Feasibility of Texas Highway Economic Evaluation Model for High-Occupancy Vehicle Projects

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The increasing importance of improving the efficiency of transportation facilities has resulted in the need for a systematic economic model to evaluate those kinds of projects. An important category of projects includes high-occupancy vehicle (HOV) projects, which encourage higher vehicle occupancy rates by restricting the use of some portion of the facility to some vehicle types or minimum number of occupants. This paper examines the feasibility of using the Texas highway economic evaluation model (HEEM) to evaluate HOV projects and recommends changes to the current model in three major areas, including the assumptions used in the model, the user cost calculations, and the method of allocating corridor traffic to specific routes within the corridor. The assumptions of the model examined include the percentage of trucks, the occupancy rates, and the value of time. The calculations for vehicle operating costs, including running costs and cycling costs, are examined, along with the vehicle types used in those calculations. The allocation of corridor traffic is an important aspect of evaluating HOV projects and other types of highway projects. The allocation method used in HEEM is compared with a method that minimizes the total user costs. The method involves determining the allocation such that the marginal user costs for each route in the corridor are equal. User cost equations are presented that can be used to allocate corridor traffic for any number of routes within the corridor. The cost functions are based on the user cost calculations in HEEM.

The near completion of the Interstate highway system and the increasing shortage of funds for future highway construction have caused state highway agencies to concentrate on upgrading and increasing the capacity of existing streets and highways. The projected shortage of funds has also forced the scaling down or deletion of many planned improvements on new and existing facilities. As a result, it has become increasingly important for highway agencies to estimate potential user and nonuser benefits and costs accurately from planned highway projects.

In recognition of this problem, the highway economic evaluation model (HEEM) was developed to measure the benefits and changes in mobility from a planned highway project. This paper examines a version of the model adapted for Texas and currently in use by the Texas State Department of Highways and Public Transportation (1).

HEEM provides for a streamlined and systematic approach for evaluating highway projects on a segment, route, or system basis in terms of a benefit/cost ratio, called an economic measure (EM), and mobility measure. EM for each project is the ratio of the present value of the estimated user benefits to the estimated construction costs. The user benefits are the sum of time savings, vehicle operating cost savings, and accident cost savings less the added (incremental) maintenance costs. Mobility is measured in terms of average daily speed for both the do-nothing and construct alternatives.

HEEM requires a relatively small amount of input data, including characteristics of existing and proposed highways, construction dates and costs, corridor traffic (current and projected), and key assumptions that the model provides but can be modified for a specific project evaluation if necessary. Table 1 (2) lists the current values of those key assumptions for Texas.

HEEM provides 33 different highway types that can be evaluated in the model along with the relevant specifications of speed, volume [average daily traffic (ADT)], cycles, accidents, and maintenance costs for each highway type. The model also provides the mathematical relations to calculate the user costs and EM. No knowledge of the relations are required to run the model.

Unfortunately, HEEM does not estimate a highway project's effect on air pollution as does other currently used procedures (3,4). Also, the model does not provide for the evaluation of fuel consumption and bus or other transit projects (as opposed to highway projects) as do procedures presented in the new American Association of State Highway and Transportation Officials (AASHTO) Redbook (5).

As a result, projects that increase the efficiency of existing capacity, including priority treatment to high-occupancy vehicles (HOVs), cannot be evaluated by using HEEM. HOV projects have been receiving considerable attention in recent years and it is therefore of interest to consider modifying HEEM so that a systematic economic evaluation of HOV projects could be accomplished. Three major areas must be addressed in modifying HEEM to evaluate HOV projects. The first area is the appropriateness of the key assumptions (default values if not changed for specific projects) presented in Table 1 as they apply to HOV projects. The second area is the underlying user cost relation and the third area is the allocation procedure for allocating future projected traffic routes within the corridor.

ASSUMPTIONS OF MODEL

Buffington and others (6) examine each one of the key assumptions from HEEM in detail. One assumption is especially important in evaluating HOV projects, namely the percentage of trucks and a related issue, the occupancy rate.

A single statewide average percentage of trucks is assumed in HEEM for separating corridor traffic into two vehicle types, passenger cars and trucks. It is unclear what supporting evidence was used in arriving at the 8 percent statewide average and if the truck category includes pickup and panel trucks.

Table 2 presents data based on a selected random sample of 326 highway sections scattered over Texas and indicates that 8 percent is too low for a statewide average. These data compare favorably with national data, compiled by the U.S. Department of Transportation, as given in Table 3 (7). A related problem, evident in Table 3, is the wide variability in the proportion of single-unit trucks and multi-unit trucks among highway types and location.

These problems are especially critical in evaluating HOV projects since the use of certain lanes are typically restricted to certain types of vehicles or vehicles that require a minimum number of occupants. A single statewide average would clearly be inappropriate. Instead, each highway project and each route evaluated in that project should be assigned a locally determined percentage of trucks, with single-unit trucks and multi-unit trucks separate. In the absence of a valid local estimate, estimates in Tables 2 and 3 could be used for conventional projects, and data from other HOV projects, such as the data reported by D. Baugh and Associates (8) could be used in the evaluation of HOV projects.

Table 1. HEEM's key assumptions for Texas.

Assumption	Description	Assumed Value in 1981
Truck percentage	Percentage of commercial truck traffic in typical traffic flow	Varies by facility default 8 percent
Value of time	Value of time lost due to congestion or circuitous travel	
Automobile	Average passengers per automobile at 1.3 persons/vehicle	$0.15/vehicle min
Truck	Average commercial truck	$0.28/vehicle min
Rate of inflation	Long-term rate of general inflation	8 percent
Construction cost-escalation rate	Long-term rate of construction cost escalation including inflation and the effects of higher environmental and design standards	8 percent
Discount rate	Minimum anticipated annual return of user benefits on dollars invested in highway construction projects	20 percent
Diversion route speed	Speed assigned to traffic diverted from a corridor that has reached capacity	
Rural		25 mph
Urban		15 mph

Table 2. Percentage of trucks on Texas highways by road system and location.

	Location					
	Rural		Urban		All	
Road	Percent	No.	Percent	No.	Percent	No.
Interstate highway	23.33	24	10.84	3	21.91	27
Loop highway	2.27	1	11.25	4	9.56	5
U.S. highway	17.68	116	2.86	1	17.55	117
State highway	15.26	56	10.37	1	15.50	57
Farm-to-market road	10.68	121		0	10.68	121
All	14.99	317	9.73	9	14.85	326

Note: Table is based on 1975 data collected from the Texas State Department of Highways and Public Transportation Roadway Information System File. Data excludes pickup and panel trucks.

Table 3. Percentage distribution of national vehicle miles of travel by type of vehicle, highway type, and location.

Type of Vehicle	Main Rural (%)	Local Rural (%)	Urban Streets (%)	All Roads (%)
Car	70.7	82.6	83.5	78.9
Bus	0.4	0.8	0.3	0.4
Single-unit truck[a]	19.1	15.5	14.8	16.4
Combination truck	9.8	1.1	1.4	4.3

[a] Includes panel and pickup trucks.

Not only must the distribution of vehicles be estimated with a reasonable degree of accuracy, but in order to calculate user time costs, the average number of occupants in each vehicle must also be estimated accurately. HEEM assumes an occupancy rate of 1.3 persons/car and 1 person/truck. The table below (9) gives vehicle occupancy rates for buses and passenger cars that operate in rural and urban areas. Transit buses are assumed to operate only in cities that have a population of at least 300 000.

	Occupancy Rate (persons/vehicle)		
Vehicle Type and Location	Avg	Peak Hour	Practical Maximum
Passenger car			
All trips including work and intercity trips	2.2	1.6	3.5
Intercity trips	2.9		
Bus			
Transit	9.0	18.0	25.0
Intercity	20.0		30.0

The assumed occupancy rate for passenger cars in HEEM is acceptable only for urban peak hours, especially since HEEM's calculations include nonpeak hours.

The occupancy rate in evaluations of HOV projects is especially important because one of the goals of such projects is to induce persons to use higher-occupancy modes of travel, including buses, vans, and carpools. The occupancy rates in HEEM cannot currently be adjusted except indirectly through the value of time assumption, which is assumed to be the same for all routes in the corridor being evaluated. A constant occupancy rate is generally not appropriate for HOV project evaluations; therefore, HEEM should be modified to accept variable occupancy rates based on local estimates when available, otherwise estimates such as those in the table above could be used. Memmott and Buffington (10) provide some recommended occupancy rates for various HOV projects.

The occupancy rate affects user costs principally through the value of time calculations. Since time savings usually account for the greatest portion of user savings that result from a highway improvement, the assumed unit values of time used in calculating time savings is of utmost importance.

Initially, HEEM assumed, in 1975 dollars, a value of time of 9 cents/vehicle-min (assuming 1.3 persons/vehicle) for the average automobile and 18 cents/vehicle-min (assuming one driver and considering the value of equipment) for the average commercial truck. The assumed automobile value of time is almost identical to that recommended by Buffington and McFarland (4) as well as by Thomas (11) and Lisco (12), when adjusted to 1975 prices. Also, this value is near the upper end of the range of values recommended in the AASHTO Redbook (5). Therefore, after updating, HEEM's assumed value of time for automobiles is acceptable for time savings calculations if the amount of time saved, income level of occupants, or purpose of trip are not taken in account.

HEEM's initially assumed value of truck time is almost the same as that recommended by Buffington and McFarland (4) as well as by Adkins (13) for heavy multi-unit trucks. An average value of 16 cents/vehicle-min, as given in the table below, would be more representative of the average commercial truck. The distribution of average trucks is assumed to be 34.7 percent single-unit trucks and 65.3 percent multi-unit trucks.

Source	Value of Time in 1975 (¢/vehicle-min) Single-Unit Truck	Multi-unit Truck	Avg Truck
AASHTO Redbook (5)	11.5	13.0	12.5
TTI study (4)	13.4	18.0	16.4

The AASHTO Redbook (5) recommends slightly lower values of truck time, based on a study by Wilbur Smith and Associates (14).

Since the values of time recommended by Buffington and McFarland (4) are based on truck and driver costs that prevail in the Southwest, a weighted average value of 16 cents/vehicle-min in 1975 prices would be preferred for evaluations of Texas highway projects. However, a superior method would be to treat each truck type separately, which would eliminate the necessity of calculating a weighted average. HEEM is not currently capable of incorporating additional vehicle types.

HEEM assumes a single value of time for cars. However, there is evidence in the literature to indicate that the value of time for passenger cars and buses varies with the amount of time saved per trip, family income, and the purpose of the trip (5,15,16). Thomas and Thompson (15) pioneered the research in this area in the late 1960s by using a revealed behavior approach. Their findings are based on a survey of motorists at sites in 10 states who faced a choice of a faster toll road or a slower free road. The value of time was based on how much money motorists were willing to pay in tolls to save a certain amount of time. They concluded that the value of time saved is a function of trip time saved, the motorist's family income, and trip purpose.

The AASHTO Redbook (5) gives a procedure for using the findings of Thomas and Thompson. Table 4 is based on that procedure, which divides both the amount of time saved and trip purpose into three different categories. As Table 4 shows, values of time can vary widely among the different categories and a single value of time may not be appropriate when these factors may differ significantly for different routes or over time for a single route.

USER COST CALCULATIONS

HEEM calculates user costs for time costs, accident costs, and vehicle operating costs. Operating costs are broken down into two categories, namely, running costs and cycling or speed change costs. The running costs, updated to March 1975, are based on those by Winfrey (18) and the AASHTO Redbook (5). The cycling costs are based on those used by Winfrey.

Figure 1 depicts the cost curves. The running costs for speeds below 25 mph are calculated by using a different equation than the running costs above 25 mph. There is a slight discontinuity at 25 mph as a result. The cycling cost equations estimate the cost of 10-mph cycles as a function of initial speed. This is as a linear function of average traffic volume by highway type and number of lanes. Cycling costs and average speeds can be adjusted for technical performance factors, such as shoulder and lane width, vertical alignment, and percentage of trucks.

Comparison of these operating costs to other estimates presents some difficulty because running costs and cycling are not generally separated in the same fashion as in HEEM. However, assuming 5.4 cycles/vehicle mile, HEEM's operating costs are roughly similar to AASHTO Redbook (5) costs for speeds below 25 mph. For speeds above 25 mph HEEM unit costs are more similar to operating costs recommended by Buffington and McFarland (4). The cycling cost component accounts for most of the difference in the combined costs generated from these data sources, which indicates the need for new cycling data, compiled for different highway types and traffic conditions, in order to estimate vehicle operating costs accurately.

Another problem is the limited vehicle types used in HEEM. The operating costs for all truck types are calculated on the basis of one truck type, assumed to be the multi-unit type. Difference in the operating costs of single-unit trucks and multi-unit trucks is considerable, especially at lower speeds. This becomes pertinent in calculating bus operating costs for HOV projects. One solution would be to use a weighted average of operating costs based on the distribution of trucks. However, the assumption of one set of weighted average unit costs for statewide use will yield vehicle operating cost estimates of varying accuracy. A superior method would be to revise HEEM to handle more vehicle types. The accuracy of the user cost calculations would improve and it would give the flexibility of handling unusual vehicle distributions, which is typically the case in HOV projects.

ALLOCATION OF CORRIDOR TRAFFIC

One of the most critical factors in HOV projects is the vehicle use of the restricted lanes. HEEM uses as an input the projected corridor ADT for a pro-

Table 4. Value of time as a function of time saved and trip type.

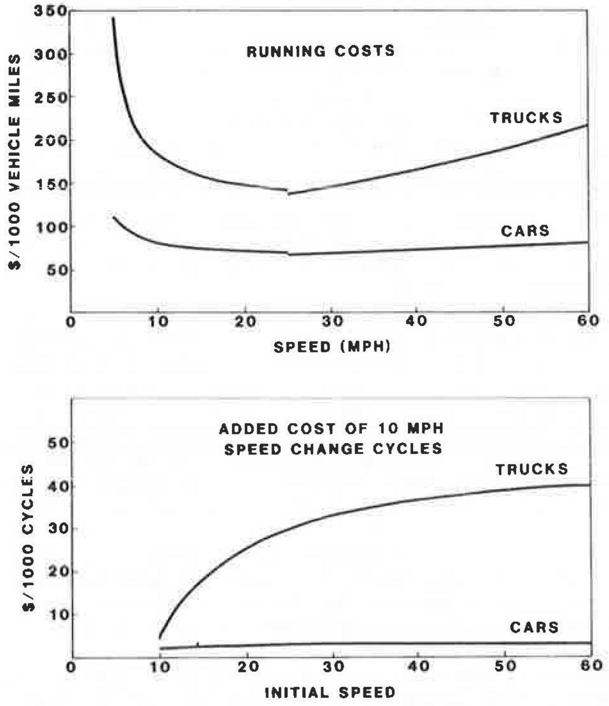
Time Saved	Trip Type	Value of Time per Traveler Hour ($)^a	Percentage of Average Hourly Family Income^b
Low time savings, 0-5 min	Work	0.47	6.3
	Personal business	0.01	0.1
	Social-recreational	0.05	0.7
	Weighted avg	0.18^c	2.4
Medium time savings, 5-15 min	Work	2.42	32.5
	Personal business	1.12	15.0
	Social-recreational	0.87	11.7
	Weighted avg	1.47^c	19.7
High time savings, 15-20 min	Work	4.06	54.5
	Personal business	4.31	57.9
	Social-recreational	2.24	30.1
	Weighted avg	3.54^c	47.5

[a] Original values in Thomas and Thompson report (15) are updated to 1975 values by using the U.S. consumer price index.

[b] Based on 2080 working hours/year for the $15 500 average income of the $14 000-$17 000 range or $7.45/h. Use these percentages to adjust value of time factors proportionately when average family incomes are located outside the $14 000-$17 000 range.

[c] Arrived at by weighting individual values of time by trip purpose by following percentage of trip distribution (17): work trips = 36.7 percent, personal business trips = 40.8 percent, and social-recreational trips = 22.5 percent.

Figure 1. Vehicle operating cost-speed relation by vehicle type used in HEEM.



1975 PRICES

jected year and then calculates the projected ADT for each year up to the projected year by using either a constant growth rate or declining growth rate formula (19). The corridor traffic for each year is then allocated to the existing route, alternate route (if specified), and any excess is diverted to an unspecified circuitous route. The same allocation process is then repeated for the proposed route, the existing route (if it is not built over), an alternate route (if specified), and any excess is again diverted.

HEEM uses a very simple method to allocate corridor traffic--the route that has the highest ADT capacity receives all the traffic up to its congestion point or breakpoint, as it is referred to in the guide to HEEM (1). The breakpoint varies for most routes, but is is about 50 percent of capacity ADT on city streets and about 75 percent on rural streets. For rural divided highways and freeways the percentage is about 60 percent, compared with about 65 percent for urban expressways and freeways.

After the breakpoint for the highest capacity route is reached, all unallocated corridor traffic is then allocated to the next highest capacity route up to its breakpoint. This process continues until all routes being examined in the corridor have been allocated traffic up to the breakpoint. Traffic is then allocated to the highest capacity route up to its capacity, and the process continues in the same order as before until all routes have been allocated traffic to their capacities. Any additional unallocated traffic is then placed on the diverted route, which is severely penalized with an extremely low diversion speed of 15 mph in urban areas and 25 mph in rural areas.

It would be unlikely that this method would approximate actual traffic allocation. It would be especially unrealistic for HOV projects where the typical experience has been underuse of the HOV lanes compared with the unrestricted lanes (8).

The problem is how to allocate corridor traffic to approximate actual allocation within the limitations of HEEM's input data. Several sophisticated traffic demand models can be used to predict the traffic allocation given a projected corridor traffic, but the data requirements to calibrate the models are too large and expensive to be used regularly in evaluating highway projects and are certainly outside the capability of HEEM.

Another approach to the traffic allocation problem is to examine user costs. A basic axiom of microeconomic theory is that individuals seek to maximize utility. In reference to the use of transportation facilities in general, that would be equivalent to minimizing user costs. Most traffic demand models seek to minimize time or distance, but they are just components of user costs. In general, each motorist will choose the route and mode of travel that will minimize the perceived or expected individual user costs.

The problem is in accurately specifying the cost functions for each potential motorist in the corridor, which is clearly impossible. However, HEEM does provide average user cost functions that could be useful in approximating traffic allocation if the distribution of individual cost functions are fairly normally distributed. The reason for this is that persons on either end of the distribution will tend to be insensitive to changes in the average user costs for alternative routes. The allocation will be determined at the margin by motorists who are indifferent as to which route to choose, and, if those motorists are near the mean of the distribution, then an average cost function may approximate the allocation process.

Total user cost of corridor traffic is defined as the sum of user costs for each route in the corridor,

$$TC = \sum_{i=1}^{n} C_i(y_i) \qquad (1)$$

where

TC = total corridor user cost;
C_i = total user cost for route i for a given ADT, y_i;
y_i = average daily traffic volume along route i; and
n = number of routes in the corridor.

Total corridor traffic equals the sum of the traffic for each route; therefore,

$$T = \sum_{i=1}^{n} y_i \qquad (2)$$

Forming the Lagrangean,

$$L = \sum_{i=1}^{n} C_i(y_i) + \lambda\left(T - \sum_{i=1}^{n} y_i\right) \qquad (3)$$

where λ is the Lagrangean multiplier.

Then, if we minimize L with respect to each of the y_i and eliminate the λ,

$$C_i'(y_i) = C_j'(y_j) \quad \text{for all } i \neq j \qquad (4)$$

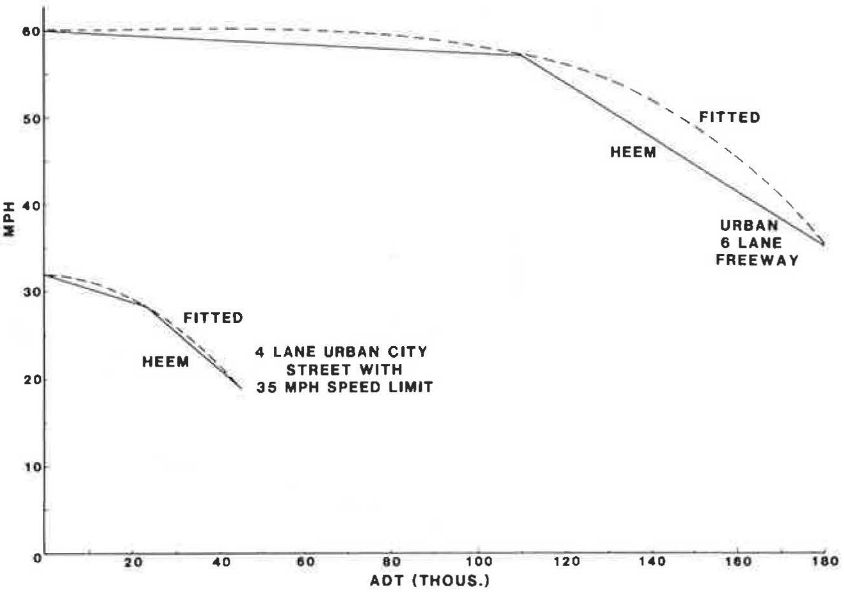
where $C_i'(y_i)$ is the marginal cost for i.

In order to minimize total user cost, the marginal cost for each route must be equal. For a given corridor traffic volume, an equilibrium will occur where the marginal motorist is indifferent as to which route in the corridor to take.

HEEM's user cost equations are not all smooth, continuous functions. Therefore, approximations are required in order to adapt this allocation technique to HEEM.

The speed-volume relation in HEEM is estimated with two straight lines, one running from the ini-

Figure 2. Approximation of speed-volume relation.



tial speed at 0 ADT to the breakpoint. The second line runs from the breakpoint to the point where the facility reaches capacity. The following function provides a good approximation to the relation,

$$f(y) = C - e^{a}y^{b} \qquad (5)$$

where

y = ADT,
f(y) = speed (mph) for a given traffic volume y,
b = [ln(C - E) - ln(C - D)]/(lnA - lnB),
a = ln(C - E) - blnA,
A = capacity ADT,
B = breakpoint ADT,
C = beginning speed (mph),
D = breakpoint speed (mph), and
E = capacity speed (mph).

Figure 2 compares the approximation by using Equation 5 with HEEM's speed-volume relation for two representative highway types.

As shown in Figure 1, the running costs are discontinuous at 25 mph. These equations can be approximated closely by using the following formulas, which are in terms of dollars per 1000 vehicle miles in January 1975 prices,

$$R_c = 194.3964 + 3.4337f(y) - 0.01926f(y)^2 - 61.7585\ln f(y) \qquad (6a)$$

$$R_t = 413.2859 + 4.31590kf(y) + 0.00947[kf(y)]^2 - 119.7313\ln[kf(y)] \qquad (6b)$$

where

R_c = automobile running costs,
R_t = truck running costs, and
k = avg speed of trucks/avg speed of cars, for a given traffic volume y.

Yearly running costs (RN) are

$$RN = (365 \cdot L \cdot y/1000)\ [(1 - r)R_c + rR_t] \qquad (7)$$

where r is the percentage of trucks and L is the length in miles of route.

The cycling costs per 1000 cycles in January 1975 prices (depicted in Figure 1) are calculated by using the following formulas:

$$CY_c = 3.9499 - [13.8413/f(y)] \text{ cars} \qquad (8a)$$

$$CY_t = 47.2458 - [428.198/kf(y)] \text{ trucks} \qquad (8b)$$

The number of cycles per vehicle mile is given as,

$$NCY = [F + G(y)]/tpf \cdot N \qquad (9)$$

where

tpf = technical performance factor used to adjust speed and cycling costs for abnormal conditions ($0 < tpf \leq 1$),
N = number of lanes,
F = 0.238 997 G = 0.000 183 for freeways and divided highways,
F = 5.1959 G = 0.000 190 for four-lane undivided highways, and
F = 2.2732 G = 0.000 355 for two-lane undivided highways.

For metered freeways, the number of cycles is assumed to stop rising at 3.1 cycles/vehicle mile, so the number or cycles for metered freeways can be approximated with

$$NCY_m = (F + cy + dy^3)/tpf \cdot N \qquad (10)$$

where

$$d = G^3/[(3.1N - F)^2 - 3A^2G^2] \qquad (11)$$

and

$$c = -3A^2d \qquad (12)$$

The yearly cycling costs (TCY) are then calculated,

$$TCY = (365 \cdot L \cdot y/1000)(NCY)\ [(1 - r)CY_c + rCY_t] \qquad (13)$$

The total operating costs (TOC) are the sum of the running costs and the cycling costs,

$$TOC = RN + TCY \qquad (14)$$

Time costs (VT) are calculated as,

$$VT = [21\,900 \cdot L \cdot y/f(y)]\ [(1 - r)(OC_c)(T_c) + (r/k)(OC_t)(T_t)] \qquad (15)$$

where

OC_c = car occupancy rate,

Figure 3. Comparison of total vehicle user cost functions.

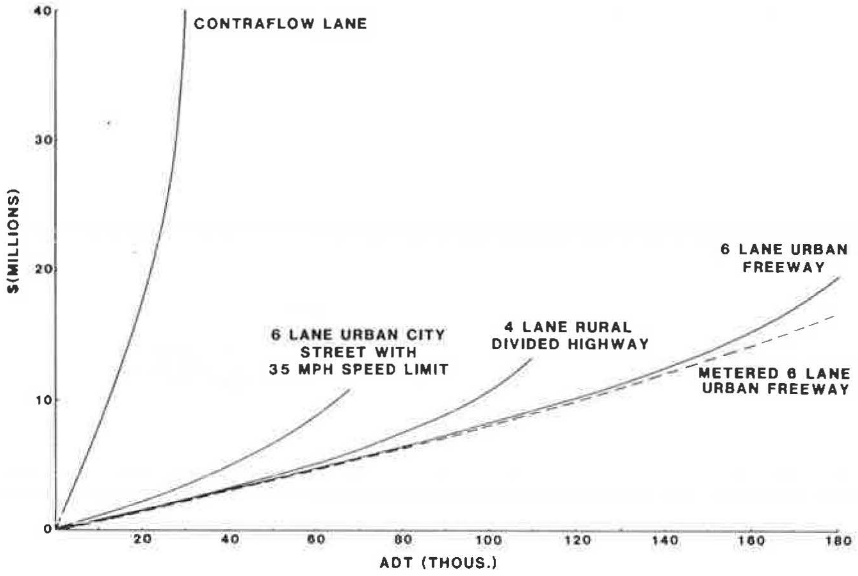
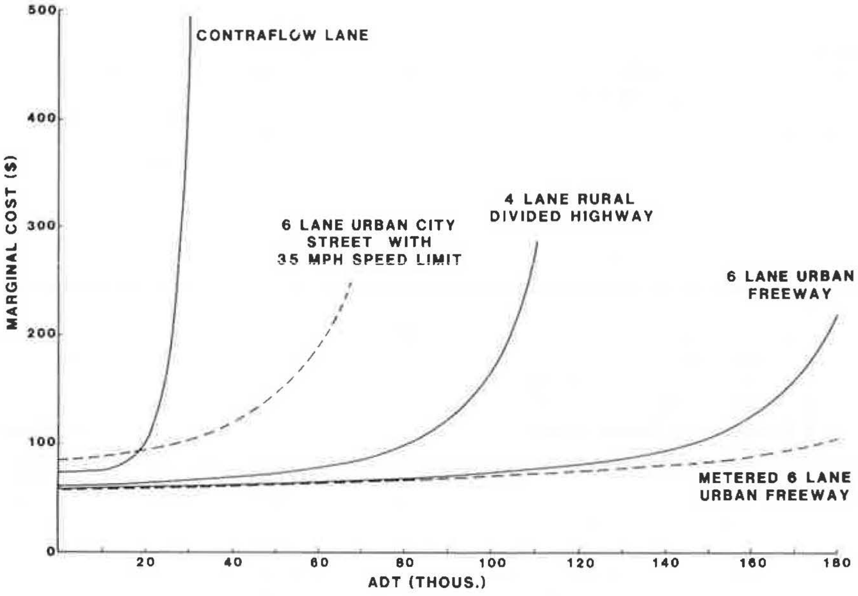


Figure 4. Comparison of marginal user cost functions.



OC_t = truck occupancy rate,
T_c = car value of time per person ($/min), and
T_t = truck value of time per person ($/min).

Accident costs (AC) are one given as,

$$AC = [365 \cdot L \cdot y \cdot H/(10^6) \cdot sf]\ [I + (Jy/1000)] \qquad (16)$$

where

H = mean cost per accident,
I = intercept term for accident rate per million vehicle miles,
J = slope term for accident rate per million vehicle miles as a function of ADT (thousands), and
sf = safety factor used to adjust accident rate for abnormal conditions, such as shoulder and lane width.

Total user costs (TC) are the sum of operating costs, time costs, and accident costs,

$$TC = TOC + VT + AC \qquad (17)$$

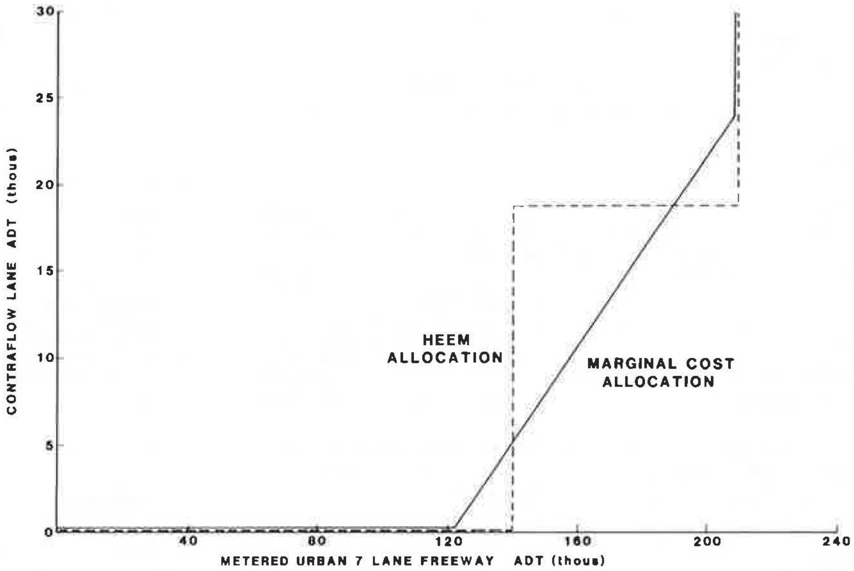
The shape of some representative total user cost functions is depicted in Figure 3. These curves are based on the 1975 default values for HEEM and the user cost functions presented above.

The marginal cost functions per person (MC) can be obtained by taking the derivitive of the total cost functions (Equation 17) with respect to the ADT volume and dividing by the weighted occupancy rate.

$$MC = (dTC/dy) \cdot \{1/[(1 - r)\,OC_c + rOC_t]\} \qquad (18)$$

The marginal cost functions are sufficiently complex that an analytical solution is generally not possible; however, a solution can be obtained through iteration techniques, which can easily be performed in a computer program such as HEEM. Memmott and Buffington (10) give the marginal cost functions for the total cost functions, presented above, as well as a method for programming the allocation process by using marginal user cost functions. Figure 4 presents the marginal cost functions for the total

Figure 5. Comparison of HEEM allocation method with marginal cost-allocation method for a contraflow lane.



cost functions in Figure 3.

The marginal cost-allocation method is an equilibrium model, where the marginal costs for the last motorist on each highway in the corridor are equal. This would involve selection of the level of marginal cost such that ADTs for each highway in the corridor sum to the corridor ADT.

Figure 5 gives an example of the marginal cost allocation compared with the current HEEM allocation method. In this example traffic must be allocated between only two highways, a contraflow lane and a metered urban freeway. HEEM first would allocate all traffic to the metered freeway up to 140 000 ADT, then all additional traffic would be allocated to the contraflow lane up to 18 750 ADT, and this would continue until both reach their capacity.

The marginal cost allocation gives a much more uniform allocation, with the contraflow lane not being used until traffic on the metered freeway reaches about 120 000 ADT, then traffic allocates proportionately between the contraflow lane and the other freeway lanes until the unrestricted lanes reach capacity. This allocation would be much closer to what would be expected in actual application.

Another important aspect of the marginal cost-allocation method is that its usefulness extends beyond the evaluation of HOV lanes. It could be used in a great variety of highway projects where future traffic volumes must be allocated between two or more highway facilities. If relevant user costs are specified correctly, then this method should provide a reasonably good approximation of corridor allocation. It is certainly superior to using only travel time as the relevant variable, which is the method used in most other models, such as the Federal Highway Administration's highway investment analysis package (HIAP) (20).

CONCLUSION

Several modifications should be undertaken in order to modify HEEM to analyze HOV projects, including the following:

1. In the absence of a specific project estimate, the percentage of trucks default value should vary for relevant highway characteristics rather than by using one statewide average;
2. A variable occupancy rate for each corridor route should be added to the input data;
3. The number of vehicle types should be increased to improve the accuracy of the estimates for time savings and vehicle operating costs;
4. The value of time parameter should vary to account for trip time savings, family income, and trip purpose;
5. Vehicle operating costs should be updated to reflect actual expenses more accurately; and
6. The marginal cost-allocation method should be used to allocate corridor traffic volume.

The use of marginal user cost functions to allocate traffic has the potential to give a reasonably accurate estimate of future demand for a highway facility. Of course this method is sensitive to the specifications of the cost functions and the assumed values of the parameters, but it does not require the amount of data other methods require. The calculations are relatively simple and derived from minimizing user costs.

The marginal cost-allocation method is especially valuable in, but not limited to, evaluating HOV projects because the use of the facility is of critical importance. This method, along with other changes recommended for HEEM in this paper, should give government agencies a fairly reliable economic model to use in evaluating HOV and other highway projects.

Several other areas of the current HEEM model could possibly be improved, but these are outside the scope of the paper. These other areas are covered in detail by Buffington and others (6). However, HEEM provides a solid framework to use in looking at the desirability of a particular highway project and, as improvements are made over time, it should provide a reliable systematic method for evaluating not only conventional highway construction projects but also the increasingly important HOV projects and related methods to increase the efficiency of transportation facilities.

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Impact of Highway Improvements on Property Values in Washington State

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The purpose of the study is to examine the effects of major highways on the value of surrounding properties. The study applied several tested theoretical techniques to a data base derived from 9359 sales records and interviews with owners of homes and businesses. In each of five study areas, hedonic pricing techniques, with all variables kept constant except those under examination, produced a quality-adjusted price index. This index for the years during which a highway was opened was then compared with an index for a comparable area not affected by highway change. Owners' perceptions concerning highway impacts, gained from 383 interviews, were also analyzed. Improved access to residential areas provided by highway construction resulted in property appreciation 15-17 percent greater than comparable properties that lacked such access advantage. Even where highest noise level readings occurred, accessibility-induced property appreciation more than offset noise-induced depreciation. Highway noise had little effect on commercial, industrial, or residential properties greater than 600 ft from the highway. Extensive care ensured accuracy and data reliability. For example, each property sale was investigated to exclude any invalid transactions or sales where extensive improvements might influence appreciation. Validity to the 95 percent confidence level was the norm for hedonic regressions and related statistical computations. The results provide an accurate, reliable method for predicting the potential access benefits and noise costs in terms of relative changes in property value. This evidence will provide facts for detailed discussion during project planning.

The purpose of this study is to measure the effects of limited-access highways on property values. Transportation improvements of all kinds are being evaluated more carefully than ever during the planning stages. This attention to detail is well justified because the implications of such projects transcend the engineering disciplines and have environmental, social, and economic effects of major importance. In the economic area, one of the im-