV lanes in route guidance networks, in addition to freeways and surface streets, when HOV lanes exist on the corridors. Specifically, this study aims to:

- Identify policy options for incorporating HOV lanes in route guidance networks, so that route guidance information can be provided to both HOV's and SOV's.
- Assess travel-time impacts of these policy options relative to a commonly planned route guidance scenario that does not include HOV lanes in the network.

This study emphasizes the assessment of travel-time merits of policy scenarios that include HOV lanes in route guidance networks relative to a commonly planned scenario that does not include HOV lanes in route guidance networks, but not relative to the existing traffic condition when route guidance systems are not in use. This is because potential travel-time impacts due to route guidance systems have already been extensively investigated and reported in the literature.

This study does not address the technology development of dynamic route guidance systems (e.g., hardware and software design). For analysis purposes, this study assumes that dynamic route guidance technologies are available to provide information about the "best" routes within the network for intended journey. It is conceivable that real-time information on traffic conditions and "best" routes could also bring about other benefits (besides travel-time savings), for example, changes in fuel consumption, vehicle emissions, and traffic accidents. However, quantifications of these other potential benefits are outside the scope of this study.

ORGANIZATION OF THIS REPORT

This report is organized into six sections as follows. Section 1 presents a hypothetical corridor defined for the evaluation purpose, as well as two policy scenarios for including HOV lanes in route guidance networks. Section 2 describes methodology for determining route choices and travel time under these policy scenarios. It includes descriptions of route selection processes for guided and unguided vehicles, as well as a route assignment simulation procedure. Section 3 presents analysis results for a "serious" freeway congestion level, while Section 4 presents results for a "slight" freeway congestion level. In Section 5, implications of the analysis results are discussed. Finally, Section 6 presents the conclusion.

1. HYPOTHETICAL CORRIDOR AND POLICY OPTIONS FOR INCORPORATING HOV

LANES IN ROUTE GUIDANCE NETWORKS

1.1 A Hypothetical Corridor

For analysis purposes, a hypothetical corridor comprised of two freeways, an HOV lane, and 10 arterial streets is defined as shown in Figure 1. One hypothetical freeway, I-206, is about 8 miles long and runs east to west. The other hypothetical freeway, SR-5, is about 1.6 miles long and runs north to south. Both freeways have four lanes in each direction. On I-206, there is an exclusive-access HOV lane (5.3 miles long), with controlled access and egress at both ends of the facility. This HOV lane is separated from the I-206 mainline by permanent barriers. Therefore, access and egress to the HOV lane outside the designated access and egress points are not possible. Three of the ten arterial streets (M, N, and L) run east to west, while the remaining seven (P through W) run north to south. These arterial streets generally have two lanes in each direction, except M and N with three lanes in each direction. All intersections between the arterial streets are controlled by traffic lights, and all turning movements are permitted at these intersections. Free-flow speeds for the arterial streets and freeways are assumed to be 35 and 65 mph, respectively. There is a central business district (CBD) at the southwestern end of this corridor; and BAY, CAY, and DAY are three residential zones to the east of the CBD.

1.2 Route Guidance Scenarios To Be Evaluated

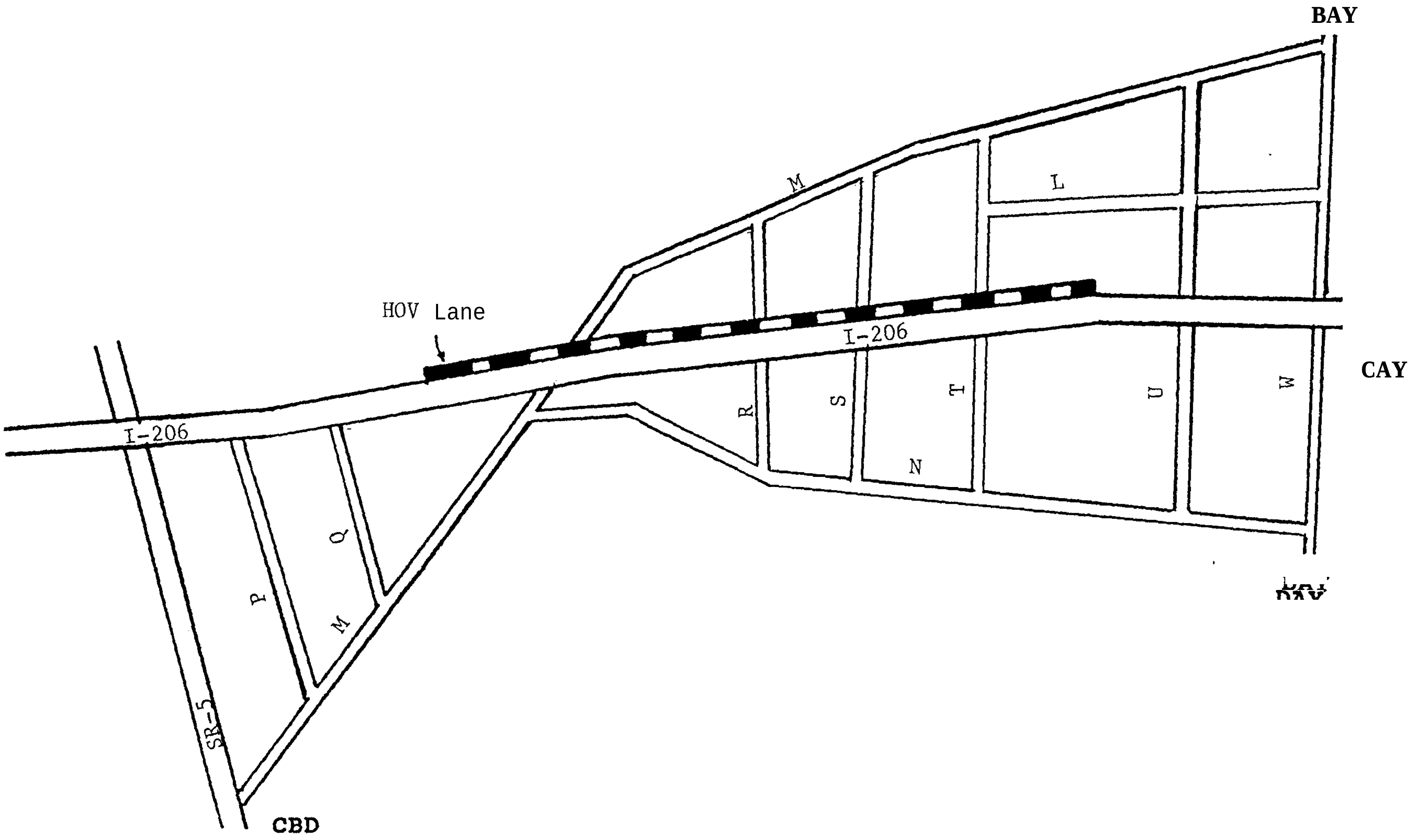


Figure 1
Hypothetical Corridor Defined for Analysis

Two alternative policy options for including HOV lanes in route guidance networks to provide information to both HOV's and SOV's are evaluated against the commonly planned policy scenario in which route guidance networks do not include HOV lanes. All three scenarios are described below, in the context of the above hypothetical corridor.

Base-Case Scenario: HOV lane is not part of route guidance network

The scenario in which the HOV lane is not included in the route guidance network is considered to be the base-case scenario here. This is because it represents a commonly perceived scenario for early deployment of dynamic route guidance systems, and its potential travel-time benefits have been extensively documented in the literature. Under this base-case scenario, only the mainline of the two freeways and all the arterial streets are included in the route guidance network, but not the HOV lane on I-206.

Scenario II: HOV lane is included in route guidance network

Under Scenario II, the HOV lane, in addition to the freeway mainline and arterial streets, is also included in the route network. In this way, information on the shortest paths can be provided to vehicles equipped with route guidance devices, some of which are eligible to use the HOV lane (i.e., HOV's) while some others are not (i.e., SOV's). Theoretically speaking, the available route-choice set for HOV's is larger than that for SOV's because HOV's (if they wish) can also use the route-choice set for

SOV's, but SOV's are not legally permitted to use the HOV lane.

Unlike the base-case scenario, vehicle travel time characteristics under Scenario II has not been examined by prior studies.

Scenario III: HOV lane is included in route guidance network and equipped HOV's have priorities in route selection over equipped SOV's

Scenario III is an extension of Scenario II, in that available shortest paths within the network would be assigned to equipped HOV's first, while the routes assigned to equipped SOV's would be subject to having minimized travel time for equipped HOV's. The rationale for wanting to give priorities in route selections to equipped HOV's over equipped SOV's is based on a perception that HOV's (relative to drive-alone) are a good public policy. Therefore, when advanced route guidance technologies are deployed, it would still be desirable to give travel-time advantage to HOV's over SOV's as far as possible, so that HOV's can still have the same or greater travel-time advantage over SOV's than they currently do now.

2. METHODOLOGY

Travel-time merits of Scenarios II and III (relative to the base-case scenario) will be assessed by comparing travel time for vehicles traveling from the CBD to BAY, CAY, and DAY, when all scenarios are deployed in identical conditions. Travel between the CBD to these three residential zones can be accomplished via the freeways, arterial streets, or various combinations of the freeways and arterial streets.

The analysis assumes that there are a total of 2,700 vehicles per hour (vph) traveling from the CBD to BAY, CAY, and DAY, with the volume equally divided among the three destinations. Of this hourly volume, 840 vph are HOV's and 1,860 vph are SOV's; ratios of HOV's to SOV's are identical for the three O-D pairs. About 33 percent of vehicles traveling from the CBD to BAY, CAY, and DAY are equipped with route guidance devices. Under Scenarios II and III, this percent of route guidance devices used applies to both HOV's and SOV's. Under the base-case scenario, all HOV's are unguided by design, and the 33-percent usage rate only applies to SOV's.

The following paragraph describes route selection processes for unguided and guided vehicles assumed in the analysis. This is then followed by the description of a route assignment simulation procedure used for determining routes and travel time for all vehicle classes (guided HOV's, guided SOV's, unguided HOV's, and unguided SOV's).

2.1 Route Selection Process

Route selection assumptions can influence results of route-choice and travel-time analyses. However, they are likely to be less critical for the evaluation performed in this study because the goal here is to assess travel-time impacts of Scenarios II and

III relative to the base-case scenario, when all scenarios are implemented under identical conditions and route selection assumptions.

Route selection processes for vehicles equipped with route guidance'devices can be different from those not equipped with the devices, as follows.

Route Selection Process Assumed for Unguided Vehicles

Unguided vehicles do not have "real-time" traffic information to help guide their journey. Benshoof (1970) and Wright (1976) reported that most people driving to work tended to use the same routes day after day, even though some of them might know of alternative routes. Al-Deek et al (1988), in a survey of commuters in the Los Angeles area, reported that an overwhelming majority of the drivers indicated that they tended to use routes that maximized the length of available freeways, thus minimizing the use of surface streets. These kinds of routes are referred to as "freeway-biased" routes. At the other extreme, a relatively small percentage of the drivers indicated that they tended to avoid using freeways altogether and, instead, completed their journey using only surface streets. These kinds of routes are referred to as "arterial-biased" routes. The remaining drivers (who also accounted for a relatively small percentage) indicated that they tended to use other remaining routes, which combined freeways and surface streets without necessarily trying to maximize travel on freeways or surface streets. These other routes are referred to as "other" routes. .

For travel from the CBD to BAY, CAY, and DAY, one "freeway-biased" route generally exists for one O-D pair, while there are many possible "arterial-biased" routes per O-D pair. To lessen the complexity of the analysis, a small number of these are designated as "arterial-biased" routes; the designated routes usually incur relatively shorter travel distance (compared with other non-designated routes) and/or do not incur "back-tracking." Non-designated arterial-biased routes are then included in the category of "other" routes.

Using the survey data reported by Al-Deek et al (1988) as guidelines, the analysis in this paper assumes the following route choice processes for unguided HOV's and unguided SOV's:

- Of all unguided HOV's, 89 percent will use the HOV lane and choose "freeway-biased" routes. The remaining 11 percent will use "other" routes that use the HOV lane. "Arterial-biased" routes will not be used by unguided HOV's in traveling from the CBD to BAY, CAY, and DAY because such routes preclude the use of the HOV lane on I-206.
- Of all unguided SOV's, about 76 percent will use "freeway-biased" routes, 14 percent designated "arterial-biased" routes, and 10 percent "other" routes.

Route Selection Process for Guided Vehicles

Guided vehicles can have "real-time" information on traffic conditions and the shortest paths. Currently, research is needed to determine the extent to which motorists actually make use of the received information. For analysis purposes, this study assumes that all drivers of guided vehicles will use the information provided to them to complete their intended journey. Furthermore, because route guidance devices are aimed at reducing travel time of individual guided vehicles, the shortest paths will be determined from traffic assignments that seek to minimize "users" travel time, as opposed to "systems" travel time (Wardrop, 1952).

2.2 Route Assignment Simulation

Ideally, the determination of route used and travel time for all vehicle classes should be accomplished by means of a dynamic traffic simulation/assignment model that integrates freeways, HOV lanes, and surface streets. Unfortunately, such a model was not available at the initiation of this study. Although models such as INTEGRATION (1990) and CONTRAM (1989) have been known to have some dynamic features, their applications to date have been too limited for us to assess their applicability for this study. The lack of ideal dynamic assignment models for analyzing complex dynamic route-guidance system applications was stated by Van Vuren (1990), "It is unlikely that in the foreseeable future the dynamic assignment problem will be formally solved."

In the absence of an ideal dynamic traffic simulation/assignment model, a simulation procedure was developed specifically for the evaluation in this study. This procedure makes use of available traffic simulation and traffic assignment models. This procedure is described below.

Because guided vehicles have access to information to help minimize travel time, their route choices significantly depend on travel time values on individual links. For freeways, link travel time values are known to be sensitive to the volume-to-capacity ratio (FHWA, 1973). For surface streets with signalized intersections, intersection delays critically affect link travel time. Intersection delays in turn are influenced by many factors such as signal timing, turning movements, and traffic volumes. Conventional traffic assignment models, such as MINUTP (COMSIS, 1991), have generally been used to perform route assignments. The route assignment algorithm in MINUTP (i.e., the ASSIGN module) is based on the following travel time/flow function:

$$T_c = T_0 + 0.15\ (V/C)^4 \tag{1}$$

where T_c is link travel time

T_0 is free-flow travel time

V is link volume

C is link capacity

Equation (1) can yield reasonable approximations of link travel time, and thus route-assignment results, for freeway networks. For the hypothetical corridor of this study, however, it was felt that such a function would yield link travel time estimates that might be unreliable for surface streets. In an attempt to improve the reliability of the route-assignment results for the hypothetical corridor, an "incremental" route assignment simulation procedure is developed to combine FREQ8PC (Imada et al, 1985), TRANSYT-7F (USDOT, 1974), and MINUTP (COMSIS, 1991). FREQ8PC, a computerized traffic simulation model for freeways, is used to estimate travel time and delays on freeways. TRANSYT-7F, a computerized traffic simulation model for surface streets and intersections, is used to estimate intersection delays and link travel time on surface streets. Link travel time output from FREQ8PC and TRANSYT-7F then provides the impedance input for the ASSIGN algorithm in MINUTP, which is used for determining the shortest paths between O-D pairs.

The "incremental" route assignment simulation procedure using FREQ8PC, TRANSYT-7F, and MINUTP in combination is summarized below.

1. Interzonal trips are divided into four equal proportions, for use in "incremental" traffic assignment. That is, interzonal trips are "loaded" onto the network in four increments for four route assignment increments, each with 25 percent of the trips.

2. For each route assignment increment, interzonal trips by unguided vehicles are "loaded" onto the network in accordance with the route selection process mentioned above for unguided vehicles. FREQ8PC and TRANSYT-7F are run to estimate link travel time (T_1) for the entire network. T_1 is then used for running ASSIGN to determine the shortest paths (with the capacity restraint option) for guided vehicles. The output from ASSIGN is a set of link volumes (V,). V_1 are then "loaded" onto the network to re-run

FREQ8PC and TRANSYT-7F to compute a new set of link travel time (T_2).

3. The process in (2) is then repeated for the second route-assignment increment, and so on, until 100 percent of interzonal trips are all assigned.

4. Once all interzonal trips are assigned, final link volumes from ASSIGN are "loaded" onto the network to run FREQ8PC and TRANSYT-7F to obtain final travel time on all links.

5. Travel time on individual routes for particular O-D pairs is then computed by totaling appropriate link travel time values.

2.3 Loading of Guided HOV's and SOV's

For the base-case scenario (in which the HOV lane is not included in the route guidance network), all HOV's are unguided by design. Routes used by SOV's that are equipped with route guidance devices are the shortest paths, while routes used by SOV's without route guidance devices may or may not be the shortest paths.

For Scenario II, in which the HOV lane is included in the route-guidance network, there are some HOV's and some SOV's equipped with route guidance devices. The shortest paths for these guided HOV's and guided SOV's are determined from the above "incremental" traffic assignment simulation, with <u>combined "loading"</u> of guided HOV's and guided SOV's during each route assignment increment. This implies that, under Scenario II, available "best" routes in the network are assigned to guided HOV's and guided SOV's simultaneously.

For Scenario III, the "incremental" route assignment is performed using sequential "loading" of guided HOV's and guided SOV's, so as to give available shortest paths in the network to guided HOV's while the routes assigned to guided SOV's are subject to the equipped HOV's having minimized their travel time.

2.4 Sensitivity Analysis

Determinations of routes used by guided and unguided vehicles, as well as their travel time, are performed for two different levels of existing freeway congestion. Existing freeway congestion is congestion currently existing without the use of route guidance systems. Please note that the existing condition is not the base-case scenario, because the latter is associated with the deployment of route guidance systems on the freeway mainline and surface streets without including the HOV lane. For brevity, the two levels of existing freeway congestion are called "serious" and "slight" freeway congestion. This sensitivity investigation would enable us to assess whether travel-time merits of Scenarios II and III relative to the base-case scenario might be sensitive to the freeway congestion level. These "serious" and "slight" freeway congestion conditions are defined below.

"Serious" Freeway Congestion: Profiles of speeds along I-206 and SR-5 under existing "serious" freeway congestion are shown in Figure 2. The figure indicates that, on I-206, speeds range from

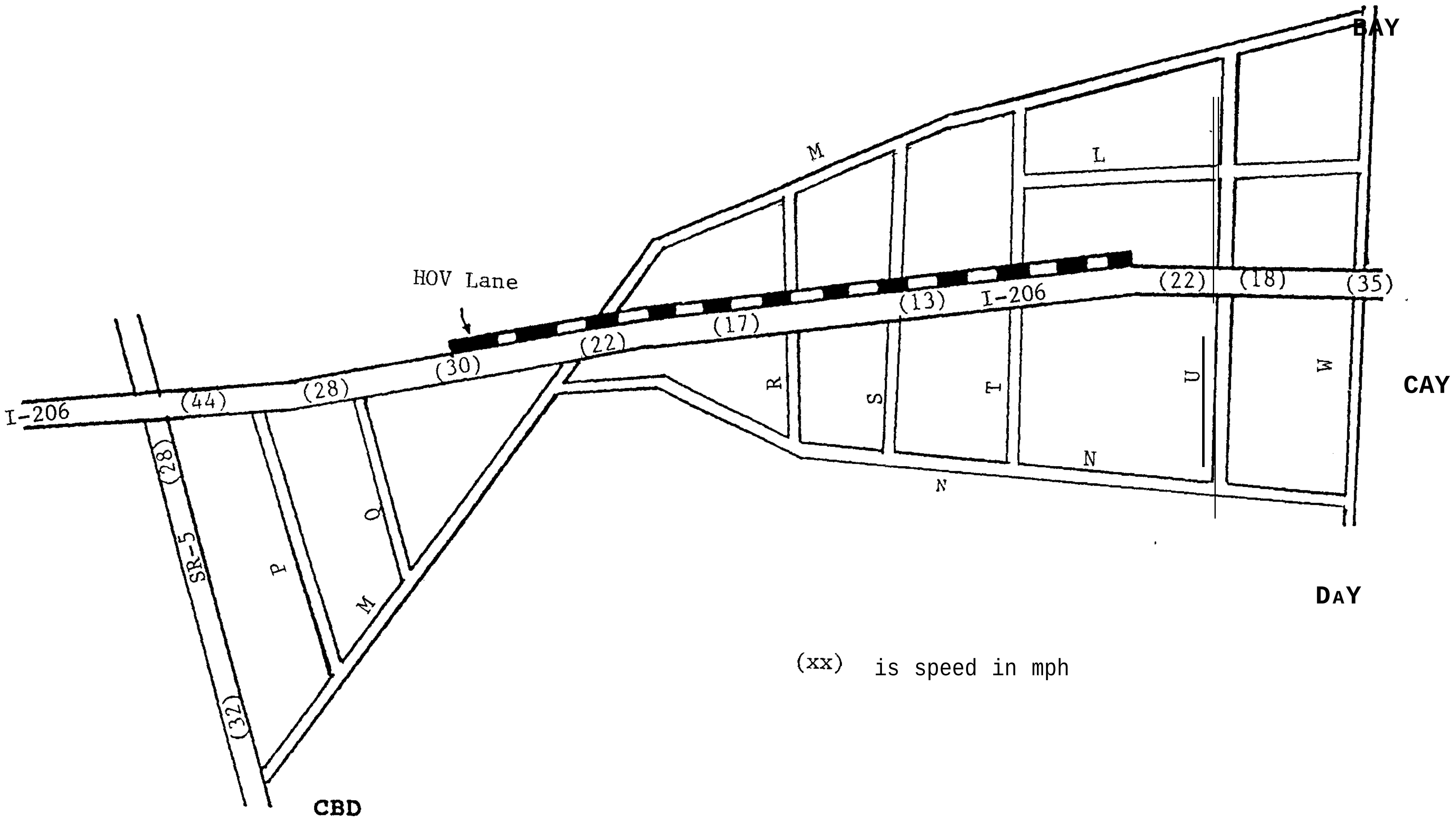


Figure 2: Speed Profile in "Serious" Freeway Congestion

13 to 30 mph (LOS F). On SR-5, speeds are mostly about 30 mph (LOS F). For surface streets, existing levels of service are much better than those on the two freeways, mostly LOS B to C (not shown in Figure 2).

Table 1 shows existing travel time (i.e., travel time without the use of route guidance systems) on the "freeway-biased" route and designated "arterial-biased" routes under "serious" freeway congestion. Table 1 indicates that, under "serious" freeway congestion, existing travel time on "freeway-biased" routes could be as much as 1.5 times that on the designated "arterial-biased" routes.

o ***"Slight" Freeway Congestion:*** Speed profiles on I-206 and SR-5 under existing "slight" freeway congestion are shown in Figure 3. The Figure indicates that on I-206, speeds vary widely, from 22 mph (LOS F) upstream of the HOV lane's egress, to 35 mph (LOS E) upstream of the HOV lane's access, and to 45-55 mph (LOS D) for most of the remaining freeway sections. On SR-5, speeds are mostly around 45 mph (LOS D). For surface streets, the levels of service are identical to those in "serious" freeway congestion.

Existing travel time under "slight" freeway congestion on the "freeway-biased" route and designated "arterial-biased" routes are also shown in Table 1. The table indicates that existing travel time on the "freeway-biased" routes is lower than that on the designated "arterial-biased" routes for "slight" freeway congestion (the former is about 0.8 times the latter). This is opposite to

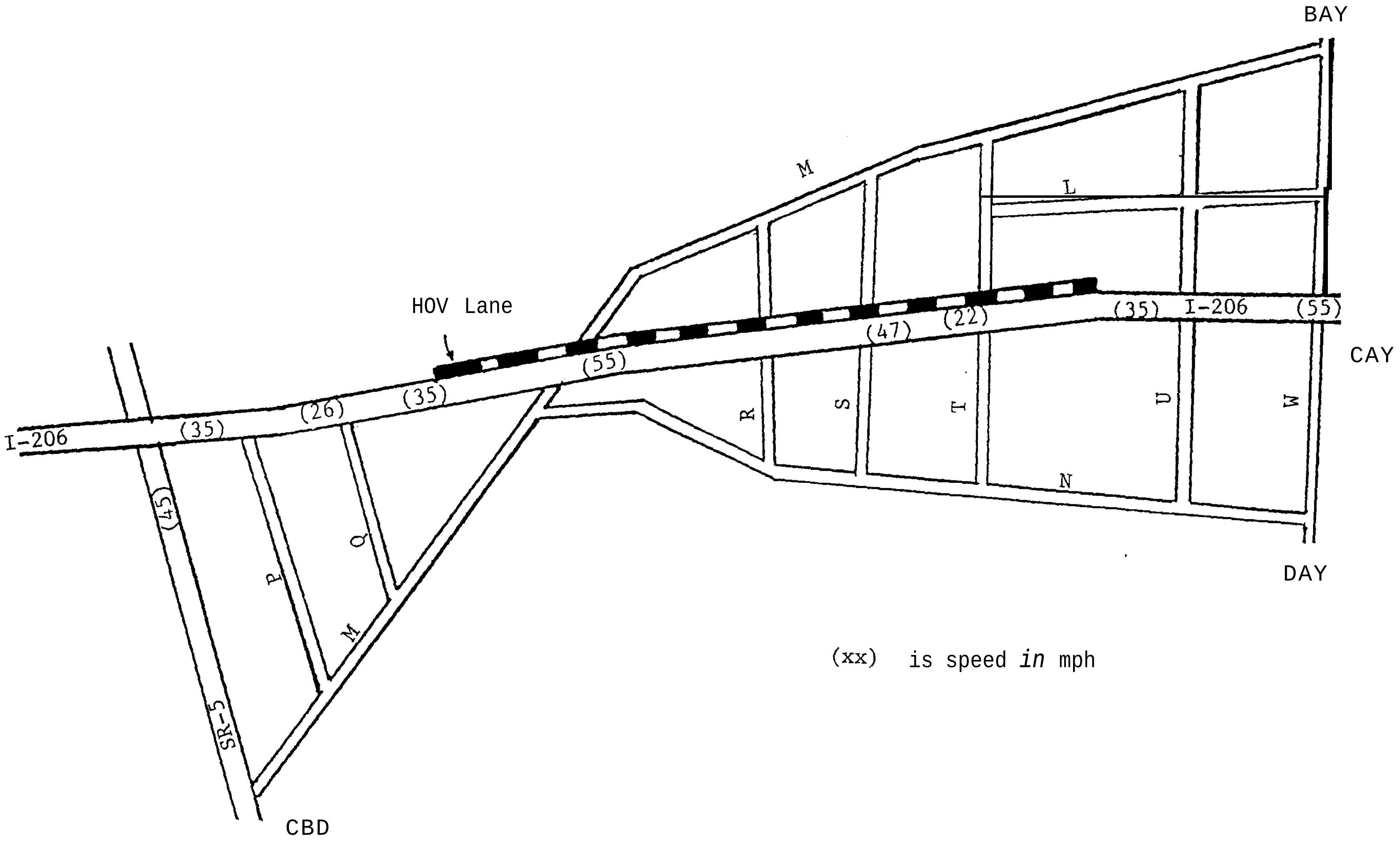


Figure 3: Speed Profile in "Slight" Freeway Congestion

TABLE 1

Comparison of Existing Travel Time on "Freeway-Biased" and "Arterial-Biased" Routes

From CBD To	Degree of Freeway Congestion	Existing Average Travel Time (minutes) "Freeway-Biased" Route	Existing Average Travel Time (minutes) "Arterial-Biased" Routes
BAY	Serious	30.5	19.5
	Slight	18.0	19.5
CAY	Serious	29.0	20.0
	Slight	16.0	20.0
DAY	Serious	30.5	20.0
	Slight	18.0	20.0

relative travel time between the two routes in "serious" freeway congestion.

Analysis results for "serious" and "slight" freeway congestion levels are presented separately below.

3. SIMULATION RESULTS FOR "SERIOUS" FREEWAY CONGESTION

Simulation results are presented with an emphasis on comparing routes and travel time characteristics under Scenarios II and III with those under the base-case scenario.

3.1 Routes Used By Vehicles

Routes used by unguided HOV's and unguided SOV's under all three scenarios are the same, in terms of roadway links making up individual routes (Table 2). Please note that even though roadway links making up individual routes used may be identical among all three scenarios, travel time values on these same roadway links could differ from scenario to scenario, depending on the vehicle volume. From Table 2, 89 percent of unguided HOV's use "freeway-biased" routes, while the remaining 11 percent use various "other" routes. Unguided HOV's do not use designated "arterial-biased" routes because such routes preclude the use of the HOV lane on I-206. Seventy-six percent of unguided SOV's use "freeway-biased" routes, 14 percent use designated "arterial-biased" routes, and 10 percent use various "other" routes.

Under the base-case scenario, all HOV's are unguided by design, and their route sets are the same as those shown for

Table 2

Routes Used by Unguided HOV's and SOV's Under All Three Scenarios

From CBD TO:	Roadway Links Within Route	
	Unguided HOV's	Unquided SOV's
BAY	SR5,I-206,W * "Other" routes ***	SR5,I-206,W * M ** M,N,W ** "Other" routes ***
CAY	SR5, I-206 * "Other" routes ***	SR5,I-206 * M,W ** M,N,W ** "Other" routes ***
DAY	SR5,I-206,W * "Other" routes ***	SR5,I-206,W * M,N ** "Other" routes ***

TABLE 3

Routes Used by Guided HOV's and SOV's Under Base-Case Scenario in "Serious" Freeway Congestion

From CBD TO:	Roadway Links Within Route	
	Guided HOV's	Guided SOV's
BAY	No guided HOV's by design[(a)]	M **
CAY	No guided HOV's by design[(a)]	M,N,W ** M,W **
DAY	No guided HOV's by design[(a)]	M,N ** SR5,I-206,S,N ***

* "Freeway-biased" route
** "Arterial-biased" route
*** "Other" route
(a) Route sets are identical to those for HOV's shown in Table 2.

unguided HOV's in Table 2. Route sets for guided SOV's under the base-case scenario are shown in Table 3, which indicates that these guided SOV's mostly use designated "arterial-biased" routes plus one "other" route. However, guided SOV's under the base-case scenario do not use "freeway-biased" routes.

Under Scenario II, there are both guided HOV's and guided SOV'S. Route sets for these guided vehicles are shown in Table 4. Comparison of Table 3 with Table 4 reveals that route sets for guided SOV's under Scenario II are almost identical to those under the base-case scenario (in terms of roadway links making up individual routes used). However, comparison of Table 2 with 4 reveals that route sets for guided HOV's under Scenario II differ from route sets for HOV's under the base-case scenario.

Under Scenario III, there are both guided HOV's and guided SOV'S. Route sets for these guided vehicles are shown in Table 5. Comparison of Tables 2, 4, and 5 reveals that route sets for guided HOV's under Scenario III differ somewhat from those under Scenario II, as well as from route sets for HOV's under the base-case scenario. However, route sets for guided SOV's under Scenario III are identical to those under Scenario II (in terms of roadway links making up individual routes used). These results imply that the priorities given to guided HOV's over guided SOV's in the selection of available shortest paths could affect routes used by guided HOV's, without apparently affecting route sets for guided SOV's.

Table 4

Routes Used by Guided HOV's and sov's Under Scenario II in "Serious" Freeway Congestion

From CBD TO:	Roadway Links Within Route	
	Guided HOV's	Guided SOV's
BAY	M,Q,I-206,U,L,W *** SR5,I-206,U,L,W ***	M **
CAY	M,Q,I-206 *** SR5,I-206 *	M,N,W ** M,W **
DAY	SR5,I-206,U,N *** M,Q,I-206,U,N ***	M,N ** M,I-206,S,N *** M,W ***

Table 5

Routes Used by Guided HOV's and sov's Under Scenario III in "Serious" Freeway Congestion

From CBD TO:	Roadway Links Within Route	
	Guided HOV's	Guided SOV's
BAY	SR5,I-206,U,L,W ***	M **
CAY	SR5,I-206 *	M,N,W ** M,W **
DAY	SR5,I-206,W * SR5,I-206,U,N ***	M,N ** M,I-206,S,N *** M,W ***

*	"Freeway-biased" route
**	"Arterial-biased" route
***	"Other" route

3.2 Vehicle Travel Time

Question 3.2.1: Are there differences in the range of travel time among the three scenarios ?

As mentioned above, route sets for guided HOV's could differ from scenario to scenario, while route sets for guided SOV's tend to be stable across different scenarios (in terms of roadway links making up individual routes used). For any particular route, the vehicle volume and travel time could vary by the scenario. Table 6 shows the range of travel time on route sets used by guided HOV's and guided SOV's under the base-case scenario, Scenario II, and Scenario III. The table shows that the range of route travel time under Scenarios II and III could be considerably smaller than that under the base-case scenario (up to 60 percent smaller). This is found to be true for both guided HOV's and SOV's, consistently for all three O-D pairs. Between Scenarios II and III, the range of travel time for guided HOV's under Scenario III could be smaller than that for guided HOV's under Scenario II, while there is little difference in the range of travel time for guided SOV's between the two scenarios.

As previously mentioned, route sets used by unguided vehicles under all three scenarios are identical, in terms of roadway links making up individual routes used. However, the simulation results indicate that the range of travel time for route sets used by unguided vehicles under Scenarios II and III could be up to 35 percent smaller than that under the base-case scenario. This is

Table 6

Range of Travel Time on Routes Selected for Guided Vehicles in "Serious" Freeway Congestion

Policy Option	Travel time (Minute)					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Guided HOV	Guided SOV	Guided HOV	Guided sov	Guided HOV	Guided sov
Base-case	16.5-26.0*	23.0	16.0-25.0*	23.5-29.0	16.0-25.0*	25.0-29.0
Scenario II	14.5-18.0	23.0	15.5-19.0	24.0-26.0	16.5-19.5	24.5-26.5
Scenario III	14.5	22.0	15.5	23.0-25.5	15.5-16.5	24.0-26.0

*These are unguided vehicles by design under the base-case scenario

Table 7

Range of Travel Time on Routes Used by Unguided Vehicles in "Serious" Freeway Congestion (from CBD to BAY)

Policy Option	Travel time (Minutes)				
	Unguided HOV's		Unguided SOV's		
	Freeway Biased Routes	Other Routes	Freeway Biased Routes	Arterial Biased Routes	Other Routes
Base-case	17.0	16.5-26.0	30.0	23.0-30.0	27.5-39.0
Scenario II	17.0	16.0-22.0	30.5	23.0-27.5	27.5-35.5
Scenario III	16.5	16.0-21.0	30.0	22.0-27.0	27.0-34.0

consistent for all three O-D pairs. There appears to be little difference in the range of travel time for unguided vehicles between Scenario II and Scenario III. For illustration, the range of travel time for unguided vehicles from CBD to BAY is shown in Table 7. The trends in the relative travel-time range for guided vehicles among the three scenarios for the other O-D pairs are similar to that for CBD-to-BAY journey.

The above results suggest that one advantage of including the HOV lane in the route guidance network (over the base-case scenario) appears to be that vehicle travel time could become less variable and more predictable for guided as well as unguided vehicles, but particularly for the former. When comparing Scenario II with Scenario III, the travel-time results suggest that by giving priorities in the selection of the shortest paths to guided HOV's (over guided SOV's), the range of travel time for guided HOV's could become less variable, without apparently affecting the range of travel time for guided SOV's or unguided vehicles.

Question 3.2.2: Are there differences in average travel time (per vehicle) among the three scenarios ?

Vehicles are not equally distributed among individual routes used. To estimate average travel time per vehicle for a particular vehicle class (e.g., guided HOV's, guided SOV's, unguided HOV's, and unguided SOV's), travel time on individual routes has to be weighted by the numbers of vehicles actually using those routes. Tables 8 through 10 show such weighted average travel time

Table 8

Average Travel Time** for All Vehicle Classes from CBD to BAY in "Serious" Freeway Congestion

Policy Option	Average Travel Time (Minutes per Vehicle)*						
	HOV's			**SOV's**			
	Guided	Unguided Freeway Biased	Unguided Other Routes	Guided	Unguided Freeway Biased	Unguided Aterial Biased	Unguided. Other Routes
Base-case	N/A	17.0	21.5	23.0	30.0	26.5	33.0
Scenario II	16.0	17.0	20.0	23.0	30.5	25.0	32.0
Scenario III	14.5	16.5	19.0	22.0	29.5	24.5	31.0

* Average travel time is rounded to the nearest 0.5 minutes.

** Average travel time is weighted by volumes on individual routes.

Table 9

Average Travel Time** for All Vehicle Classes From CBD to CAY in "Serious" Freeway Congestion

Policy Option	Average Travel Time (Minutes per Vehicle)*						
	HOV's			SOV's			
	Guided	Unguided Freeway Biased	Unguided Other Routes	Guided	Unguided Freeway Biased	Unguided Aterial Biased	Unguided. Other Routes
Base-case	N/A	16.0	22.0	27.0	29.0	29.5	33.5
Scenario II	17.0	16.0	20.0	25.0	29.5	25.5	33.0
Scenario III	15.5	15.5	19.0	24.5	28.5	24.5	31.5

* Average travel time is rounded to the nearest 0.5 minutes

** Average travel time is weighted by volumes on individual routes

Table 10

Average Travel Time** for All Vehicle Classes
From CBD to DAY in "Serious" Freeway Congestion

Policy Scenario Option	Average Travel Time (Minutes per Vehicle)*						
	HOV's			SOV's			
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other. Routes
Base-case	N/A	16.5	21.0	27.5	29.5	29.0	32.0
Scenario II	18.0	16.5	20.0	26.0	30.0	25.5	30.5
Scenario III	16.0	16.5	18.5	25.0	29.5	25.0	29.5

* Average travel time is rounded to the nearest 0.5 minutes
** Average travel time is weighted by volumes on individual routes

(expressed as minutes per vehicle) for the four vehicle classes for each of the O-D pairs. Table 11 shows percent changes in weighted average travel time for guided HOV's and SOV's under Scenarios II and III, relative to the base-case scenario. Table 12 shows percent changes in weighted average travel time for unguided HOV's and unguided SOV's under Scenarios II and III relative to the base-case scenario. Table 11 indicates that:

- The deployment of Scenario III could reduce average travel time for guided HOV's and guided SOV's relative to HOV's and guided SOV's under the base-case scenario, respectively. These reductions could range from 6 to 17 percent (depending on the O-D pair) for guided HOV's, and as much as 9 percent for guided SOV's.
- Relative to HOV's under the base-case scenario, the deployment of Scenario II could either reduce or increase average travel time for guided HOV's, depending on the O-D pair. However, Scenario II could reduce average travel time for guided SOV's (relative to guided SOV's in the base-case scenario) by up to 6 percent.

Table 12 indicates that:

- Relative to the base-case scenario, Scenario III could reduce average travel time for unguided HOV's and unguided SOV's. These reductions could range from 3 to 6 percent for unguided HOV's, and from 2 to 3 percent for unguided SOV's.
- Relative to the base-case scenario, Scenario II appears

Table 11

Percent Changes in Weighted Average Travel Time Per Guided Vehicle for Scenarios II and III Relative to Base-case Scenario ("Serious" Freeway Congestion)

- means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Guided HOV	Guided sov	Guided HOV	Guided sov	Guided HOV	Guided sov
Scenario II	-8.6	0	+3.0	-7.4	+5.9	-5.5
Scenario III	-17.1	-4.3	-6.0	-9.3	-5.9	-9.1

Table 12

Percent Changes in Weighted Average Travel Time Per Unguided Vehicle for Scenarios II and III Relative to Base-Case Scenario ("Serious" Freeway Congestion)

- means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov
Scenario II	0	0	0	0	-1.7	0
Scenario III	-5.7	-3.0	-3.0	-3.3	-5.1	-1.7

to have little impact on average travel time of unguided HOV's or unguided SOV's.

The above results indicate that, from the perspective of the amount of travel time savings, Scenario III appears to be better than the base-case scenario or Scenario II. Scenario II in turn appears to be slightly better than the base-case scenario.

Question 3.2.3: If the base-case scenario is deployed (in which **HOV** lanes are not part of the route-guidance network), could potential travel-time benefit of route guidance devices encourage driving alone with the devices, as oppose to ridesharing ?

This question is of interest because it is conceivable that, under the base-case scenario, the promise of travel-time savings offered by route guidance devices may encourage motorists to drive alone, as opposed to ridesharing. To explore this question, mean travel time values for HOV's, guided SOV's, and unguided SOV's for all three O-D pairs combined are determined. Under the base-case scenario when the freeways are operating at LOS F throughout, these mean travel time values for HOV's (which are unguided by design), guided SOV's, and unguided SOV's are found to be 17.1, 25.8, and 29.8 minutes, respectively. These suggest that if a motorist who currently drives alone wishes to reduce his existing travel time, he may choose to either buy route guidance devices or rideshare (the latter option would permit the use of the HOV lane). Between these two options, the motorist is likely to achieve greater travel-time savings from ridesharing than from driving alone with route guidance devices (i.e., travel-time savings of 43 percent for ridesharing versus 13 percent for driving alone with route guidance devices). Given that high-occupancy vehicles (as opposed to single-occupancy vehicles) are perceived to be a good public policy, this finding suggests that driving alone with route guidance devices when freeways are severely congested is still less attractive than ridesharing as far as travel-time incentives are concerned.

3.3 Vehicle-Hours of Travel

Table 13 shows the numbers of the four vehicle classes on various kinds of routes for the three O-D pairs combined. Estimated numbers of vehicle-hours of travel incurred by all vehicles traveling from CBD to BAY, CAY, and DAY, are shown in Tables 14-16, respectively. These tables indicate that, relative to the base-case scenario, Scenario III could reduce the number of vehicle-hours of travel, consistently for HOV's and SOV's across all three O-D pairs. A similar trend, although to a smaller extent, is also indicated for Scenario II relative to the base-case scenario.

Table 17 shows total vehicle-hours of travel for all three O-D pairs combined, for the three scenarios. The table indicates that Scenario III could result in 4.6 percent reduction in vehicle-hours of travel relative to the base-case scenario, while Scenario II could yield 1.5 percent reduction in vehicle-hours of travel relative to the base-case scenario.

Table 13

Number of Vehicles for Three O-D Pairs Under Different Scenarios

Policy Option	HOV's (vph)			SOV's (vph)				Total
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes	
Base-case	N/A	745 (27.6%)	95 (3.5%)	597 (22.1%)	969 (35.9%)	186 (6.9%)	108 (4.0%)	2,700 (100%)
Scenario II	303 (11.2%)	478 (17.7%)	59 (2.2%)	597 (22.1%)	969 (35.9%)	186 (6.9%)	108 (4.0%)	2,700 (100%)
Scenario III	303 (11.2%)	478 (17.7%)	59 (2.2%)	597 (22.1%)	969 (35.9%)	186 (6.9%)	108 (4.0%)	2,700 (100%)

Table 14

Vehicle-Hours of Travel for Three Scenarios in
"Serious" Freeway Congestion (From CBD to BAY)

Policy Option	Vehicle-Hours									
	HOV's				SOV'S					
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	**Subtotal HOV'S**	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes	**Subtotal SOV'S**	**ta** l
Base-case	**N/A**	70.3	11.5	81.8	73.3	161.5	27.4	19.8	282.0	363.8
Scenario II	26.9	45.1	6.7	78.7	73.3	164.2	25.8	19.2	282.5	361.2
Scenario III	24.4	43.7	6.3	74.7	73.0	158.8	25.3	18.6	275.7	350.1

1
363.8
361.2
350.1

Table 15

Vehicle-Hours of Travel for Three Scenarios in "Serious" Freeway Congestion (From CBD to CAY)

Policy Option	Vehicle-Hours									
	HOV's				SOV'S					**Total**
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	**Subtotal** HOV'S	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes	**Subtotal** SOV'S	
Base-case	N/A	66.1	11.7	77.8	89.6	156.1	30.0	20.1	295.8	373.6
Scenario II	28.6	42.2	6.7	77.7	82.9	158.8	26.4	19.8	287.9	365.6
Scenario III	26.1	41.1	6.3	73.5	81.3	153.4	25.3	18.9	278.9	352.4

Table 16

Vehicle-Hours of Travel for Three Scenarios in "Serious" Freeway Congestion (From CBD to DAY)

olicy ption	Vehicle-Hours									
	HOV's				SOV's					Total
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	Subtotal HOV'S	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes	Subtotal SOV's	
ase-case	N/A	68.2	11.2	79.4	91.2	158.8	30.0	19.2	299.2	378.6
cenario I	30.3	43.7	6.7	80.7	86.2	161.5	26.3	18.3	292.3	373.0
cenario II	26.9	43.7	6.2	76.8	82.9	158.8	25.8	17.7	285.2	362.0

Table 17

Vehicle-Hours of Travel for All Three
O-D Pairs Combined (in "Serious" Frreway Congestion)

Policy Option	Total Vehicle-Hours	% Reduction Relative to Base-Case
Base-case	1116.0	
Scenario II	1099.8	-1.5
Scenario III	1064.8	-4.6

- means time savings, + means disbenefit

Table 18

Routes Used by HOV's and Guided SOV's Under Base-Case Scenario
in "Slight" Freeway Congestion

From CBD TO:	Roadway Links Within Route	
	HOV's	Guided SOV's
BAY	(a)	SR5,I-206,W * M,I-206,W ***
CAY	(a)	SR5,I-206 * M,I-206 ***
DAY	(a)	SR5,I-206,W * SR5,I-206,U,N *** M,Q,I-206,W *** SR5,I-206,T,N ***

(a) These are unguided vehicles by design.
Their route sets are identical to those shown for HOV's in Table 2.

* "Freeway-biased" route

*** "Other" route

4. SIMULATION RESULTS FOR "SLIGHT" FREEWAY CONGESTION

4.1 Routes Used by Vehicles

Route sets for unguided HOV's and unguided SOV's (in terms of roadway links making up individual routes used) in "slight" freeway congestion is the same as those previously shown in Table 2.

Under the base-case scenario, all HOV's are unguided by design, and their route sets are identical to those shown for HOV's in Table 2. Route sets for guided SOV's under the base-case scenario are shown in Table 18, which indicates that guided SOV's for a particular O-D pair mostly use the "freeway-biased" route and 1-3 "other" routes, without using "arterial-biased" routes. This is in contrast to results for "serious" freeway congestion.

Under Scenario II, route sets for guided HOV's and guided SOV's are shown in Table 19. The table indicates that under Scenario II, guided HOV's for a particular O-D pair use the "freeway-biased" route plus 1-2 "other" routes. Comparison of Table 18 with 19 reveals that route sets for guided SOV's under Scenario II differ slightly from those under the base-case scenario. Nevertheless, guided SOV's for a particular O-D pair still mostly use the "freeway-biased" route, plus one to three "other" routes, without using "arterial-biased" routes.

Under Scenario III, route sets for guided HOV's and guided SOV's are shown in Table 20. Comparing Table 19 with Table 20 reveals that route sets for guided HOV's and guided SOV's under

Table 19

Routes Used by Guided HOV's and SOV's Under Scenario II in "Slight" Freeway Congestion

From CBD TO:	Roadway Links Within Route	
	Guided HOV's	Guided SOV's
BAY	SR5,I-206,W * M,Q,I-206,W ***	SR5,I-206,W * M,Q,I-206,W *** M,I-206,W ***
CAY	SR5,I-206 * M,Q,I-206 ***	SR5,I-206 * M,Q,I-206 *** M,I-206 ***
DAY	SR5,I-206,W * SR5,I-206,U,N *** M,Q,I-206,W ***	SR5,I-206,W * SR5,I-206,U,N *** M,Q,I-206,W *** M,I-206,W ***

Table 20

Routes Used by Guided HOV's and SOV's Under Scenario III in "Slight" Freeway Congestion

From CBD TO:	Roadway Links Within Route	
	Guided HOV's	Guided SOV's
BAY	SR5,I-206,W * M,Q,I-206,U,L,W ***	SR5,I-206,W *
CAY	SR5,I-206 * M,Q,I-206 ***	SR5,I-206 *
DAY	SR5,I-206,W * M,Q,I-206,W ***	SR5,I-206,W * M,P,I-206,W ***

* "Freeway-biased" route

*** "Other" route

Scenario III slightly differ from those under Scenario II. Again, guided SOV's mostly use the "freeway-biased" routes; only one "other" route is used for CBD-to-DAY journey.

The above analysis of route used by guided HOV's and guided SOV's indicates that the route sets for these vehicles could be sensitive to the level of freeway congestion, as to be expected.

4.2 Vehicle Travel Time

Question 4.2.1: Are there differences in the range of travel time among the three scenarios ?

Table 21 shows the range of travel time on routes used by guided HOV's and SOV's under the base-case scenario, Scenario II, and Scenario III. The table indicates that the range of travel time on all routes used by guided HOV's under Scenarios II and III could be considerably smaller than the range of travel time for HOV's under the base-case scenario. Between Scenarios II and III, Scenario III exhibits a smaller range of travel time. The range of travel time for guided SOV's, however, does not appear to show a consistent trend in favor of any one scenario. These travel-time results imply that a potential advantage of including the HOV lane in the route guidance network is that travel time for guided HOV's could become less variable and more predictable.

For unguided vehicles, their route sets are identical among the three scenarios. The analysis shows that the range of travel time for unguided vehicles under Scenarios II and III could be

Table 21

Range of Travel Time on Routes Used by Guided Vehicles in "Slight" Freeway Congestion

Policy Option	Travel time (Minute)					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Guided HOV	Guided sov	Guided HOV	Guided sov	Guided HOV	Guided sov
Base-case	15.0-21.5*	17.0-18.5	13.0-19.5*	16.0-16.5	13.5-21.0*	17.0-17.5
Scenario II	15.0-16.0	17.5-19.0	13.0-14.0	16.0-17.5	14.0-16.5	17.5-19.0
Scenario III	13.5-15.0	18.5	13.0	16.5	14.5	18.0-19.5

*These are unguided vehicles by design

Table 22

Range of Travel Time for Unguided Vehicles in "Slight" Freeway Congestion (from CBD to BAY)

Policy Option	Travel time (Minutes)				
	Unguided HOV's		Unguided SOV's		
	Freeway Biased Routes	Other Routes	Freeway Biased Routes	Arterial Biased Routes	Other Routes
Base-case	15.0	15.0-21.5	18.5	19.0-20.0	17.0-25.0
Scenario II	15.0	15.0-17.5	18.0	19.0-20.0	17.5-20.5
Scenario III	15.0	14.5-16.5	18.5	18.5-19.5	17.5-20.0

smaller than that under the base-case scenario, particularly for travel on "other" routes. As an illustration, the range of travel time for unguided vehicles for the base-case scenario, Scenarios II, and Scenario III are shown in Table 22, for travel from CBD to BAY. The trends in the range of travel time among the three scenarios for the other O-D pairs are similar to that for CBD-to-BAY journey.

Question 4.2.2: Are there differences in average travel time (per vehicle) among the three scenarios ?

To estimate average travel time (per vehicle) for a particular vehicle class, travel time values on individual routes are weighted by the number of that class of vehicles actually using those routes. Tables 23 through 25 show average travel time (expressed as minutes per vehicle) for guided HOV's, guided SOV's, unguided HOV's, and unguided SOV's for each of the O-D pairs. Table 26 shows percent changes in average travel time for guided HOV's and guided SOV's under Scenarios II and III relative to the base-case scenario. Table 27 shows percent changes in average travel time for unguided HOV's and unguided SOV's under Scenarios II and III relative to the base-case scenario. Table 26 indicates the following:

- All guided HOV's under Scenario III could have (2 to 6 percent) smaller average travel time than HOV's under the base-case scenario. This is not the case with guided HOV's under Scenario II, in which two-thirds could have

Table 23

Average Travel Time** for All Vehicle Classes from CBD to BAY in "Slight" Freeway Congestion

Policy Option	Average Travel Time (Minutes per Vehicle)**						
	HOV's			SOV's			
	Guided	Unguided Freeway Biased	Unguided Other Routes	Guided	Unguided Freeway Biased	Unguided Aterial Biased	Unguided Other Routes
Base-case	N/A	17.5	17.5	18.5	18.5	19.0	20.0
Scenario II	15.0	16.5	16.5	18.0	18.0	19.5	19.0
Scenario III	14.5	15.5	15.5	18.5	18.5	19.0	18.5

** Average travel time is weighted by volumes on individual routes, and rounded to the nearest 0.5 minutes.

Table 24

Average Travel Time** for All Vehicle Classes From CBD to CAY in "Slight" Freeway Congestion

Policy Option	Average Travel Time (Minutes per Vehicle)**						
	HOV's			**SOV's**			
	Guided	Unguided Freeway Biased	Unguided Other Routes	Guided	Unguided Freeway Biased	Unguided Aterial Biased	Unguided Other Routes
Base-case	N/A	13.5	16.5	16.0	16.5	19.5	18.0
Scenario II	13.5	13.0	15.0	15.5	16.0	20.0	17.5
Scenario III	13.0	13.0	14.0	16.5	16.5	19.0	16.5

** Average travel time is weighted by volumes on individual routes, and rounded to the nearest 0.5 minutes.

Table 25

Average Travel Time** for All Vehicle Classes From CBD to DAY in "Slight" Freeway Congestion

Policy Scenario Option	Average Travel Time (Minutes per Vehicle)**						
	HOV's			SOV's			
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes
Base-case	N/A	14.5	17.0	17.5	17.5	18.0	19.5
Scenario II	15.5	15.5	16.0	18.0	18.5	18.0	18.5
Scenario III	14.5	14.5	15.0	18.5	18.0	17.5	18.0

** Average travel time is weighted by volumes on individual routes, and rounded to the nearest 0.5 minutes.

Table 26

Percent Changes in Average Travel Time Per Guided Vehicle for Scenarios II and III Relative to Base-Case Scenario ("Slight" Freeway Congestion)

– means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Guided HOV	Guided sov	Guided HOV	Guided sov	Guided HOV	Guided sov
Scenario II	-1.9	-2.7	-2.5	-3.1	+4.9	+2.9
Scenario III	-5.1	0	-6.1	+3.1	-1.9	+5.7

Table 27

Percent Changes in Average Travel Time Per Unguided Vehicle for Scenarios II and III Relative to Base-Case Scenario ("Slight" Freeway Congestion)

– means time savings; + means disbenefit

Policy Option	% Change in Travel Time Relative to Base-Case Scenario					
	From CBD to BAY		From CBD to CAY		From CBD to DAY	
	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov	Unguided HOV	Unguided sov
Scenario II	-0.7	-4.5	+5.2	-2.2	-2.1	+3.7
Scenario III	-1.4	-5.3	-1.5	-0.8	-1.3	+0.9

slightly lower, and one-third slightly higher, travel time than HOV's under the base-case scenario.

- Two-thirds of guided SOV's under Scenario III could have slightly higher average travel time than guided SOV's under the base-case scenario, while the other one-third have similar travel time as the base-case scenario. Two-thirds of guided SOV's under Scenario II could have slightly lower travel time than those under the base-case scenario, while the other one-third could have slightly higher travel time than the base-case scenario.

These results imply that, when the freeways are not severely congested, the inclusion of the HOV lane in the route guidance network could yield some travel-time benefits to most guided HOV's. Some of these benefits, however, could be countered by slight increases in travel time for some guided SOV's.

Table 27 indicates that:

- All unguided HOV's and most unguided SOV's under Scenario III could have slightly lower average travel time than HOV's and unguided SOV's under the base-case scenario, respectively. Two-thirds of unguided vehicles under Scenario II could have slightly lower, while the other one-third slightly higher, average travel time than unguided vehicles under the base-case scenario.

These results imply that, when the freeways are not severely congested, the inclusion of the HOV lane in the route guidance network may not result in all unguided vehicles having lower travel time relative to the base-case scenario. Indeed, some of them could have lower travel time, while some smaller portion could have higher travel time.

Question 4.2.3: If the base-case scenario is deployed, could the promise of travel-time savings offered by route guidance devices encourage drive alone with the devices, as opposed to ridesharing?

Under the base-case scenario, mean travel time values for all three O-D pairs combined for HOV's, guided SOV's, and unguided SOV's are found to be 14.6, 17.4, and 17.8 minutes, respectively, when the freeways are not severely congested. These values of mean travel time imply that a motorist, who currently drives alone, could save 2 percent in travel time by having route guidance devices. However, under similar traffic conditions, the motorist could save 18 percent in travel time by ridesharing that permits the use of the HOV lane.

4.3 Vehicle-Hours of Travel

Tables 28 through 30 show estimated numbers of vehicle-hours of travel for each of the O-D pairs, respectively. Table 31 shows vehicle-hours of travel for the three O-D pairs combined. Table 31 indicates that, unlike the results for "serious" freeway congestion, vehicle-hours of travel in "slight" freeway congestion do not appear to be sensitive to the scenario considered. Scenarios III and II show vehicle-hours of travel 0.4 and 0.2 percent lower than the base-case scenario, respectively.

Table 28

Vehicle-Hours of Travel for Three Scenarios in "Slight" Freeway Congestion (From CBD to BAY)

Policy Option	Vehicle-Hours									
	HOV's				SOV'S					**Total**
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	**Subtotal** HOV'S	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes	**Subtotal** SOV'S	
Base-case	N/A	62.0	9.3	71.3	61.4	99.6	19.6	12.0	192.6	263.9
Scenario II	25.2	39.7	5.5	70.4	59.7	96.9	20.1	11.4	188.1	258.5
Scenario III	24.4	39.7	5.2	69.3	61.3	99.6	19.6	11.1	191.6	260.9

Table 29

Vehicle-Hours of Travel for Three Scenarios in "Slight" Freeway Congestion (From CBD to CAY)

Policy Option	Vehicle-Hours									
	HOV's				SOV'S					
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	**Subtotal** HOV'S	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes	**Subtotal** SOV'S	**Total**
Base-case	**N/A**	55.8	8.8	64.6	53.1	88.8	20.1	10.8	172.8	**237.4**
Scenario II	22.7	34.5	5.0	62.2	51.4	86.1	20.7	10.5	168.7	**230.9**
Scenario III	21.9	34.5	4.6	61.0	54.7	88.8	19.6	9.9	173.0	**234.0**

Table 30

Vehicle-Hours of Travel for Three Scenarios in "Slight" Freeway Congestion (From CBD to DAY)

Policy Option	Vehicle-Hours									
	HOV's				SOV'S					
	Guided	Unguided on Freeway Biased	Unguided on Other Routes	Subtotal HOV'S	Guided	Unguided on Freeway Biased	Unguided on Aterial Biased	Unguided on Other Routes	Subtotal SOV'S	Total
Base-case	N/A	59.9	9.1	69.0	58.0	94.2	18.6	11.7	182.5	251.5
Scenario II	26.1	41.1	5.3	72.5	59.7	99.6	18.6	11.1	189.0	261.5
Scenario III	24.4	38.4	5.0	67.8	61.3	96.9	18.1	10.8	187.1	254.9

Table 31

Vehicle-Hours of Travel for All O-D Pairs Combined (in "Slight" Freeway Congestion)

Policy Option	Total Vehicle-Hours	% Reduction Relative to Scenario I*
Base-case	752.8	
Scenario II	750.9	-0.2
Scenario III	751.2	-0.4

* - means time savings, + means disbenefit

5. IMPLICATIONS OF THE RESULTS

The technology development of dynamic route guidance systems is not sufficiently far along to permit meaningful determination of implementation costs for any of the three scenarios. Nevertheless, it is almost certain that the three scenarios would incur different infrastructure as well as consumer costs. This is because the three differ in the communication requirement, information flow, and size and complexity of traffic simulation/assignment algorithm required.

When focusing on the infrastructure, the base-case scenario is likely to be the least costly and complex. It is only concerned with providing information on the "best" routes to equipped SOV's, and there is no need to distinguish between equipped SOV's and equipped HOV's. Scenario II could be more complex than the base-case scenario to implement and operate. First, the inclusion of HOV lanes in route guidance networks implies that the traffic simulation/assignment algorithm has to provide information to both equipped HOV's and equipped SOV's, which implies a larger route-choice matrix. Second, there is a need to distinguish between HOV's and SOV's, which could mean additional equipment costs. Scenarios III would have all of the features of Scenario II, plus additional complexity in the traffic simulation/assignment algorithm for providing priorities in the route selection for equipped HOV's over equipped SOV's.

From the consumers' perspective, vehicles must be equipped with route guidance devices, the cost of which will be borne by the consumer, regardless of the scenario. Under Scenarios II and III, additional onboard devices to distinguish HOV's from SOV's are also needed, which is likely to make the consumer costs for Scenarios II and III higher than those for the base-case scenario.

In addition to costs, system-design flexibility is also another important consideration, particularly for early deployment of new technologies with no on-the-road experience. In this regard, route guidance systems under the base-case scenario could be implemented as either "distributed" or "centralized" systems. By "distributed" systems, it is meant that drivers can receive "real-time" traffic information from a traffic operation center (TOC), and the onboard computer would perform the "best" route selection for that vehicle independently of other guided vehicles. "Centralized" systems are those in which drivers receive information on the "best" routes from a centralized TOC. This implies that trip assignments are accomplished at the TOC level. Unlike the base-case scenario, Scenario III is likely to require "centralized" systems. For Scenario II, further research is needed to determine whether it can be implemented as "distributed" systems; "centralized" systems are likely to be able to accommodate Scenario II.

Advantages and disadvantages of "centralized" versus "distributed" systems are described by Chen (1992). First, major capital costs of "centralized" systems are likely to be the infrastructure. The implementation could be slow because of the need for jurisdictional cooperation in system installation and operation. Costs of in-vehicle devices could be relatively low, and thus it may be easier to attract users. "Distributed" systems could require expensive in-vehicle devices, and the early user could be limited. Further, there is a question of who is in control. "Centralized" systems would be more amenable to "systems optimum," while "distributed" systems would be more amenable to "user optimum."

The above discussion on costs and flexibility suggests that the base-case scenario is probably a more practical scenario for early deployment of dynamic route guidance systems. However, Scenarios II and III could be viable scenarios, if they exhibit enough travel-time advantages over the base-case scenario. Table 32 compares several travel-time statistics among the three scenarios. Close examination of Table 32 indicates the following:

1. When comparing Scenario II with the base-case scenario, the former could yield about 5 percent travel-time savings for guided SOV's in "serious" freeway congestion, and negligibly small travel-time savings in "slight" freeway congestion. Average travel time for guided HOV's under Scenario II is similar to that for HOV's under the base-case scenario (all of which are unguided by design). Further, travel-time values for unguided vehicles are similar between Scenario II and the base-case scenario. These results suggest that the inclusion of the HOV lane in the route guidance network with simultaneous determinations of the shortest paths for guided HOV's and guided SOV's could result in the roadway capacity being used in a slightly more optimal manner (relative to

Table 32

Selected Travel-Time Statistics for the Three Scenarios

Statistic	"Serious" Freeway Congestion			"Slight" Freeway Congestion		
	Base-Case	Scenario II	Scenario III	Base-Case	Scenario II	Scenario III
Aver. travel time per guided HOV (mins.)	N/A*	17.0	15.3	N/A*	14.6	14.0
Aver. travel time per guided SOV (mins.)	25.8	24.6	23.8	17.4	17.2	17.8
Aver. travel time per unguided HOV (mins.)	17.1	17.3	16.8	14.6	14.6	14.3
Aver. travel time per unguided SOV (mins.)	29.8	29.9	29.3	17.8	17.8	17.8
Ratio of travel time for all HOV's to guided SOV's	0.66	0.70	0.64	0.84	0.85	0.80
Ratio of travel time for all HOV's to unguided SOV's	0.57	0.58	0.52	0.82	0.82	0.82
Ratio of travel time for guided HOV's to unguided HOV's	NA*	0.98	0.91	NA*	1.0	0.98
Total vehicle-hours	1,116	1,100	1,065	753	751	750

*For the base-case scenario, all HOV's are unguided by design not including the HOV lane in the route guidance network).

2. When comparing Scenario III with the base-case scenario, Table 32 indicates that Scenario III could result in about 11 and 8 percent of travel-time savings for guided HOV's and guided SOV's, respectively, in "serious" freeway congestion. In "slight" freeway congestion, however, these guided' vehicles under Scenario III exhibits negligible travel-time advantage over the base-case scenario. Travel time for unguided vehicles under scenario III is smaller (but probably negligibly smaller) than that under the base-case scenario. These results suggest that: (i) the inclusion of the HOV lane in the route guidance network, plus providing priorities in route selection to guided HOV's over guided SOV's, could result in better use of the roadway capacity relative to not including the HOV lane in the route guidance network; and (ii) Scenario III appears to be a better scenario than Scenario II because of its shorter travel time.

3. Comparison of travel time between HOV's (guided or unguided ones) and SOV's (guided and unguided ones) within each of the three scenarios suggests that HOV's have considerable travel-time advantage over SOV's, regardless of the scenario. Further, comparison of travel time values between guided HOV's and unguided HOV's under Scenario III (15.3 minutes versus 16.8 minutes) suggests that route guidance devices could be beneficial for HOV's in reducing travel time. Therefore, it is conceivable that Scenario III could achieve dual purposes -- providing incentives for using the HOV lane as well as for adopting route guidance

devices. On the other hand, the difference in travel time between guided HOV's and unguided HOV's under Scenario II (17.0 versus 17.3 minutes) is small. Therefore, Scenario II may not provide enough travel-time incentives for HOV's to want to adopt route guidance devices.'

4. The use of high-occupancy vehicles (HOV's) is generally considered to be a good public policy, because it minimizes total vehicle-miles of travel on the road. Currently, when there is no dynamic route guidance in use, vehicles using HOV lanes can save time compared with vehicles not eligible to use HOV lanes. When dynamic route guidance technologies become available, it will still be desirable to maintain (or further increase) travel-time advantage for HOV's relative to SOV's. Two statistics are presented in Table 32 as measures for comparing such an advantage for HOV's among the three scenarios -- the ratio of average travel time per HOV to average travel time per guided SOV, and the ratio of average travel time per HOV to average travel time per unguided SOV. Lower values of these ratios indicate greater travel-time advantage for HOV's over SOV's. Comparison of these two ratios between Scenario III and the base-case scenario indicate that Scenario III could result in greater travel-time advantage for HOV's over SOV's in both "serious" and "slight" freeway congestion levels. However, comparisons of these two ratios between the base-case scenario and Scenario II reveal little difference between the two scenarios.

5. Total vehicle-hours of travel is one indicator of overall

congestion within the network; lower vehicle-hours of travel indicate less congestion. Vehicle-hours of travel for the three O-D pairs combined are shown in Table 32. The table indicates that Scenario III could yield the smallest vehicle-hours of travel among the three scenarios in "serious" freeway congestion; while there is little difference between Scenario II and the base-case scenario. In "slight" freeway congestion, there is little difference in vehicle-hours of travel among the three scenarios. Therefore, from the perspective of the "systems" impact, it appears that Scenario III is the most desirable among the three scenarios.

6. Travel-time statistics shown in Table 32 indicate that the freeway congestion level could influence travel-time merits of Scenarios III and II relative to the base-case scenario. Generally speaking, as the freeway becomes more congested, potential travel-time advantages of Scenarios III and II over the base-case scenario appear to become more pronounced. This implies that, if the freeways rarely reach the "serious" congestion level, Scenario III or Scenario II would add little to travel-time benefits of the base-case scenario. In this case, the base-case scenario is likely to be an adequate strategy for implementing dynamic route guidance systems. If it is decided that the HOV lane should be included in the route guidance network, consideration could be given to exploring the feasibility of implementing Scenario III.

6. CONCLUSION

Evidence from the literature review suggests that potential travel-time benefits of route guidance information are likely to be corridor-specific. We believe that preliminary findings from this study concerning potential advantages of Scenarios III and II relative to the base-case scenario are also likely to be corridor specific; Because this study is the first to address the incorporation of HOV lanes in route guidance networks to provide information to both HOV's and SOV's, generalization of the findings to all corridors may be premature, without further investigations of many more corridors. Findings presented here are based on the analysis of a hypothetical corridor, and investigations of real-world corridors and road networks are needed.

Findings from this study lend support to heretofore efforts to implement dynamic route-guidance systems in urban corridors. It has been shown that commonly perceived plans for dynamic route-guidance systems (the base-case scenario), although not including HOV lanes in the route-guidance network, are likely to result in HOV's still having considerably lower travel time than guided SOV's, particularly in serious freeway congestion. Therefore, from the travel-time perspective, there is no compelling reason to believe that the base-case scenario would result in HOV's switching to drive-alone (with route guidance devices). Finally, findings from this study suggest that the feasibility of Scenario III warrants further investigation for corridors that have HOV lanes, as a possibly better scenario than the base-case scenario.

The travel time and route assignment analyses performed in this study make use of available conventional traffic simulation and route assignment models, all of which are static in nature. The magnitude of derived travel-time benefits should be considered as illustrative, rather than definitive, for identifying the direction of the travel-time merits of Scenarios II and III relative'to the base-case scenario.

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