

Simplified Approach for Estimating the Cost-Effectiveness of HOV Facilities

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A simplified approach for evaluating the cost-effectiveness of high-occupancy vehicle (HOV) facilities is presented in this paper. The procedure consists of assessing cost-effectiveness of HOV facilities on the basis of the value of travel time savings experienced by users of HOV facilities. This approach is also used as a basis for discussing general relationships between HOV lane cost-effectiveness and HOV lane travel corridor characteristics in Houston, Texas. The approach appears to be useful tool for (a) assessing the cost-effectiveness of an existing HOV facility when a detailed benefit-cost analysis cannot be funded and (b) quickly assessing HOV lane feasibility during planning when only limited funds or data are available.

During the past 15 to 20 years there has been growing concern about congestion on urban highways. Many urban areas have either implemented or plan to implement high-occupancy vehicle (HOV) facilities. One of the most common objectives associated with HOV projects is that they be cost-effective (i.e., the benefits of the HOV projects are greater than their costs). Clearly, if these projects are to compete successfully for the limited highway and transit funds that are available, the projects must be viewed as cost-effective.

BACKGROUND

To alleviate congestion in Houston, Texas, the Metropolitan Transit Authority of Harris County (METRO) and the Texas State Department of Highways and Public Transportation (SDHPT) have been developing a network of HOV facilities consisting of 95.5 miles of barrier-separated priority lanes (1). As of August 1990, 46.9 miles of this system were in operation in four corridors (Figure 1).

To evaluate HOV effectiveness in relieving congestion, extensive data are being collected during HOV lane implementation by the Texas Transportation Institute. Data collection activities are being funded by METRO and SDHPT. An issue that has arisen is how to assess the cost-effectiveness of the Houston HOV lanes, which are locally referred to as transitways.

Purpose of Paper

The primary purpose of this paper is to present a simplified, macroscopic approach to assess the cost-effectiveness of HOV lanes. This sketch-planning approach has evolved from the

evaluation of the Houston transitway system. Although the basic methodology can be applied to HOV lanes in general, the discussion will focus on the cost-effectiveness of HOV facilities similar to Houston's. The physical characteristics and dimensions of a typical single-lane, reversible transitway in Houston are illustrated in Figure 2.

Organization of Paper

The macroscopic approach used to determine the cost-effectiveness of Houston transitways will be presented. This approach will then be used as a basis for discussing general relationships between HOV lane cost-effectiveness and the following transitway corridor characteristics: (a) the travel time savings experienced by transitway users; (b) the relative level of congestion on adjacent freeway lanes; and (c) transitway ridership. A discussion of the situations under which the approach might be applied will conclude this paper.

APPROACH

Compared with the addition of general purpose lanes, the benefits of HOV lanes include increasing the effective person-movement capacity of a freeway corridor and favorable impacts on air quality and energy consumption. The primary quantifiable benefit of HOV lanes, however, is the value of the time saved by their users. It would appear that, if an HOV lane was cost-effective solely on the basis of the value of travel time savings, then the project would be even more cost-effective when all of the other potential benefits were considered. The assumptions made on the discount rate and project life for the economic analysis lead to different conclusions about the level of travel time savings required to make the HOV lane cost-effective on the basis of only the value of time saved.

In the evaluation of the cost-effectiveness of the Houston transitway system, this approach of focusing on the value of time saved by transitway users has been employed with the following assumptions: (a) a 20-year project life with no salvage value (a conservative assumption); (b) a 4 percent discount rate; and (c) a constant stream of benefits over the life of the project (also a conservative assumption if the analysis is using early year benefits because the benefits resulting from travel time savings should increase over time as transitway utilization and freeway congestion both increase). Using these assumptions and the equation listed in the following section, it can be determined that an annual benefit equivalent of 7.4

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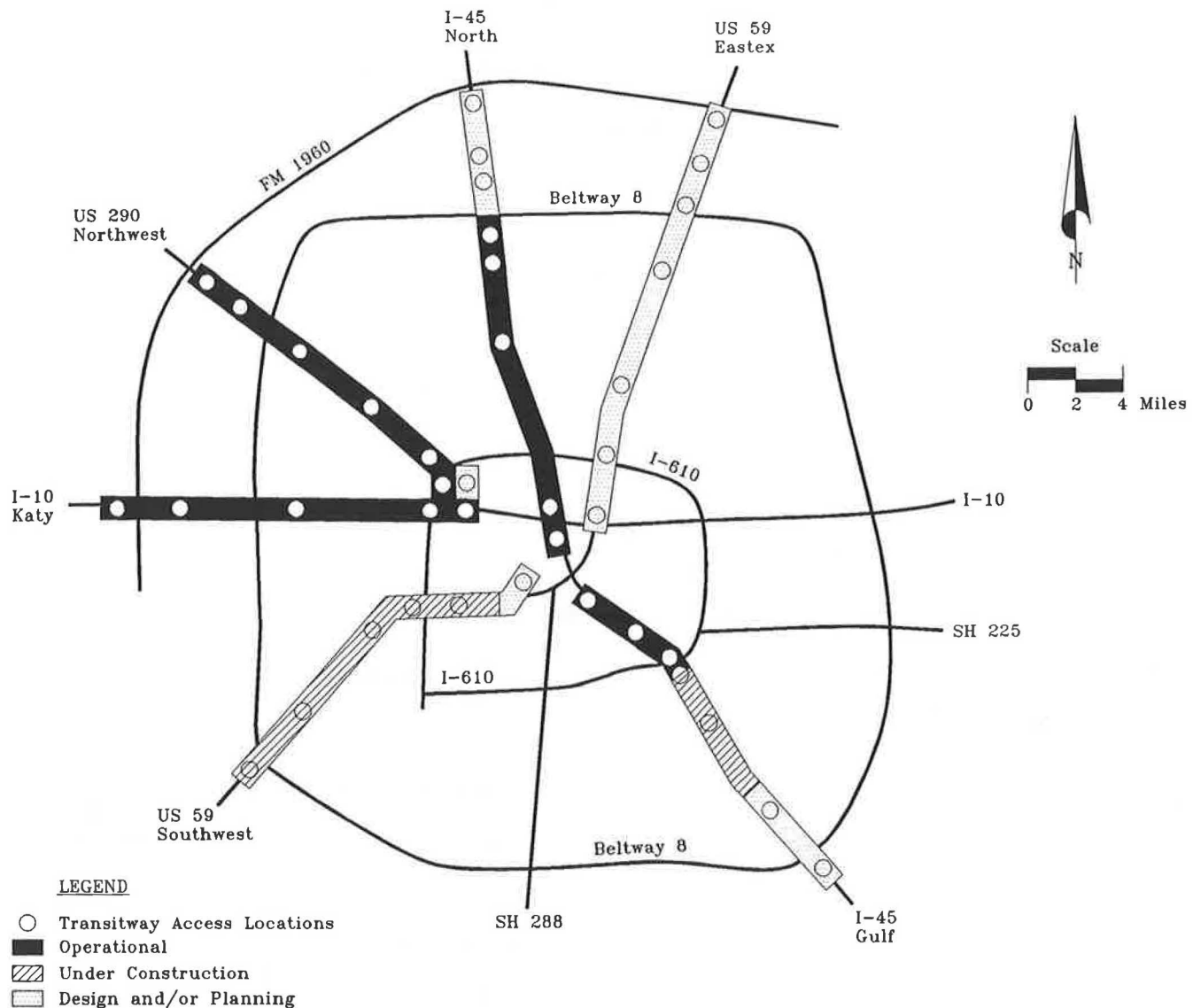


FIGURE 1 Status of transitway development program in Houston, August 1990.

percent of the total construction cost is needed to achieve a benefit-to-cost (B/C) ratio of 1.0. A suggested conservative rule of thumb, however, is to use 10 percent of the total construction cost as a general break-even point. As illustrated in the following example, a B/C ratio of approximately 1.4 would result from an annual value of transitway travel time savings equal to 10 percent of the total construction cost; operating and maintenance costs are not included in the example because they are usually small compared with construction costs.

Example

The total construction cost of an HOV facility is determined to be \$30 million (including right-of-way and park-and-ride lot construction costs), and the yearly value of travel time savings is \$3 million (10 percent of total construction cost). The discount rate is 4 percent and the project life is estimated

to be 20 years. The B/C ratio, based only on the value of travel time savings and total cost, can be calculated as follows:

$$P = A \frac{(1+i)^n - 1}{i(1+i)^n}$$

where

P = present worth of annual value of travel time savings;

A = annual value of travel time savings;

i = interest rate (discount rate); and

n = number of years.

In the current example,

$$P_T = 3,000,000 \frac{(1 + .04)^{20} - 1}{.04 (1 + .04)^{20}}$$

$$= 3,000,000 (13.59)$$

$$= 40,770,000 = \text{present worth of travel time savings.}$$

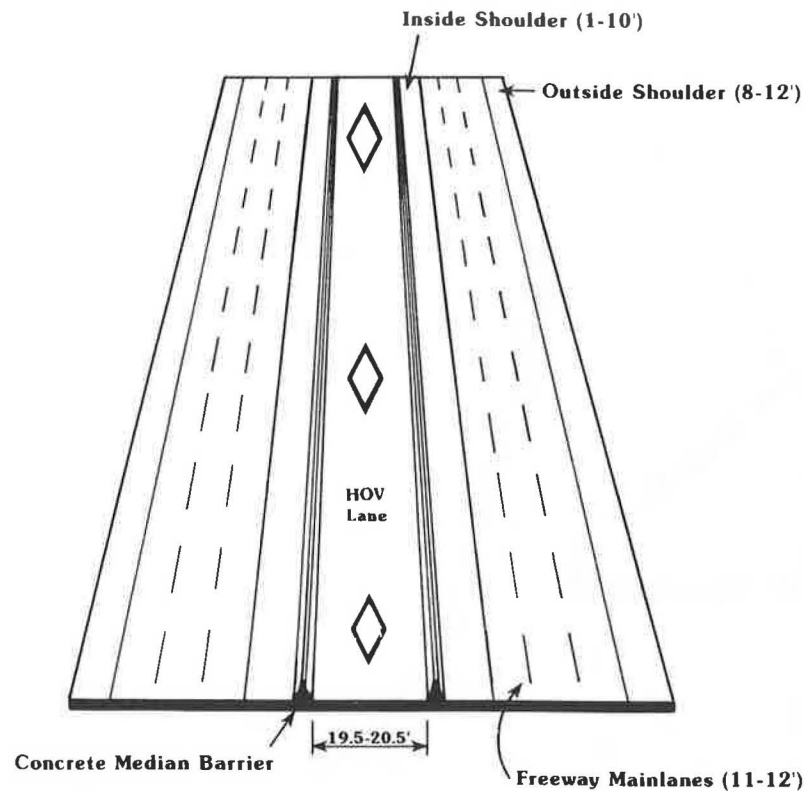


FIGURE 2 Characteristics of a typical Houston transitway.

Therefore,

$$B/C = \frac{40,770,000}{30,000,000} = 1.4.$$

Additional Considerations

It is suggested that any right-of-way or construction costs of park-and-ride lots that supplement the transitways also be included in the initial construction cost. Furthermore, some HOV operating and maintenance costs can be significant; in some instances these costs should, therefore, be included.

In addition to the stated assumptions, the supposition that the users of the transitways will be the only individuals to experience travel time savings relative to pre-HOV implementation is also conservative. Subsequent to implementation of HOV facilities, travelers of the general-purpose freeway lanes will typically experience a decrease in travel time. Data from Houston, however, indicate that although a decrease in travel times on the freeway mainlanes is often noted following the implementation of a transitway, the travel time savings are relatively small and short-lived because of the latent demand that exists in the congested travel corridors.

APPLICATION OF APPROACH

The simplified approach presented in this paper will be applied to the data collected in transitway travel corridors in

Houston in this section. These data include: (a) transitway travel time savings; (b) relative levels of congestion on the adjacent freeway lanes (measured in ADT/lanè); and (c) transitway ridership.

Travel Time Savings

One of the major components of the data that was collected is the identification of travel time savings experienced by users of the transitways. Historical travel time savings associated with the Houston transitway system are displayed in Table 1 (2). These time savings are expressed in both minutes and minutes per mile and represent the yearly average travel time saved on the transitways.

Multiplying the travel time savings in Table 1 by corresponding ridership data (which will be discussed later in this paper) produces the person hours of savings shown in Table 2. These average daily person hours of savings are then multiplied by \$9/hr (the value of time) and 250 weekdays of operation to arrive at the annual values of travel time savings displayed in Table 2.

It is important to note that travel time data for the Houston transitways are only collected on nonincident days of freeway and transitway operations. The travel time savings shown in Table 1 are, therefore, extremely conservative, since the data do not take into account any additional savings that may take place when incidents occur on freeway mainlanes. Data from Houston, however, indicate that increasing the value of travel time savings by 100 percent to account for incidents would be reasonable (1). The annual value of travel time savings

shown in Table 2 reflects this adjustment. Also included in Table 2 are the initial construction costs of the transitways and the annual value of travel time savings expressed as a percentage of the initial construction costs.

The historical transitway travel time savings (in minutes per mile) are plotted against their corresponding annual value of time savings expressed as a percentage of the initial construction costs (Figure 3). By applying the foregoing approach to this plot, it appears that the travel time savings for a Houston-type HOV lane needs to be approximately 0.8 min/mi for the facility to be cost-effective, solely on the basis of travel time savings. This finding generally agrees with previous findings by Baugh and Associates that indicate HOV lanes need to offer a time savings of approximately 1.0 min/mi to be considered effective (3).

In Figure 4, the travel time savings, in minutes, are plotted against the annual value of travel time savings expressed as a percentage of construction costs. The data in Figure 4 indicate that for a Houston-type HOV lane to be cost-effective solely on the basis of travel time savings, a time savings of approximately 8 min must be achieved. This general finding is also in agreement with previous research, which found that a total time savings of 5–10 min must be attained for an HOV facility to be considered effective (4).

Traffic Congestion on Adjacent Freeway Lanes

A characteristic of HOV lane travel corridors that is necessary for significant travel time savings to be experienced by individuals using the HOV facility is the presence of traffic congestion

on the adjacent freeway mainlanes. In consideration of the peaking characteristics typically associated with HOV lanes, it would seem that peak-hour or peak-period volumes on the freeway mainlanes are the most closely related volume data to peak hour-peak period HOV lane travel time savings.

The relationship between speed and volume data, however, made it impossible to determine the magnitude of congestion on the basis of volumes alone. This problem can best be explained by examining the theoretical relationship between speed and volume illustrated in Figure 5 (5). A vehicular flow of 1,800 passenger cars/hr/lane could be present for two different conditions of flow: an uncongested flow with an average travel speed of approximately 48 mph or an unstable, congested flow with an average travel speed of approximately 20 mph. Peak-hour and possibly peak-period freeway volume data, would need to be supplemented with travel speed data to correctly assess the traffic operations on the freeway.

To retain accuracy and keep within the context of a simplified approach, average daily traffic (ADT) per lane counts were, therefore, obtained to illustrate the levels of traffic congestion on the freeway mainlanes. The magnitude of ADT per lane associated with the beginning of an undesirable level of congestion is generally accepted to be between 15,000 and 17,000 vehicles/day/lane. Measures of traffic flow for freeways and their relationships with general levels of service are shown in Table 3 (6).

The average weekday traffic (AWT) per lane values in Table 4 were derived by dividing the AWT data by their corresponding basic number of lanes (7). The weighted average calculated for each transitway corridor is considered to represent the relative level of congestion prevailing on the freeway mainlanes of each transitway travel corridor.

TABLE 1 SUMMARY OF HISTORICAL TRAVEL TIME SAVINGS, HOUSTON TRANSITWAY SYSTEM

Transitway	Year Data Were Collected	Average Travel Time Savings (minutes) ¹		Length of Transitway Facility (mi)	Average Travel Time Savings (min/mi) ²	
		Peak Hour	Peak Period		Peak Hour	Peak Period
Gulf (I-45S)	1988	4.6	2.9	6.5	0.7	0.5
Gulf (I-45S)	1989	2.3	0.9	6.5	0.4	0.1
Katy (I-10W)	1988	13.9	7.3	11.9	1.2	0.6
Katy (I-10W)	1989	14.2	6.9	11.9	1.2	0.6
North (I-45N)	1988	8.4	3.8	9.1	0.9	0.4
North (I-45N)	1989	6.6	3.4	9.1	0.7	0.4
Northwest (US 290)	1989	4.1	1.7	9.5	0.4	0.2

Notes: Peak hour defined as the hour in which transitway travel time savings is the greatest. As a result, they are not always the same hours but are normally 7–8 a.m. and 5–6 p.m. Peak periods designated as 6–9:30 a.m. and 3:30–7:00 p.m. for all transitways except the North Transitway, whose peak periods are designated as 6–8:30 a.m. and 3:30–6:30 p.m.

¹Yearly average of travel time savings in minutes for transitway users during morning and evening peak hours and peak periods

²Yearly average of travel time savings in minutes per mile for transitway users during morning and evening peak hours and peak periods

TABLE 2 ANNUAL VALUE OF TRAVEL TIME SAVINGS AND TRANSITWAY CONSTRUCTION COSTS

Transitway	Year Data Were Collected	Person-Hours of Savings ¹	Annual Value of Travel Time Savings (\$million) ²	Initial Construction Cost (\$million) ³	Annual Value of Travel Time Savings as % of Construction Cost (%) ⁴
Gulf (I-45S)	1988	315.8	1.42	27	5.0
Gulf (I-45S)	1989	248.7	1.12	27	4.1
Katy (I-10W)	1988	1,353.2	6.09	32	19.0
Katy (I-10W)	1989	1,701.4	7.66	32	23.9
North (I-45N)	1988	990.1	4.46	29	15.4
North (I-45N)	1989	674.8	3.04	29	10.5
Northwest (US 290)	1989	126.1	0.57	44	1.3

¹ The average daily person-hours of savings experienced by transitway users

² The average daily person-hours of savings multiplied by \$9/hr (value of time), 250 weekdays of operation, and a factor of 2 to adjust for incidents on the freeway

³ The initial construction cost associated with the section of transitway for which transitway and freeway travel time data were collected

⁴ The annual value of travel time savings divided by the corresponding initial construction cost, expressed as a percentage

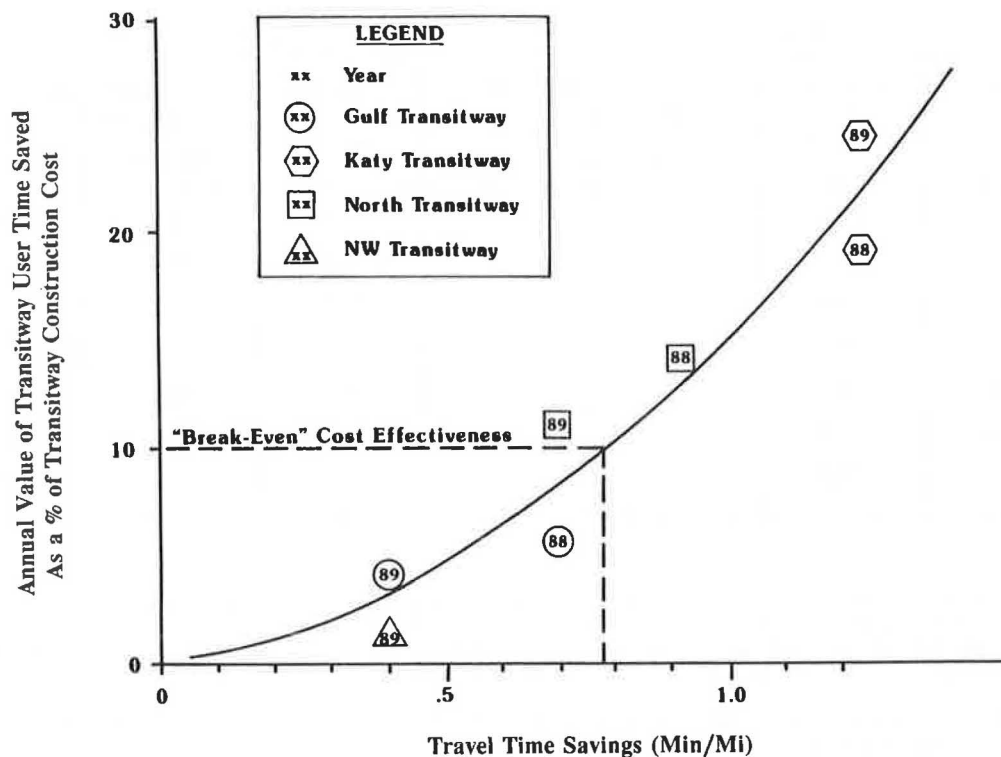


FIGURE 3 Estimated peak-hour travel time savings per mile required for transitway to be cost-effective.

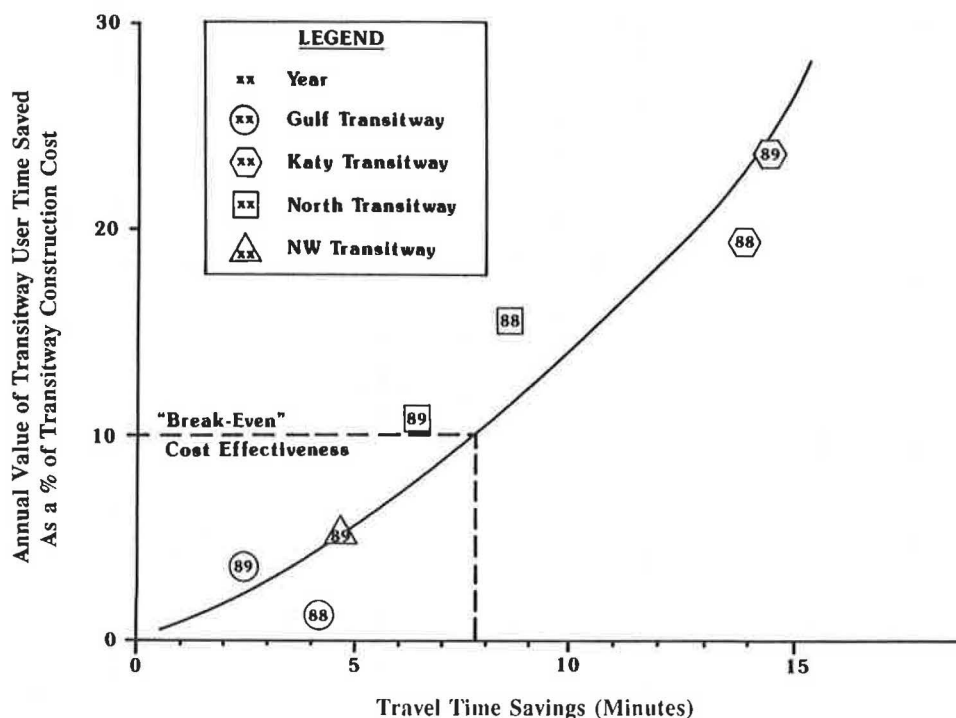


FIGURE 4 Estimated peak-hour travel time savings required for transitway to be cost-effective.

The AWT per lane values developed in Table 4 have been displayed with their corresponding travel time savings for peak hours on the transitway in Table 5. The relationship between these data has been plotted in Figure 6. The best-fit line shown in Figure 6 was determined to be exponential and indicates that transitway travel time savings will probably not occur until a daily volume of 15,000 vehicles per lane has been reached.

Using the data shown in Figure 6, a plot of the AWT per lane data (Table 4) versus corresponding annual values of travel time savings expressed as a percentage of construction cost was developed and is shown in Figure 7. The general relationship between these data indicates that the magnitude of AWT per lane must reach approximately 23,000 before a Houston-type HOV facility will be cost-effective, on the basis of value of travel time savings alone. This general finding is in agreement with recent research regarding HOV congestion guidelines (8). As is noted in Table 6, when daily freeway volumes exceed 20,000 vehicles/lane, HOV projects are considered feasible and warrant evaluation during planning and design. It is important to keep in mind that this analysis only considers the benefit of travel time savings; the quantification of other benefits would likely lower the thresholds needed to achieve cost-effectiveness.

Ridership

While travel time savings are an important aspect of a cost-effective HOV facility, the establishment of a significant level of ridership is also necessary. Ridership levels have historically increased exponentially with increasing travel time savings for the Houston transitways (Figure 8). This is logical

because an HOV facility offering greater travel time savings would be more attractive to commuters and would experience a higher magnitude of utilization.

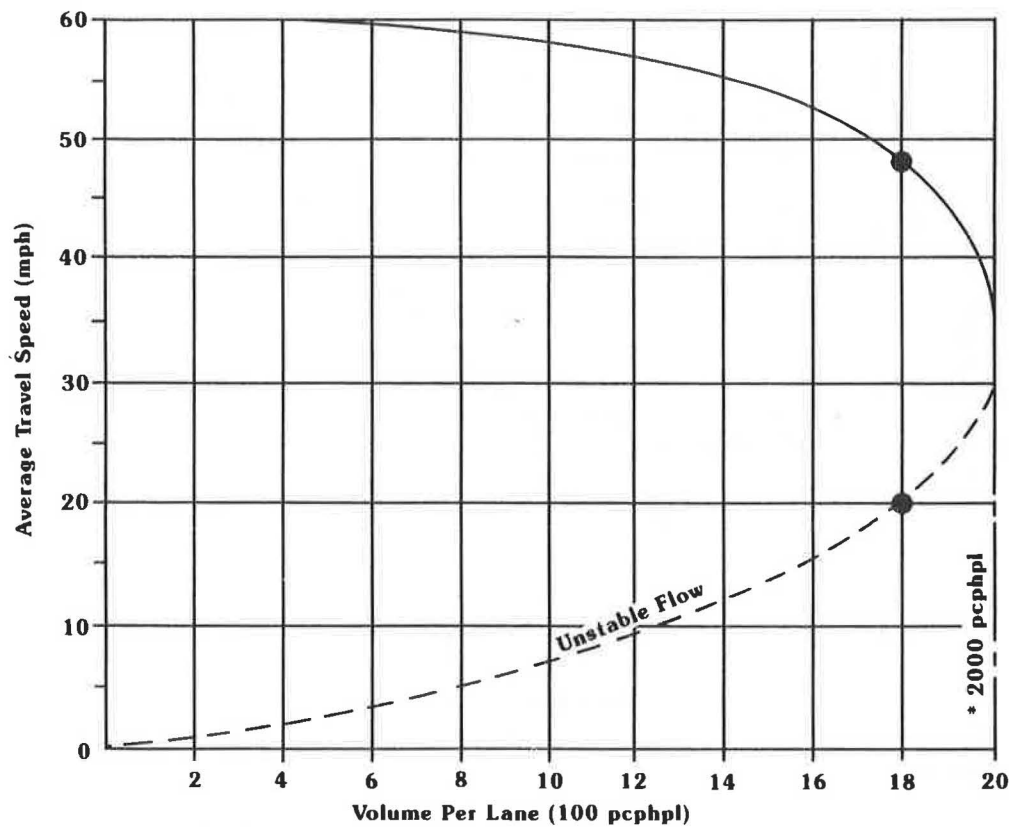
The estimated level of peak-hour ridership required for a Houston-type HOV lane to be cost-effective on the basis of the value of travel time savings alone is approximately 3,000 persons (Figure 9). The magnitude of daily ridership needed to attain the same level of cost-effectiveness is approximately 10,000 persons (Figure 10).

Summary

This section of the paper has applied a simplified approach for estimating the cost-effectiveness of HOV facilities. This approach, when applied to the historical travel time savings, freeway AWT per lane, and ridership data on the Houston transitway system, suggests that the thresholds shown in Table 7 should be met for a Houston-type HOV facility to be deemed cost-effective solely on the basis of the value of travel time savings.

CONCLUSIONS

As the competition for funding intensifies, increasing attention is being directed toward the cost-effectiveness of various transportation improvements, including HOV facilities. The approach presented in this paper provides a fairly simple, macroscopic procedure for evaluating, in an extremely conservative manner, the cost-effectiveness of HOV facilities with designs similar to those in Houston. This approach appears to be a potentially useful tool in the following situations: (a)



Note: Diagram shown for 8-lane roadway with design speed of 70 mph

* Theoretical Capacity

pcphpl - Passenger cars per hour per lane

FIGURE 5 Speed-flow relationship under ideal conditions.

TABLE 3 MEASURES OF TRAFFIC FLOW FOR BASIC FREEWAY SECTIONS

Level of Service	Density ¹	Speed ²	MSF ³	V/C ⁴	ADT/Lane ⁵	DVMT/LM ⁶
A	12	60	700	0.35	N/A	N/A
B	20	57	1,100	0.54	13,000	11,500
C	30	54	1,550	0.77	15,000	13,000
D	42	46	1,850	0.93	17,000	15,000
E	67	30	2,000	1.00	18,500	17,000
F ⁷						

Note: All figures shown are for a design speed of 70 miles per hour

N/A: Not available at this level of service

¹Traffic density in passenger cars per mile per lane per hour

²Average travel speed in miles per hour

³Maximum service flow rate in passenger cars per hour per lane

⁴The ratio of traffic volume to theoretical facility capacity

⁵Average daily traffic volume per lane

⁶Daily vehicle miles of travel per lane-mile

⁷Highly variable, unstable conditions

TABLE 4 FREEWAY MAINLANE AWT DATA, 1987-1989

Freeway Corridor	Count Location	Frwy AWT, 1988 ¹	Frwy AWT, 1989 ¹	Basic No. of Lanes ²	AWT/Lane, 1988	AWT/Lane, 1989
Gulf	Broadway	196,600	201,400	8	24,600	25,200
	Griggs	139,500	140,000	8	17,400	17,500
	Dowling	165,900	160,100	8	20,700	20,000
	Corridor Avg. ³				20,900	20,900
Katy	Silber	197,900	186,100	8	24,700	23,300
	Bunker Hill	187,700	187,100	6	31,300	31,200
	Kirkwood	147,300	158,300	6	24,600	26,400
	Corridor Avg. ³				26,600	26,600
North	W. Cavalcade	162,600	168,900	8	20,300	21,100
	Crosstimbers	221,100	218,900	8	27,600	27,400
	Tidwell	171,800	172,100	8	21,500	21,500
	Little York	173,500	178,000	6	28,900	29,700
	Corridor Avg. ³				24,300	24,600
Northwest	Watonga	198,000	203,500	8	24,800	25,400
	Antoine	149,600	152,900	8	18,700	19,100
	Pinemont	123,200	130,900	6	20,500	21,800
	N. Gessner	97,900	99,000	6	16,300	16,500
	Corridor Avg. ³				20,300	20,900

N/A: Not applicable

¹Average weekday traffic volume²Exhibited no changes from 1988 to 1989³Weighted average based on basic number of lanes; represents average ADT/lane conditions for the freeway corridor

TABLE 5 PEAK HOUR TRANSITWAY TRAVEL TIME SAVINGS AND AWT/LANE DATA

Transitway Corridor	Year Data Were Collected	Average Peak Hour Travel Time Savings (min/mi) ¹	Avg. AWT/Lane for Corridor ²
Gulf (I-45S)	1988	0.7	20,900
Gulf (I-45S)	1989	0.4	20,900
Katy (I-10W)	1988	1.2	26,600
Katy(I-10W)	1989	1.2	26,600
North (I-45N)	1988	0.9	24,300
North (I-45N)	1989	0.7	24,600
Northwest (US 290)	1988	0.2	20,300
Northwest (US 290)	1989	0.4	20,900

¹Yearly average of travel time savings in minutes per mile for transitway users during morning and evening peak hours; rounded to the nearest 0.1 minutes per mile²Weighted average based on basic number of lanes; represents average AWT/lane conditions for the freeway corridor

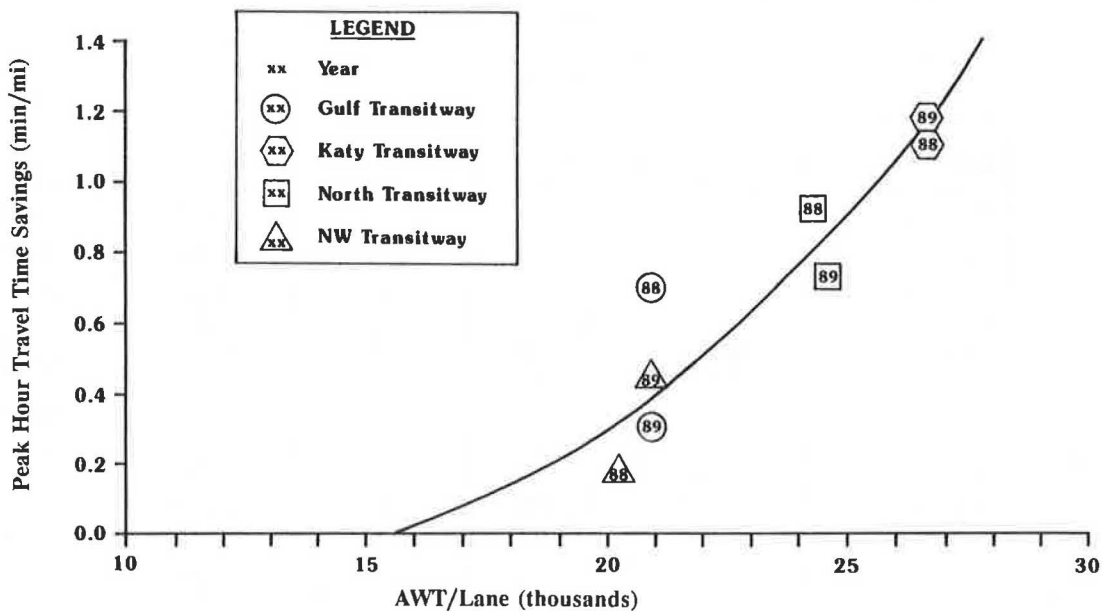


FIGURE 6 Plot of peak-hour travel time savings versus AWT/lane.

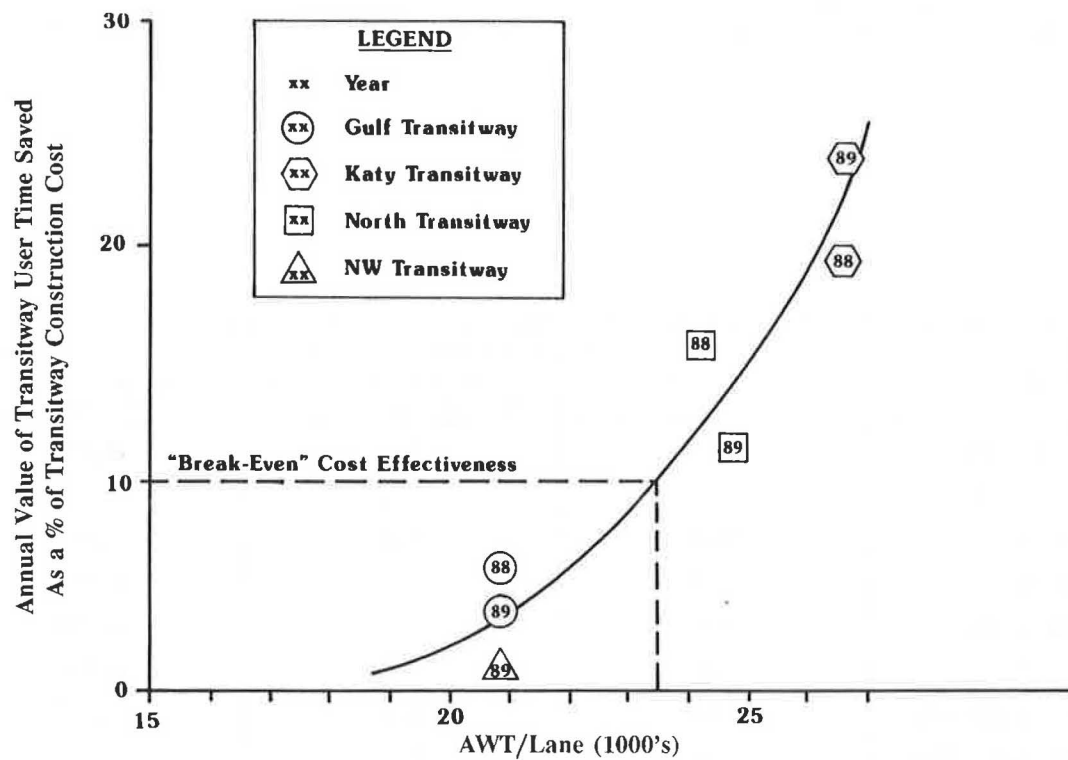


FIGURE 7 Estimated freeway AWT/lane required for transitway to be cost-effective.

TABLE 6 HOV CONGESTION GUIDELINES (4,9)

ADT Per Lane	HOV Congestion Guideline
Over 20,000	Projected congestion is heavy enough for HOV implementation to be considered feasible based on congestion only and worthy of thorough evaluation in the planning and design process. Determination of an HOV improvement as feasible based on congestion alone does not imply the improvement is recommended.
15,000-20,000	Projected congestion is sufficient for HOV implementation to be considered plausible based on congestion only and deserving of analysis in the planning process.
0-15,000	HOV improvement not likely to be cost-effective.

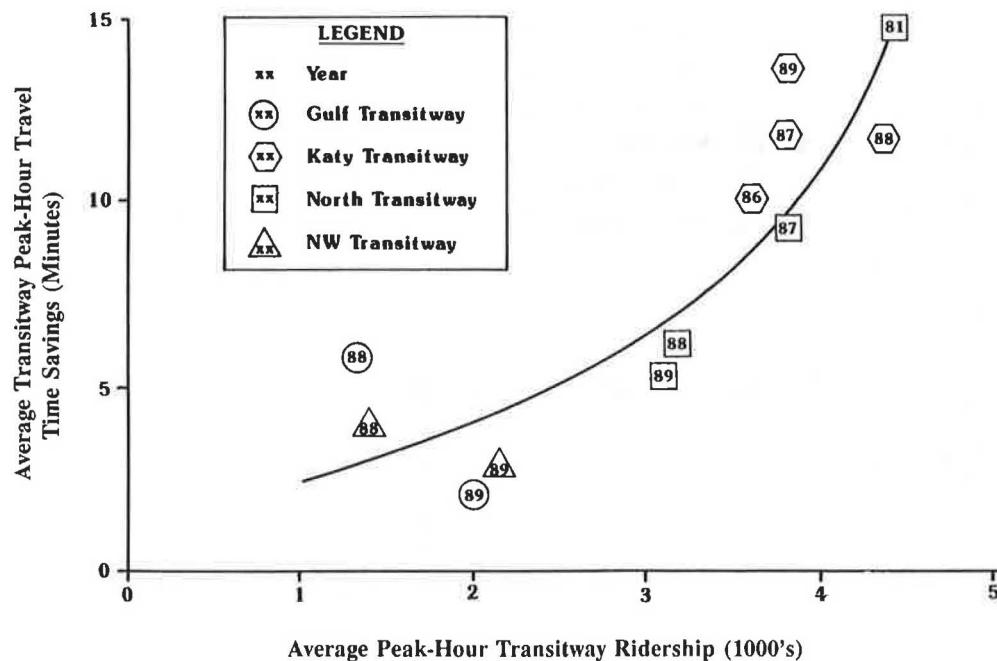


FIGURE 8 Relationship between peak-hour transitway ridership and peak-hour transitway travel time savings.

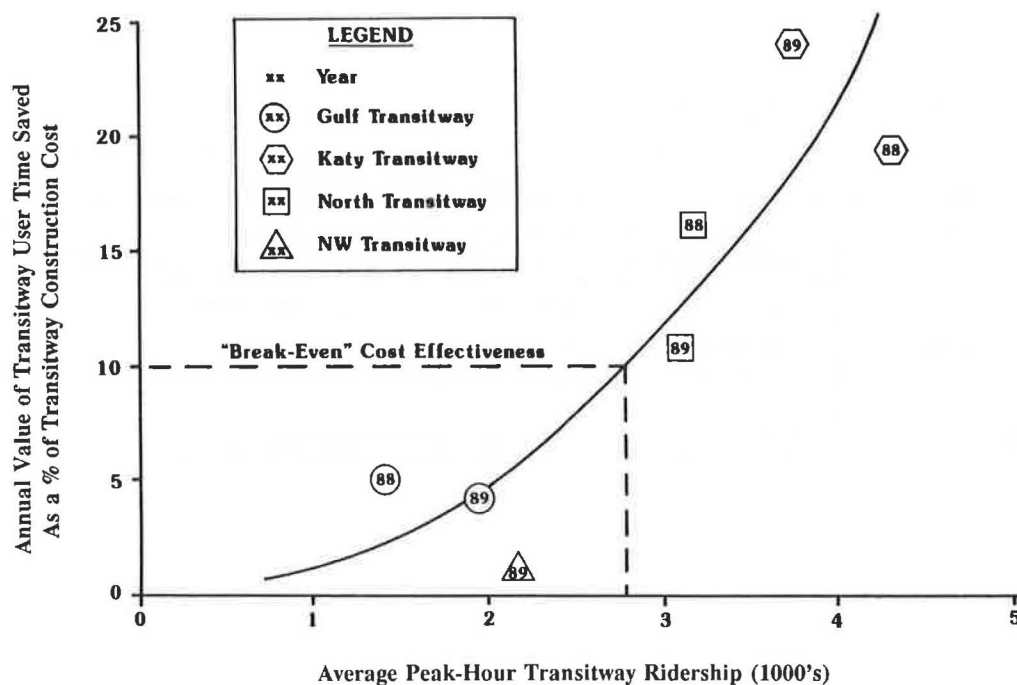


FIGURE 9 Estimated peak-hour transitway ridership required for transitway to be cost-effective.

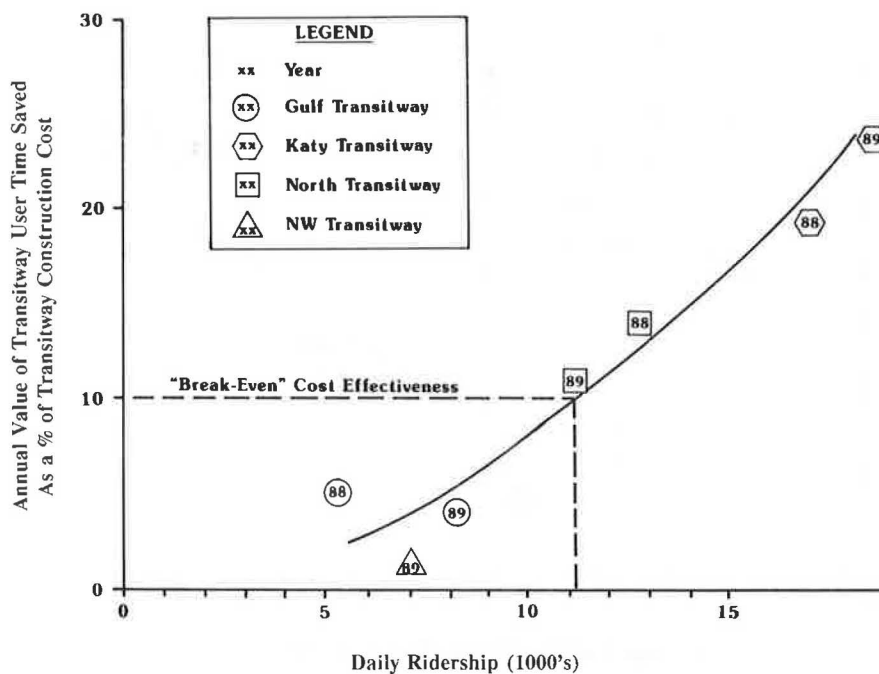


FIGURE 10 Estimated daily transitway ridership required for transitway to be cost-effective.

TABLE 7 ESTIMATED THRESHOLDS ASSOCIATED WITH COST-EFFECTIVE HOUSTON-TYPE HOV LANES

Indicator	Minimum Threshold Which Needs To Be Met If HOV Lane Is To Be Considered Cost Effective ¹
Average peak hour HOV lane travel time savings	0.8 minutes per mile of HOV facility and/or 8 minutes of total travel time savings
Freeway average weekday traffic	23,000 vehicles per day per lane
Average peak hour HOV lane ridership	3,000 persons per hour
Average daily HOV lane ridership	10,000 persons per day

¹Minimum threshold which needs to be met if a "Houston-type" HOV lane is to be considered cost effective, based on travel time savings alone

the cost-effectiveness of an existing HOV facility needs to be assessed, but a detailed benefit-cost analysis for the facility cannot be funded and (b) the quick assessment of HOV lane feasibility at a conceptual planning level is needed, and a limited amount of funding and data is available.

The approach presented in this paper only considers the HOV facility benefit of travel time savings and, as such, should be viewed as an extremely conservative procedure in estimating the cost-effectiveness of HOV lanes. The suggested use of the approach presented in this paper as a possible method to assess the potential cost-effectiveness of an HOV facility should, by no means, be considered a substitute for a detailed alternatives analysis. Invariably, the implementation of HOV facilities will be subject to site-specific conditions, such as the size and density of activity centers in an urban area, the amount of available funding, and so on. The methodology presented in this paper could, however, serve as a preliminary assessment of HOV facility feasibility.

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Since 1974, the Texas State Department of Highways and Public Transportation has sponsored ongoing research on priority treatment for high-occupancy vehicles. In more recent years, the Metropolitan Transit Authority of Harris County has been actively involved in this research program. The in-

formation presented in this paper is a result of this research. The oversight and funding provided by the sponsoring agencies are gratefully acknowledged.

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