Negative Impacts of Busway and Bus Lane Conversions into High-Occupancy Vehicle Facilities

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The extensive planning and construction of high-occupancy vehicle (HOV) facilities during the past 20 years has resulted in more efficient freeway operations in many cities. There are, however, considerable differences among the effects of different types of HOV facilities, such as those converted from the existing lanes versus the newly constructed ones and HOV lanes versus exclusive busways. Actually, most of the newly constructed HOV facilities and conversions of busways into HOV facilities have resulted in increased vehicular capacity rather than passenger capacity of highways, which is contrary to the Intermodal Surface Transportation Efficiency Act mandate. Planning of HOV facilities, therefore, requires a careful analysis of goals as well as impacts in each particular case. Different types of HOV facilities are analyzed, principles for planning transit preferential facilities are developed, and one major problem—negative impacts of HOV facilities on bus systems—is explored. A hypothetical model based on experiences from different cities is developed and used for comparative evaluation of four cases: busways and HOV facilities obtained by conversion or addition of lanes. The present conflict between traditional urban transportation planning and the current mandated transportation systems approach is also analyzed. Relationships among policies, actions, and goals in planning HOV and busway facilities are discussed. Several revisions in the current policies and practices regarding busways and HOV facilities are recommended.

During the 1970s the importance of providing *separate rights-of-way for transit* to make it competitive with the automobile was recognized in many countries. This separation is needed on all major transit lines regardless of technology used. Although for most rail systems such separation is physically necessary, it was realized that the technological compatibility of buses with street/highway traffic should not prevent their separation for functional reasons.

Excellent busway facilities were built in several cities around the world, including Washington (Shirley Busway), Los Angeles (El Monte), Pittsburgh, Ottawa, Lima, Essen, and Adelaide, during that period. These busways were seen as distinct transit incentives, and many cities introduced these facilities in parallel with various auto use disincentives.

In the United States, however, two new developments occurred subsequently. First, the policy of *promoting high-occupancy vehicles (HOVs)* by giving them separate lanes or roadways was introduced. This has been a correct policy, and it has had a very positive impact on increasing productivity of highway facilities. Second, the fact that exclusive bus facilities are not always physically filled by buses led to the claims that they are "underutilized" (*1*), that is, the idea was accepted that *other vehicles should be permitted to "fill the space between buses."* This "empty lane syndrome," based on the fallacious belief that filling the lanes does not have any negative impacts on buses, has resulted in degradation of bus services. It has also introduced an incentive to use the major competitors of transit: vanpools, carpools, and, where new lanes are constructed, even single occupancy automobiles.

The first of these new developments is very positive; it introduces the principle that more productive modes should be favored over less productive ones. However, the conversion of busways to HOV facilities has had major negative impacts from the transportation systems policy point of view for two reasons. First, the common "transit incentive/auto disincentive package," used successfully in many countries, has been gradually converted into a far more expensive and less efficient "transit incentive/auto incentive package." And second, downgrading of busways into HOV facilities has virtually eliminated exclusive busways as a viable, high-quality transit system.

Looking nationally, excellent busways in several cities that were planned and built in the early 1970s have by now been downgraded to indistinguishable part-time bus operations that primarily serve the peak hour passengers but fail to provide all-day regular bus services.

The purpose of this paper is to analyze the impacts of HOV facilities on bus services and on the role of transit in urban transportation. The rationale for providing priorities and separation of transit is given, and the impacts of various types of HOV facilities on modal split are analyzed.

"FLEXIBILITY" OF BUSES: ADVANTAGE OR LIABILITY?

The fact that buses can operate on most streets mixed with general traffic and require few extra fixed facilities is often considered to be their "flexibility" and a great advantage, particularly in comparison to rail transit. This flexibility of buses, however, is often misunderstood and misused. It is presented as if it were *always* a great advantage of the bus mode. Actually, "flexible routing" means that service is individualized, such as taxi service; but it also means that people who have bus service may soon lose it because routes can be relocated. "Flexible scheduling" may imply that users cannot rely on the convenience of a fixed schedule. "Flexible pricing," often found in taxi services, leads to much more illegal overcharging of passengers than "fixed pricing," which users can easily understand.

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Although flexibility in operation may generally be an advantage for bus services with low and moderate passenger volumes, it also implies lack of permanence, lack of distinction from other traffic, and great difficulty in achieving separation of buses from other vehicles. Wherever a separate bus lane is provided, that strip of pavement is very attractive to all other vehicle drivers as well. In many cities in this country political pressures and court decisions have succeeded in preventing introduction or even in discontinuing operation of excellent busway facilities. Consequently, bus compatibility with other highway traffic has become a major liability of this mode wherever a distinctive high quality transit has to be provided.

BUS TRANSIT AS A SYSTEM

Bus services in most cities consist of buses operating on streets and highways in mixed traffic and stopping frequently at locations marked by bus stop signs and shelters. These services attract mostly captive riders. To attract a substantial portion of automobile drivers to transit, it is necessary to provide attractive buses, special infrastructure, and services that represent a distinct, high-performance *bus transit system (BTS).*

The basic component of a BTS is a mostly separated right-of-way that allows buses to have higher speed, reliability, and safety than vehicles traveling in general purpose lanes. *Priority treatments, separate rights-of-way, stations, and clear information give buses a distinct image and permanence.* These features add considerably to the ability of BTS to attract passengers. Their stations can be integrated with concentrated land use developments.

Another basic characteristic of the BTS is that it should be *regular transit,* that is, it should offer service among many points of the served area (many-to-many) at all times of the day. This should be distinguished from *commuter transit,* which usually operates many-to-one and one-to-many services during peak hours only.

SURVEYS OF CONDITIONS OF BUS TRANSIT

The authors recently conducted a study of the conditions of bus services in the cities of North America and several other countries (*2*). For that study two surveys were made: one of major transit agencies and the other of bus transit experts. The surveys focused on the priorities given to bus transit and, particularly, on the problem of "backsliding," or gradual abandonment, of bus priority measures. Table 1 summarizes the results of the survey in three categories of facilities: bus/HOV lanes on streets, exclusive bus/HOV streets and roadways, and bus/HOV lanes on freeways.

The table shows that most North American cities have *extremely limited lengths of bus or HOV lanes on city streets.* Except for the two largest systems, in Ottawa and Pittsburgh, the remaining 11 cities in the Table 1 have a total of only 68.3 km of exclusive bus lanes. Similarly, there are *few exclusive streets for buses or HOVs.* Excluding Ottawa and Pittsburgh, the surveyed cities have a total of 12.0 km of such facilities.

The length of *bus/HOV lanes on freeways* is considerably greater, amounting to a total of 389.4 km, but the distribution of these lanes is again very uneven: 308.1 of the 389.4 km (over 79 percent) are located in Houston, Seattle, and Los Angeles. Among the other 10 cities, 4 have no busway or HOV facilities on freeways, and the remaining 6 have a total length of 81.3 km. Despite the substantial lengths of the facilities in Houston and Seattle, the apparent advantage for buses is deceptive because buses are given the lowest possible priority; most of them are part-time, one-way HOV 2+ (cars with 2 or more persons) facilities, which have been gradually degraded from bus lanes, 4+ and 3+ facilities.

The best bus system in North America, and the only one that can be defined as a BTS, is in Ottawa, one of two cities that still have exclusive bus facilities (the other is Pittsburgh). The most extensive system of HOV facilities exists in Houston, but it consists, as mentioned earlier, nearly exclusively of reversible freeway lanes for HOV 2+. It is therefore a system that caters primarily to commuter traffic and has the lowest distinction of transit services among all priority systems.

These findings show that bus transit in the U.S. suffers from a serious neglect. In many U.S. cities the focus has been on improvements of commuter bus services, whereas regular, all-day services within urban areas have suffered from gradual "backsliding" or dilution of their priorities from exclusive bus to HOV facilities.

RATIONALE FOR SEPARATING BUSES FROM OTHER TRAFFIC

As in many other areas of human society, there is a dichotomy between the interests of the individual and the interests of the group, aggregation of system users, or, globally, the entire society. Similar dilemmas are found in regulating human behavior with respect to the use of urban streets. For example, there are limitations of locations where pedestrians can cross streets, restriction of vehicle movements on certain streets to one direction only, parking regulations, and so on. For the same reason it is rational to influence in various ways the use of different modes, such as automobiles, vans, and transit.

A general conceptual flow of the goals, objectives, and means in improving transportation in a given city (or area) is shown in Figure 1. In many actions toward improving transportation the main objective is to achieve a shift of travel from the private automobile to transit. Figure 1 shows that there are a number of means for achieving this objective. They consist of two groups: *transit improvements,* which include separation of rights-of-way and various priorities resulting in increased speed, reliability, and enhanced transit system image, and *auto disincentives,* such as introduction of realistic charges for auto travel, limitation of parking, and retention of congested conditions. The apparent need to increase highway capacities and "eliminate bottlenecks" has been proven ineffective in most cases because it generates additional vehicular traffic and works directly against the shift of travel to transit and other HOV categories. The focus in this paper is on the transit incentives, referring specifically to the bus mode, and on auto disincentives with respect to the limiting of freeway capacities.

The rationale for providing priority treatments of transit vehicles over private cars and other vehicles includes the following major points:

1. It is an accepted principle to *favor public over private facilities*; the society pays from its general funds for public schools, parks, and other public facilities; public funds are not used to support private schools, golf courses, and private streets. In the case of transportation, transit is the only mode that provides mobility for all citizens and thus contributes to the basic living standard of the entire population.

TABLE 1 Summary of R/W Improvements for 14 City Participants in Survey (*2*)

Transit Agency	Bus/HOV lanes on streets					Exclusive bus/HOV streets, roadways, malls				Bus/HOV lanes on freeways				
	No.	Length [km]	Usage	Place-ment	Direction	No.	Length [km]	Usage	Type of facility	No.	Length [km]	Usage	Place-ment	Direction
Calgary, CALTRANS	1	0.6	bus only -discon'd	curb	withflow	1	2	bus+LRT	mall	/	/	/	/	/
Chicago, CTA	6	5.5	bus only	curb	withflow reversib.	1	1.8	bus+taxi	mall	/	/	/	/	/
Denver, RTD	2	9.6	bus only discon'd	curb	withflow	1	3.2	bus only	mall	1	6.4	bus only	median	withflow
Hartford CTT	10	0.8	bus only	curb	withflow	/	/	/	/	1	19.2	HOV 3+	median	withflow
Houston METRO	5	8	bus only	curb	withflow	/	/	/	/	6	152.8	HOV 2+	median	reversible
Los Angeles, RTD	1	0.8	bus only	curb	contraflow	/	/	/	/	2	70.4	HOV 3+	median	withflow
Newark, NJT	3	8	bus only	curb	withflow	/	/	/	/	1	6.4	bus only	left	contraflow
Oslo, Norway	12	35	bus only and bus + taxi only	curb, median	withflow	2	6	bus only	busway	2	8	bus + taxi	right	withflow
Ottawa, OC Transpo	1 1 1	3 2.5 3.8	peak, bus only all day, bus only peak direction HOV 3+	curb second lane curb	withflow withflow withflow	1 1 1 1	25 0.4 0.4 0.7	bus only bus+taxi bus only-discon'd bus only	busway mall mall busway	1 1	8 7.5	peak, bus only peak, bus only-discon'd	curb curb	withflow withflow
Pittsburgh, PATransit	4	4.5	bus only	curb	contraflow	2	17.3	bus only	busway	1	6.4	HOV 3+	median	reversible
San Antonio, VIA	6	4.3	bus only	curb	withflow	/	/	/	/	/	/	/	/	/
San Francisco, MUNI	11	19	bus+taxi, all day	curb	withflow	/	/	/	/	/	/	/	/	/
Seattle, METRO	8	11.7	bus only and HOV	curb	withflow contraflow	2	5	bus only	busway	20	84.9	HOV 3+ HOV 2+	curb median	withflow withflow
Washington, WMATA	/	/	/	/	/	/	/	/	/	2	27.4	HOV 3+	median	withflow

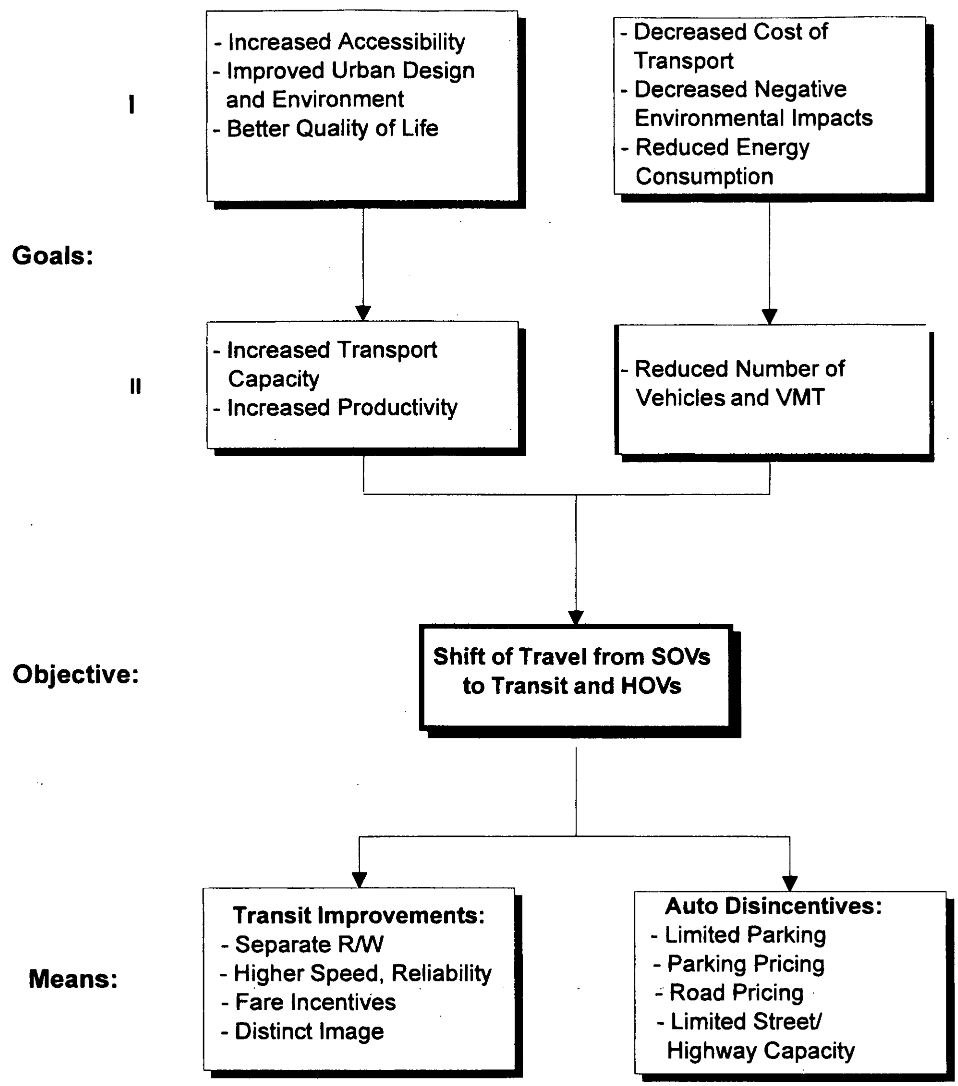

FIGURE 1 Means, objective, and goals in improving transportation by shifting automobile travel to transit.

2. Because of their large capacity and common carrier character (open to the public), *buses inherently have much higher productivity (lower cost and area per passenger-kilometer) on major travel corridors than automobiles.*
3. The conventional management of traffic on highways is based on maximizing the vehicular flow. However, since the main objective in passenger transportation is to *move persons rather than vehicles*, highway flows should be managed considering relative productivity of different modes.
4. Bus priorities are needed to give transit faster and more reliable service and thus *to offset the advantages an individual finds in using the automobile*, such as extremely low out-of-pocket cost, privacy, and personal convenience. The very low out-of-pocket cost results from several factors. First, most of the large cost items of an automobile (purchase, insurance, major repairs, registration) are so indirectly related to the distance traveled that they have no bearing on a driver's decisions for individual trips. Second, subsidized ("free") parking is a widespread practice. And third, auto users are not charged for any congestion or social and environmental impacts that auto travel causes.
5. The greater the use of buses, the greater is their advantage in *lower negative side effects* (such as congestion, air pollution, noise and energy consumption) per person-kilometers transported over the private automobiles.
6. Bus priorities are justified also by the fact that *transit in general is a key element that allows creation of a more human-based city and more livable urban environment* than is the case where all travel is performed by the private automobile.

Among the reasons for providing *exclusive rights-of-way* for buses, the following are the major ones:

1. Bus separation from general traffic is *the most effective way of achieving speed comparable with that of the automobile.* The higher running speed of buses free from congestion allows them to compensate for additional time required for stopping at bus stops compared with automobile travel.

2. Exclusive bus facilities allow *faster, more reliable, and safer operations*, which result in lower operating costs.

3. *Separate rights-of-way, stations, and other infrastructure give the bus service a distinct, positive image*. These characteristics make bus service much more attractive to the public than buses mixed in general traffic. The advantages of distinctive facilities are not only limited to immediate attraction of passengers; they also *give the system a character of permanence* and contribute to the shaping of land uses, urban form, and, finally, higher quality of urban life.

COMPARATIVE ANALYSIS OF BUSWAYS AND HOV FACILITIES

There is presently an enthusiasm for constructing additional HOV lanes in many cities. The alternative to such construction, to convert existing lanes into HOV lanes, is often not even considered. The explanation for this major omission is usually a simplistic statement that such an action would be "politically unacceptable."

The discussion in this paper, however, clearly indicates that alternatives of highway upgradings differ so substantially among themselves in their results and impacts that they should be systematically analyzed. Actually, a methodology for such a comparison has been missing. For that purpose, a procedure that allows systematic comparisons of different types of preferential facilities is presented here.

Classification of Vehicles and Right-of-Way Facilities

Highway facilities with preferential treatments can be defined by the classes of vehicles permitted to use them.

Category I facilities serve transit buses only; there are examples of such facilities in Ottawa, Pittsburgh, Adelaide (with O-Bahn), and Sao Paulo. The category, "*Busway*," is comparable with a light rail transit (LRT) system by its regime of operation. The busways have by far the strongest identity and image of all categories of preferential facilities.

Category II are the facilities that are also open to other buses (long-distance, charter, and private coaches and others), to paratransit, and to semipublic vanpools (belonging to companies, universities, hospitals, and others). Compared with Category I, this "*Public and Paratransit HOV*" facility accommodates more vehicles and carries more passengers than a comparable busway, but transit vehicles are exposed to more friction, they are subjected to competition, and thus their distinct image is weakened.

There is a major change in Category III. Instead of only public and semipublic vehicles with professional drivers, "*HOV facility*" allows entry to a much greater number of vehicles, referred to as "carpools." The definition of carpools, as well as of HOVs, has changed over time from the vehicles with at least four passengers (4+), which are mostly organized commuter carpools, to the cases in which vehicles with 3+, and finally, with 2+ passengers are included. This development and its consequences deserve a careful analysis; they are discussed in the following section.

Category IV is an unrestricted highway carrying all vehicle classes.

Downgrading Bus Transit Services Because of Vehicle Mix

Allowing private automobiles into preferential lanes changes the character of such lanes considerably for two reasons. First, vehicular volume increases greatly. The promoters of lowering the minimum occupancies of vehicles permitted to use the facility claim that thereby "the gaps between buses are utilized." Although that sounds plausible to laypeople, the tendency to "fill the gaps between transit vehicles" is a short-range view. Actually, the price that this "utilization of gaps" carries in the long run is substantial: higher vehicular volume with nonuniform composition decreases speed, reliability, and safety of traffic and thus negatively affects the truly high-occupancy vehicles: buses and vans.

Second, the level of service is further affected by the fact that the facility is used not only by the vehicles driven by professional drivers but by any licensed drivers, so that the regularity and quality of vehicle flow are decreased.

A systematic evaluation of the consequences of converting busways into HOV facilities (*3*) clearly shows that *all of the benefits from the conversion of a busway into an HOV facility are accrued by passengers of other than transit vehicles. Transit passengers, existing and potential, have only losses from such a change*. In other words, nontransit users gain, and transit users lose, in service quality. Competitiveness of transit is decreased, and, consequently, riders are lost, leading to a decrease of service frequency and further passenger losses—the well-known downward spiral of transit use.

The priority of buses is further reduced by the fact that the other lanes of the same highway now have lower traffic volumes, so that even the lower occupancy automobiles, including the single-occupant-vehicles (SOVs), have improved travel conditions. This gives SOVs an additional advantage over transit buses.

Although all of these problems occur as soon as any automobiles (starting with 4+) are permitted into the HOV facility, the situation becomes progressively worse with the transition from 4+ to 3+ and, ultimately, to the 2+ regime. This last type of facility is actually a regular highway with prohibition of only SOVs and trucks. A study of this backsliding of HOV facilities from 3+ to 2+ regimes on Seattle freeways (*4*) has shown that such a change results in substantial increases of traffic volume in the HOV facility, as well as in "refilling" of the general purpose lanes by additional vehicles. This "refilling" partly represents attraction of the latent demand, leading to the reduction of the overall average vehicle occupancy.

It is often claimed that construction of additional HOV lanes will make travel of HOV so superior to the travel in general purpose lanes that many riders will begin to carpool; this will, supposedly, decrease vehicle miles traveled (VMT). The data from Seattle (*4*), among others, indicate that this is not the case. When new HOV lanes are added and HOVs use them, travel conditions in general purpose lanes actually improve, so that SOV travel becomes more attractive. Thus, the observations in Seattle show that there is actually a shift from HOVs to SOVs, resulting in increased VMT. In Dallas (*5*), conversion of the I-30 contraflow HOV lane from 3+ to 2+ increased the HOV volume by 45 percent, and volumes in general purpose lanes also increased by 20 percent.

This Seattle study (*4*) also found that bus travel times increased with the degradation of the HOV facility from 3+ to 2+, causing protests from the bus users.

Model for Comparing Busways and HOV Facilities

To illustrate the discussion presented above in a quantitative manner, a "model freeway" in an urban corridor, sketched in Figure 2, is created. Alternative schemes of priority facilities are analyzed with respect to different shifts in vehicle classes, levels of service, and changes in modal split and average vehicle occupancies. The assumptions, four different alternative facilities, and the results of the analysis are presented here.

The model used here represents a set of conditions similar to those found in a number of cities: an existing eight-lane freeway is congested, and different possible alternatives for favoring transit and/or HOV are analyzed. The traffic volumes, their assignment, and reassignment are modelled on the basis of typical situations on urban freeways; levels of service are based on the Highway Capacity Manual.

Assumptions and Initial Conditions

The initial conditions of the analysis in terms of lane geometry and demand are typical for an urban radial freeway with saturated peak-hour flows:

- Lane configuration of the existing freeway: four lanes per direction.
- Total number of persons traveling: 12,000 persons per hour per direction.
- Number of vehicles: 1,000 two-person cars per hour, 7,000 one-person cars per hour, and 60 buses per hour with 50 persons per bus.
- Average occupancy of all vehicles: 1.49 persons per vehicle.
- Average number of vehicles per lane: 2,015 vehicles per hour.
- Current traffic flow level of service: E.
- Latent demand (the number of persons who would travel if the freeway condition were improved): 3,000 persons per hour.
- Composition of latent demand: 1,000 car captives, 1,000 transit captives, and 1,000 choice travelers.

With respect to vehicle classes permitted in the upgraded facility, two cases are considered: *exclusive busway*, and *HOV roadway*. Two ways of upgrading the facility are also considered: *converting existing freeway lanes and constructing additional lanes.*

Permutations of these cases make four alternatives, as shown in Figure 2:

- C/B—convert two existing lanes (one per direction) into a busway,
- C/H—convert two existing lanes into an HOV roadway,
- A/B—add (construct new) busway, and
- A/H—add an HOV roadway.

Each one of the four alternatives is analyzed in the sequence shown in Figure 3. From the present condition, which represents a saturated flow (2,015 vehicle/hr/lane) with mixed traffic in all lanes (*Column 1*), each of the four alternatives (*Column 2*) is analyzed in several steps.

First (*Column 3*), the present volumes are assigned to the new set of lanes when the upgraded roadway is opened; then (*Column 4*), traffic conditions on each facility are evaluated, likely shifts of passengers among modes are estimated, and vehicular volumes are reassigned. In the next step (*Column 5*), the new levels of service are evaluated, and, in the cases in which they have been improved for individual modes, the likely attraction of the latent demand is

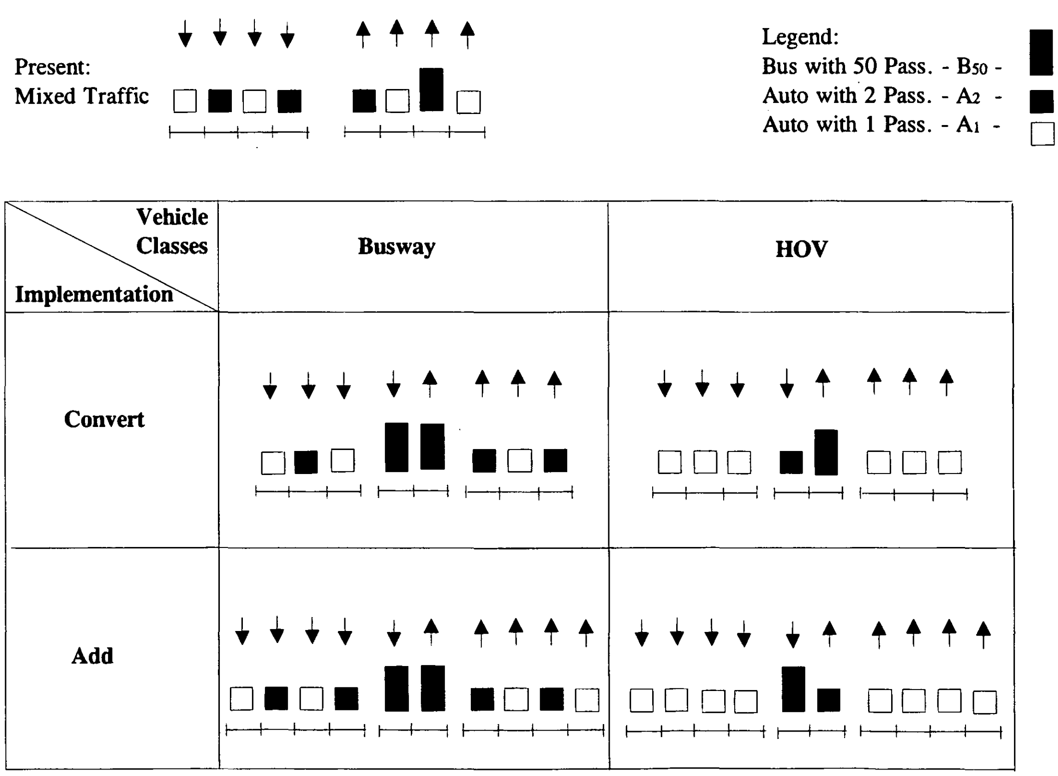

FIGURE 2 Present and alternative cross section of model freeway with priority lanes.

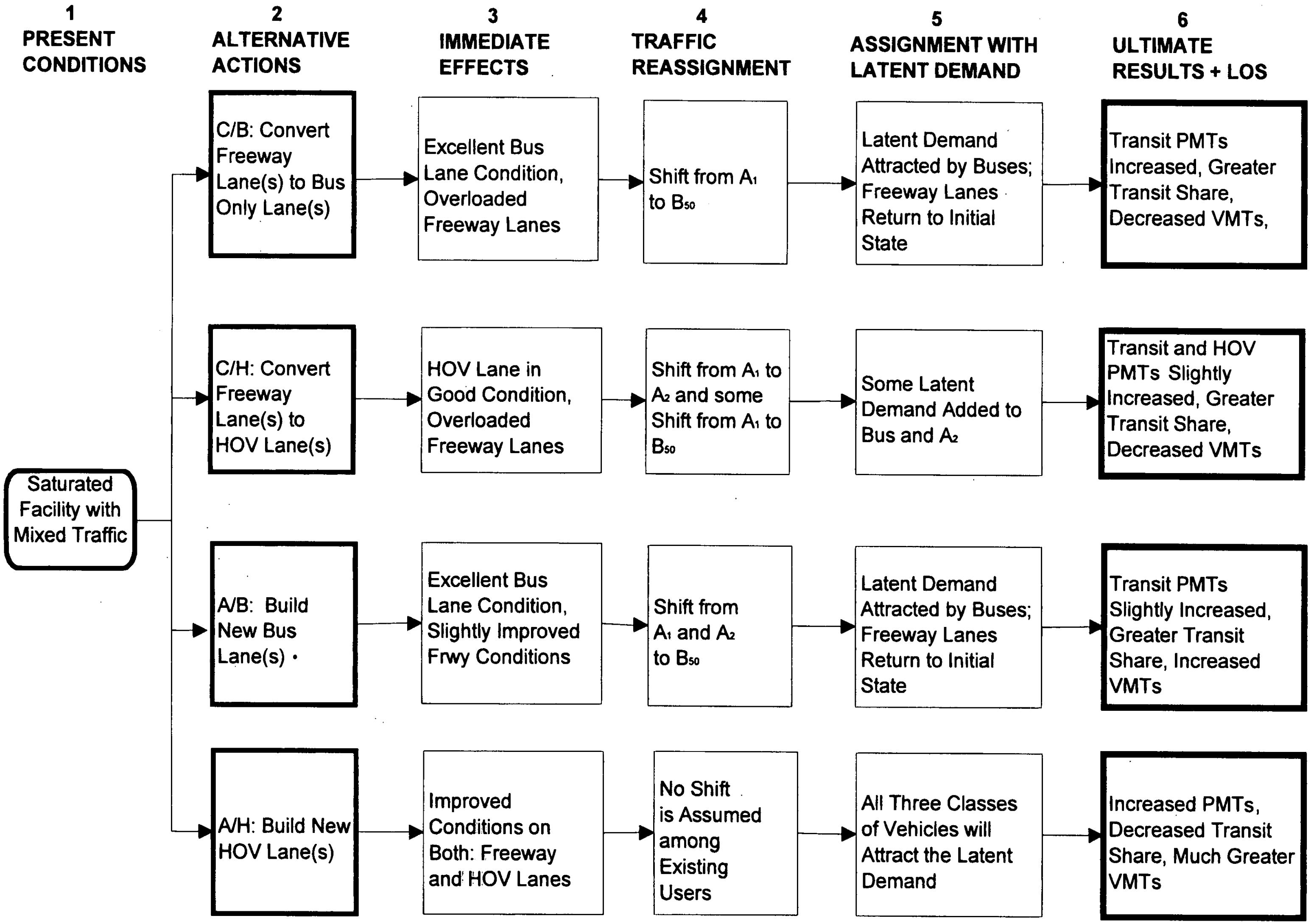

FIGURE 3 Flow chart of travel reassignments in model facility.

estimated and is shown as the "second stage" traffic assignment. The last set of boxes (*Column 6*) gives brief descriptions for the outcome of each of the four alternatives.

Computed traffic volumes and estimates of levels-of-service and of attraction of latent demand for the four alternatives are presented in Table 2. The wide columns with numerical values in this table represent the three assignments described in Columns 3, 4, and 5 of Figure 3. The two narrow columns with arrows in Table 2 give brief descriptions of the conditions and reasons for reassignments.

The last column of Table 2 shows that the C/B case is by far the best one with respect to achieving the goals of shifting the travel from automobiles to transit and reducing the total number of vehicles; this case has the smallest number of vehicles (6,160) carrying 14,800 of the 15,000 present and potential travelers. The average vehicle occupancy of 2.40 persons per vehicle is much higher than in the other three cases, and the modal split (last column) is 35 percent higher than in the A/B case (54 vs. 40 percent of the total) and is nearly 112 percent higher than in the cases with HOV facilities, T/H, and A/H (54 vs. 25 percent).

The least effective case with respect to achieving the goals is A/H: it attracts 2,500 of the 3,000 latent travelers (an increase of 21 percent over the initial 12,000 travelers), but it actually results in a significant (19 percent) *increase* in the number of vehicles by (from 8,060 to 9,570). This results in aggravated congestion and virtually no improvement in modal split and average vehicle occupancy.

The two cases with busways, C/B and A/B, clearly result in situations in which buses have a distinctly higher level of service than private automobiles. Thus, these two cases are far more successful in achieving the goal of shifting ridership from automobiles to transit. The two cases with converting the lanes (C/B and C/H) do not attract as many latent travelers as the cases with adding the lanes, but they result in lower vehicular volumes (24 and 5 percent, respectively), thus decreasing the VMT. Overall, with respect to promotion of transit and achieving modal split changes in its favor, the C/B case is the best, and the A/H case is the worst of the four alternatives.

The purpose of this model is to clarify the basic concepts of alternative preferential lanes and to select prioritized vehicle classes. The volumes and other numerical values were assumed to indicate relative more than absolute values. The findings of the model generally corroborate the real world experiences, as reported in (*4–7*); conversions of busways into HOV facilities increase total vehicular volumes on the freeway but decrease the share of transit riders; converted lanes are much more effective in shifting riders from automobiles to transit (and carpools) than construction of new lanes; opening up HOV facilities from public HOV to 4+, then to 3+ and, ultimately, to 2+ operations progressively diminishes the performance of such facilities as devices to encourage transit use.

GOALS IN HOV AND BUSWAY FACILITIES PLANNING

Present planning and implementation of HOV facilities, treatment of transit, and various related actions are not always based on clearly defined goals and objectives. Actually, the basic problem in urban transportation planning is the fundamental difference between traditional highway planning and the more recent systems approach, which is mandated by the Intermodal Surface Transportation Efficiency Act (ISTEA) and Clean Air Act Amendments (CAAA).

Traditional urban and highway planning has been generally aimed at providing adequate capacity for travel demand. Thus, highway congestion was to be solved by building more highways, as well as by increasing *vehicular capacity* through traffic engineering measures, intelligent transportation systems, and so on.

ISTEA and CAAA call for a broader approach: coordination of different modes for improved accessibility, increased efficiency, and reduction of negative impacts of transportation systems. The emphasis is on the *movement of persons and goods rather than vehicles*. Some solutions require changes in people's travel habits for long-range improvements of accessibility and creation of more livable cities. These policies are based on the experience of recent decades that urban traffic congestion cannot be solved simply by building more freeways and unlimited auto use. The problem of congestion is aggravated by the fact that auto users pay extremely low out-of-pocket costs and that they do not pay for most of the social and environmental costs they incur. An interesting analysis of this problem is discussed in a recent report by E.W. Johnson (*8*).

The differences between the traditional highway planning and multimodal systems approach are reflected in the selection among alternatives in solving highway congestion. As the flow chart in Figure 4 shows, the traditional approach of increasing highway capacity leads to results contrary to the ISTEA and CAAA requirements because it *increases VMT*. Policies leading to *reductions of VMT* consist of such actions as conversions of lanes to HOV, transit improvements, gas taxes, road pricing, and better land use planning.

Adding Versus Converting HOV Lanes

Adding HOV lanes represents the traditional approach of "solving" congestion by increasing vehicular capacity of highways. This action actually represents a "HOV incentive/SOV incentive" policy, and it usually results in decreased average auto occupancy. Although politically popular in the short run, it is extremely costly and counterproductive in the long run.

Conversion of lanes to HOV and *introduction of exclusive busways* represents a policy of "auto disincentive/bus and HOV incentive," which may be less popular in the short run, but it is the rational policy consistent with the long run transportation systems point of view.

Introduction of HOV facilities has been generally accepted as an effective way of encouraging higher vehicle occupancies and thus increasing efficiency of highways. Converting existing lanes into HOV lanes achieves this goal. However, when new HOV lanes are constructed, they decrease congestion in the short run, but they also usually decrease average occupancy because additional capacity encourages SOV travel. Thus, if the decrease of VMT is the goal, conversion should be preferable to new construction under nearly all conditions.

Why are most cities then adding HOV lanes instead of converting lanes into HOV facilities? This is actually a remnant of traditional highway planning hidden behind the explanation that "taking lanes from general traffic is politically unacceptable." The 1977 court-ordered discontinuance of the Santa Monica HOV lanes is frequently quoted as a "proof" for this claim. However, this can be seriously challenged.

First, many regulatory measures must overcome opposition of various affected groups: one-way street patterns, prohibition of street parking, or introduction of pedestrian malls nearly always have initial opponents. Yet, they are introduced for long-term effi-

TABLE 2 Model of Corridor Travel and Likely Modal Redistribution Due to Introduction of Upgraded Lanes

C/B. CONVERT A FREEWAY LANE TO A BUS LANE

	Present volumes + immediate shift				⇨	Transitional state				⇨	Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	Overloaded freeway lanes; modal shift A_1 to B_{50} and A_2 to B_{50}	A_1	A_2	B_{50}	Total	The bus attracts latent demand of 2000 pass. (1000 bus captives + 1000 of those who have choice). Some latent demand is assigned to A_1 and A_2 (400 + 400).	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		4800	1200	6000	12000		5200	1600	8000	14800
Vehicles/hour	7000	1000	60	8060		4800	600	120	5520		5200	800	160	6160
Veh/hour/freeway lane Veh/hour/bus lane*	2000 → 2667 0 → 60 x 1.5 = 90					1800 120 x 1.5 = 180					2000 160 x 1.5 = 240			
LOS for freeway lane LOS for bus lane	E → F E → A					D A					E A			
Avarage vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 2.17		A_1 and A_2 only 1.13			Total 2.40		A_1 and A_2 only 1.13	
% pass/h by transit	25.0%				⇨	50.0%				⇨	54.0%			

C/H. CONVERT A FREEWAY LANE TO HOV LANE

	Present volumes + immediate shift				⇨	Transitional state				⇨	Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	Overloaded freeway lanes; modal shift A_1 to A_2 and some A_1 to B_{50}	A_1	A_2	B_{50}	Total	Some latent demand may be attracted by the bus and A_2 (500 + 500).	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		6000	2600	3400	12000		6000	3100	3500	13000
Vehicles/hour	7000	1000	60	8060		6000	1300	68	7368		6000	1550	78	7628
Veh/hour/freeway lane Veh/hour/HOV lane*	2000 → 2333 0 → 1000 + 60 x 1.5 = 1090					2000 1300 + 68 x 1.5 = 1402					2000 1550 + 78 x 1.5 = 1667			
LOS for freeway lane LOS for HOV lane	E → F E → B					E C					E C/D			
Average vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 1.63		A_1 and A_2 only 1.17			Total 1.70		A_1 and A_2 only 1.21	
% pass/h by transit	25.0%				⇨	28.3%				⇨	26.9%			

* Car equivalency factor of 1.5 is used for buses in order to determine the LOS (HCM Chapter 12-10)

(continued on next page)

TABLE 2 (*continued*)

A/B. ADD A BUS LANE

	Present volumes + immediate shift					Transitional state					Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	Due to the big difference in LOS some shift from A_1 to B_{50} and A_2 to B_{50} is expected.	A_1	A_2	B_{50}	Total	The bus attracts latent demand (1000 bus captives + 1000 of those who have choice). Some latent demand is assigned to A_1 and A_2 (500 + 500).	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		6500	1500	4000	12000		7000	2000	6000	15000
Vehicles/hour	7000	1000	60	8060		6500	750	80	7280		7000	1000	120	8120
Veh/hour/freeway lane Veh/hour/bus lane	2000 → 2000 0 → 60 x 1.5 = 90					1800 80 x 1.5 = 120					2000 120 x 1.5 = 180			
LOS for freeway lane LOS for bus lane	E → E E → A					D A					E A			
Avarage vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 1.65		A_1 and A_2 only 1.10			Total 1.84		A_1 and A_2 only 1.12	
% pass/h by transit	25.0%					33.3%					40.0%			

A/H ADD A NEW HOV LANE

	Present volumes + immediate shift					Transitional state					Ultimate state			
Vehicle classes	A_1	A_2	B_{50}	Total	No modal shift is assumed among the existing riders.	A_1	A_2	B_{50}	Total	All three classes will attract the latent demand (1000 + 1000 + 500).	A_1	A_2	B_{50}	Total
Persons/hour	7000	2000	3000	12000		7000	2000	3000	12000		8000	3000	3500	14500
Vehicles/hour	7000	1000	60	8060		7000	1000	60	8060		8000	1500	70	9570
Veh/hour/freeway lane Veh/hour/HOV lane	2000 → 1750 0 → 1000 + 60 x 1.5 = 1090					1750 1000 + 60 x 1.5 = 1090					2000 1500 + 70 x 1.5 = 1605			
LOS for freeway lane LOS for HOV lane	E → C/D E → B					C/D B					E C/D			
Average vehicle occupancy	Total 1.49		A_1 and A_2 only 1.12			Total 1.49		A_1 and A_2 only 1.12			Total 1.51		A_1 and A_2 only 1.16	
% of pass/h by transit	25.0%					25.0%					24.1%			

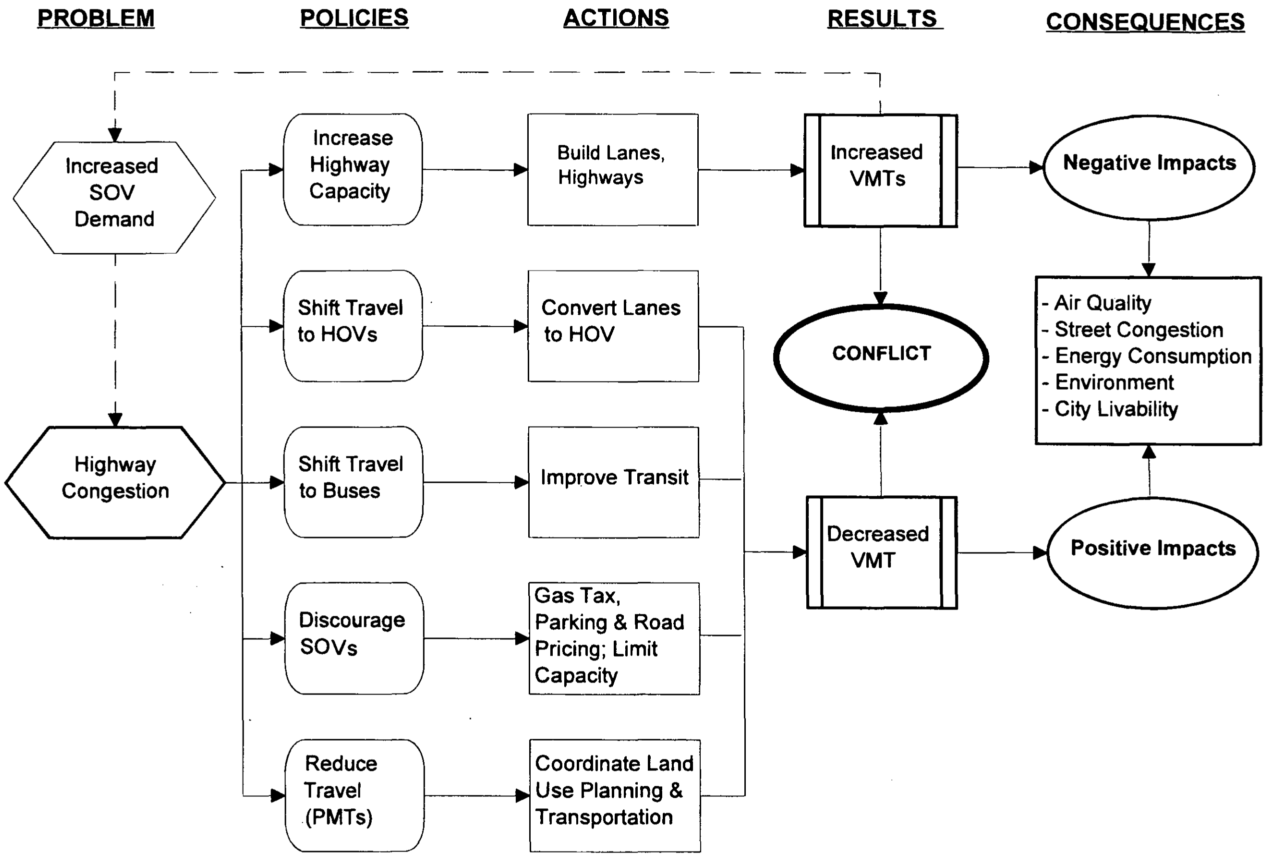

FIGURE 4 Consequences of different policies for relief of highway congestion.

ciency and social benefits. The Santa Monica Freeway decision by one judge who had little understanding of the complex urban transportation problems should not emasculate freeway planning and operations forever.

Second, conditions in urban transportation have changed greatly since 1977: so have public attitudes. In many cases there has been strong support for conversion to HOV lanes (*9*), but highway departments failed to use it; instead, they adopt the simplistic, traditional solution of constructing more lanes. These practices should be carefully reexamined.

Improving Definition of HOV

Although there is a rather strong consensus that the SOVs are by far the least efficient mode of travel from the systems point of view (although very attractive from the individual's point of view), the trend has been to classify all vehicles with 4+, 3+, or even 2+ occupants into one indistinguishable "HOV" category. This is in many situations unjustifiable.

Wherever there is present or potential substantial bus ridership, buses should be given exclusive priority over all other vehicles, not only because they are public rather than private service, but also because of their far greater physical productivity than all other highway passenger vehicles. In the example from Dallas (*5*), the introduction of an HOV lane increased the volume of HOV by 45 percent, but it also increased the SOV volume by 20 percent (consistent with the results from the described model). Thus, although HOV (without buses) have an average occupancy of 2.15, approximately two times greater than vehicles in general purpose lanes, buses have an average occupancy of 28, or approximately 11 times greater than the HOV. It would be logical to give full preference to buses, which have a far greater productivity than all other vehicles.

CONCLUSIONS

The trend of changing busways into HOV, and then from 4+ to 3+ and 2+ HOV facilities, is a clear case of backsliding of bus priorities. It represents a major obstacle to creation of *Bus Transit Systems* in U.S. cities (*2*). *These changes have practically eliminated busways as an option for high performance transit with strong image of independence from general traffic.*

Having lost the ability to secure separation of buses by regulation, cities that want to build transit systems competitive with auto travel must use physical separation of transit rights-of-way. Consequently, although busways are one of the alternatives for introducing high performance transit in other countries, U.S. cities now practically have rail modes as the only option.

HOV facilities lose many of the advantages that busways had. This is most obvious for the 2+ HOV facilities, which actually have the same traffic composition as the general purpose lanes except that they do not permit trucks and SOVs. The speed, reliability, safety, and driving comfort are negatively affected, and buses lose both their superior service and the distinctive image that they have on busways. Competition to buses is not only assisted by allowing carpools into bus lanes, but often auto drivers stop at bus stops and "steal" bus passengers (there have even been studies on how to encourage this phenomenon!). This has led to further diversion of transit riders and eventual degradation of bus services.

As another element of downgrading bus services, many HOV facilities and bus services are limited only to peak hours, and during other hours the HOV lanes revert to lanes for general traffic. Buses are now again mixed with other traffic with only a slight distinction of HOV facility; they operate for a limited number of hours and thus do not have an image of permanence and reliability. They simply represent peak hour capacity enhancing commuter services, rather than a distinctive high quality transit that serves the city throughout the day.

RECOMMENDATIONS

Transportation policies influencing modal split in our metropolitan areas are crucial for solving many urban problems. The policies toward buses should be based on careful consideration of long-term comprehensive system impacts, rather than on short-term operational changes aimed at increasing vehicle-carrying capacity of the highway. To achieve this goal the following revisions of policies and practices are recommended:

1. The trend in most cities developing HOV facilities has been to change from the best to the least favorable priority for transit. This is directly counteracting the goal of discouraging use of SOV, required by the CAAA as well as by the ISTEA. FTA should adopt a clear policy of maximum upgrading of *buses operated as regular, all-day bus service*, rather than buses as supplemental commuter services on an auto-oriented freeway network.
2. The concept of *busway* should not be considered superseded by the concept of *HOV facility*. Regardless of the successes of HOV facilities in regulating flows of different vehicle categories, in many cases *exclusive busways* and *bus lanes* should be used as the basic elements in creating high quality regular bus services. Such facilities are a *sine qua non* for introduction of *bus transit systems*, which have a great, presently underused potential in many cities and metropolitan areas.
3. Busways such as those in Ottawa, Pittsburgh, and other cities should not be downgraded by referring to them as "HOV facilities."
4. Conversion of existing general purpose into priority lanes should be preferred to adding of new lanes. It creates an automobile disincentive and transit incentive at the same time.
5. Transit funds should not be used for construction and operation of HOV facilities unless it is clearly shown that the competitive position of transit with respect to other modes would be improved significantly.
6. Any conversion of the type of facility (busway, HOV 4+, etc.) should be subjected to the environmental impact statement process because it has major impacts on the transportation system and urban environment.

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