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16. Abstract

Various freeway surveillance and traffic control projects can be implemented on Texas freeways to accomplish desired goals. In order to decide which project (if any) that should be implemented, a practical and reliable analytical procedure which considers all measurable impacts must be developed and applied. Also, accurate and up-to-date data must be available for use in such a determination. The data contained in this report should partially meet the above needs.

This report contains highway user costs that are based on 1975 conditions in the urban areas of Texas. The unit costs reported here are vehicle running cost, travel time costs, and accident costs. Also, data on air and noise pollution, as well as other highway impact data, are included in this report.

The report contains an analysis of the impact of the energy shortage on the relative costs that are used in the conventional benefit-cost or cost-effectiveness analyses.

Finally, the report contains a recommended analytical procedure that uses the benefit-cost or cost-effectiveness approach to determine whether a project is economically feasible or cost-effective. Also, the procedure can be used to select from among alternative projects the one that fulfills a particular goal or set of goals.

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BENEFIT-COST ANALYSIS: UPDATED UNIT COSTS AND PROCEDURES

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Design and Evaluation of Freeway Surveillance
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ABSTRACT

Various freeway surveillance and traffic control projects can be implemented on Texas freeways to accomplish desired goals. In order to decide which project (if any) that should be implemented, a practical and reliable analytical procedure which considers all measurable impacts must be developed and applied. Also, accurate and up-to-date data must be available for use in such a determination. The data contained in this report should partially meet the above needs.

This report contains highway user costs that are based on 1975 conditions in the urban areas of Texas. The unit costs reported here are vehicle running cost, travel time costs, and accident costs. Also, data on air and noise pollution, as well as other highway impact data, are included in this report.

The report contains an analysis of the impact of the energy shortage on the relative costs that are used in the conventional benefit-cost or cost-effectiveness analyses.

Finally, the report contains a recommended analytical procedure that uses the benefit-cost or cost-effectiveness approach to determine whether a project is economically feasible or cost-effective. Also, the procedure can be used to select from among alternative projects the one that fulfills a particular goal or set of goals.

Key Words: Benefit-cost, Cost-Effectiveness Analysis, Unit Costs, Freeway Surveillance, Traffic Control Projects.

SUMMARY AND CONCLUSIONS

This report presents the results of a study to develop a benefit-cost analysis that considers current conditions in Texas. The major areas of inquiry documented in this report are as follows: (1) development of current highway user costs, (2) determination of impact of the energy shortage on the benefit-cost analysis, (3) development of an analytical procedure for evaluating freeway surveillance and traffic control systems, and (4) the application of a recommended procedure.

The updated highway user costs, shown in this report, are based on the most accurate and applicable unit costs reported in the literature. Furthermore, these costs reflect user costs existing in Texas during early 1975. Also, to the extent possible, vehicle running costs are presented that reflecting various levels of service that might exist on Texas freeways. Other user costs are applicable to city streets and thoroughfares. Therefore, the use of these unit costs in benefit-cost analyses should yield answers that are applicable to urban conditions in Texas.

The inquiry into the impact of the energy shortage on highway user costs and benefits concludes that the benefit-cost procedure is still a practical way of assessing the desirability of highway projects or selecting the most economically feasible or cost-effective highway improvement project. The results indicate there has been a change in the relationship between real income (value of time) and real vehicle running costs, caused primarily by the fuel shortage. Assuming that the new relationship continues for the long term, there seems to be little need of arbitrarily discounting the value of time in benefit-cost analyses. The literature reveals no procedure

which derives a factor that can be used in discounting the value of time saved in relation to other user cost savings.

The recommended analytical procedure is based on the benefit-cost or cost-effectiveness approach. The procedure considers user and non-user benefits and costs of a highway project, using data for a base year and one or more relevant years after project implementation. The procedure provides for the consideration of benefits and costs that are not measurable in dollars. Included in this report are data which will aid in the measurement of effects of air and noise pollution generated by the highway user and also the effects of traffic generation characteristics on land use activities.

By comparing annualized dollar benefits and costs, discounted to present value, the economic feasibility of a project can be partially determined with the above procedure. If the cost-effectiveness approach is used, the benefits and costs can be considered in other measurable quantities in addition to dollars. The full economic feasibility of a project required due weight be given to all measurable benefits and costs attributable to it. Various rating or weighting schemes can be employed with the resulting benefit-cost ratio to arrive at a decision regarding whether or not to implement the project.

The above procedure is useful in selecting the most economically feasible or cost-effective project from among several alternative projects which could accomplish one or more goals. At least, the elimination of those projects that are not economically feasible or cost-effective will be indicated by the above procedure. Then, with the help of a value matrix, the project that best meets a particular goal or set of goals can be selected. The value matrix technique can be used to consider a mixture of subjective measures and values in a systematic manner using mathematical techniques.

In conclusion, it is recommended that the above procedure be implemented in selected situations to further define data requirements and limitations so that alterations and refinements can be made.

IMPLEMENTATION STATEMENT

The findings presented in this report can be implemented immediately to determine the economic feasibility or cost-effectiveness of a particular freeway surveillance or control project or to determine which of several alternative projects will best achieve a desired goal or set of goals. The updated user costs are applicable to conditions in the urban areas of Texas.

It is suggested that the procedure be implemented in several situations to better determine its data requirements and limitations. By so doing, alterations and refinements can be made prior to general implementation of the procedure.

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INTRODUCTION

One of the objectives of Research Study 2-18-75-202 entitled, "Design and Evaluation of Freeway Surveillance and Traffic Control Systems" is to develop a benefit-cost analysis that considers current conditions in Texas, such as present prices of fuel and the priorities set by the federal government to reduce fuel consumption and air and noise pollution attributable to public and private transportation. In order to accomplish this objective, it is necessary to update the appropriate unit costs, analyze the impact of energy shortages, and develop a candidate analytical procedure. The results of these major areas of inquiry are documented in separate sections of this report.

Benefit-cost analysis is employed by decisionmakers to assess the advisability of committing resources to a particular project or activity. In this study such an analysis is applied to evaluate freeway surveillance and traffic control systems. In short, the benefit-cost analysis requires that all annual dollar benefits and costs attributable to a proposed project be determined. A benefit-cost ratio is calculated by dividing the annual dollar benefits by the annual dollar costs.

Benefit-cost analysis is seldom a comprehensive economic analysis because it usually includes only the benefits and costs that can be stated in dollar terms. In the case of highway projects or improvements, the annual dollar benefits are limited to those attributable to highway users, such as reductions in travel time costs, vehicle running costs, and accident costs. The sum of these annual dollar benefits is compared to the sum of the annual dollar costs (annualized initial project costs plus annual recurring costs). A specified project life (years), net salvage value, and interest rate must be used to obtain the present value of the annualized costs.

Due to the difficulty of placing dollar values on certain effects of a project, the costs of these effects are not considered in arriving at a benefit-cost ratio for a given highway project. Project effects that are difficult to measure in dollars include comfort of highway users, land use changes associated with the project, aesthetic and other environmental effects, and other social-economic effects, on the community. Therefore, only a partial benefit-cost ratio is obtained.

When all the benefits accruing to a project cannot be measured in dollar terms but can be measured by other units, cost-effectiveness analysis is often used in lieu of a benefit-cost analysis. In cost-effectiveness analysis, the derived benefits are measures of effectiveness for a given project. One of two cost-effectiveness criteria can be used: (1) the equal-cost criterion which compares alternatives with equal costs, or (2) the equal effectiveness criterion which compares costs of alternatives having equal effectiveness. When several alternatives need to be considered, no two alternatives are likely to have exactly the same cost or produce the same effectiveness. Therefore, the decisionmaker must decide how much extra cost he is willing to incur in order to obtain the additional benefits. Also, when the equal cost criterion is used and there are several measures of effectiveness, no single alternative may be the best for all measures of effectiveness, and judgement must be used to select an alternative.

Both benefit-cost analysis and cost-effectiveness analysis have limiations that must be considered. In addition, price controls and other non-market factors may distort the results of these analyses. Consideration of such factors in the analysis are discussed in greater detail throughout this report.

CURRENT HIGHWAY USER COSTS

One of the tasks of this study is to update basic highway user unit costs, i.e., value of travel time, vehicle running costs, and vehicle accident costs. By updating these unit costs, benefit-cost analyses can be based on cost data expressed in current dollars that take into account differential price changes, general inflation and changes in productivity. All costs and benefits should be based on a particular base year (1). Therefore the basic costs (2,3,4,5,6,7 and 8) used in this study are updated to reflect 1975 prices in Texas. Also, where possible, the user costs are presented for six types of vehicles as described in Table 1. Finally, the user costs presented here are applicable to freeways and streets in urban areas.

Value of Travel Time

No relevant estimates of the value of travel time have been made since those by Lisco (4) and Haney and Thomas (5) for passenger cars and by Adkins, Ward, and McFarland (6) for commercial trucks and buses. Given the lack of recent estimates, the original estimates of the value of time made by the above authors were updated. Table 2 gives the original and updated values of time by vehicle type. The updated values represent a 57 percent increase in the original values as indicated by changes in the per capita gross income of Texans and the average hourly income of production workers in Texas.

Table 3 indicates the travel time costs by vehicle type and average running speed, based on the updated values shown in Table 2. For Vehicle

Table 1

Vehicle Type Descriptions, by Vehicle Type Number

Vehicle Type Number	Vehicle Type Description
1	Passenger cars
2	Single-unit trucks, 2-axle, 4-tire
3	Single-unit trucks other than 2-axle, 4-tire
4	Truck semitrailer combinations, 4 or less axles
5	All other truck and semitrailer or trailer combinations, 5 or more axles
6	Buses

Table 2

Updated Value of Time, by Vehicle Type

Vehicle Type Number	Value of Time		
	Original[a]	Updated[b]	Updated[b]
	(Dollars per Vehicle Hour)		
	Driver Only		With Passengers
1	2.70	4.24	5.51[c]
2	4.28	6.72	6.72
3	5.11	8.02	8.02
4	6.37	10.00	10.00
5	7.07	11.10	11.10
6	7.43	11.67	54.07[d]

[a]Original values for Type 1 vehicles are based on the T. E. Lisco study (4) and the D. G. Haney and T. Thomas study (5), and original values for Types 2, 3, 4, 5, and 6 are based on the W. G. Adkins, A. W. Ward, and W. F. McFarland study (6).

[b]Updated values are based on a 57 percent increase from the base year to early 1975 as indicated by U.S. Bureau Census of Population data on per capita gross income changes for Texas and by U.S. Bureau of Labor Statistics data on the average hourly income for production workers in Texas.

[c]Assuming 1.3 persons per vehicle at $4.24 per person.

[d]Assuming 10 passengers per vehicle hour at $4.24 per passenger plus $11.67 for driver and bus.

Table 3

Travel Time Costs, by Vehicle Type and Average Running Speed

Average Running Speed	Vehicle Type[a]					
	1[b]	2	3	4	5	6[c]
Miles Per Hour[d]	----------Cents Per Vehicle Mile[e]----------------					
5	110.20	134.40	160.40	200.00	222.00	1081.40
10	55.10	67.20	80.20	100.00	111.00	540.70
15	33.73	44.80	53.47	66.67	74.00	360.47
20	27.55	33.60	40.10	50.00	55.50	270.35
25	22.04	26.88	32.08	40.00	44.40	216.28
30	18.37	22.40	26.73	33.33	37.00	180.23
35	15.74	19.20	22.91	28.57	31.71	154.49
40	13.78	16.80	20.05	25.00	27.75	135.18
45	12.24	14.93	17.82	22.22	24.67	120.16
50	11.02	13.44	16.04	20.00	22.20	108.14
55	10.12	12.22	14.58	18.18	20.18	98.31
60	9.18	11.20	13.37	16.67	18.50	90.12
65	8.48	10.34	12.34	15.38	17.08	83.18
70	7.87	9.60	11.46	14.29	15.86	77.24

[a]Based on updated values shown in Table 2.

[b]Based on $4.24 per vehicle hour multiplied by 1.3 persons per vehicle to give a total of $5.51 per vehicle hour.

[c]Based on $54.07 per vehicle hour, which adds $4.24 per passenger for 10 passengers to the updated value of $11.67 per vehicle hour.

[d]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[e]To convert cents per mile into cents per kilometer, multiply by .6214.

Types 1 and 6, the values are based on an assumed number of persons (passengers) per vehicle. Passenger cars (Type 1) are to carry 1.3 persons. Commercial buses (Type 6) are assumed to carry 10 passengers which are given a Vehicle Type 1 value of time.

Vehicle Running Costs

No recent vehicle running cost studies are sufficiently comprehensive to replace the earlier studies made by AASHO (2) and Winfrey (7). Consequently, the factors used for updating the vehicle running costs are based on the difference between individual unit prices or costs given by Winfrey in 1962 and those prevailing in Bryan-College Station, Texas in early 1975. The updating factors are given in Table 4 for three typical vehicle types. In the case of maintenance and repair costs, the updating factors are based on a four-door sedan driven an assumed life span of 10 years and a distance of 100,000 miles, as developed from 1960 and 1974 data published by the FHWA (9). In the absence of reliable maintenance and repair cost data on trucks, the same updating factor used for passenger cars is used for trucks.

To keep the updating procedure simple but reasonably accurate, a weighted average cost factor was developed for each of the three typical vehicle types, as shown in Table 4. Since a higher portion of a vehicle's total running cost is required to buy fuel than to buy tires, etc., each individual unit cost factor is weighted by its proportion of the total running cost. Also, since that proportion varies to some extent with the speed of travel, the individual unit cost factors are weighted by speed of travel. For this study, the weighting is based on Winfrey's running costs for the selected uniform speeds of 5, 30, 50, and 80 miles per hour for passenger cars; 5, 30, 50, and 65 miles per hour for single-unit trucks; and 5, 30, 50, and 60 miles

Table 4

Factors Used to Update Vehicle Running Costs from 1962 to 1975, by Type of Cost and Vehicle Type[a]

Type of Cost	Vehicle Type: Passenger Car	Vehicle Type: Single-Unit Truck	Vehicle Type: 3-S2 Diesel Truck
	------------Percent Increase------------		
Individual Unit Costs			
Fuel	74	100	156
Engine Oil	62	143	143
Tires	56	56	63
Maintenance and Repairs	65[b]	65[c]	65[c]
Depreciation	42	52[d]	52
Combined Unit Costs			
Weighted Average Cost[e]	59	74	85

[a]Using Winfrey's (7) 1962 unit costs and 1975 Bryan-College Station, Texas unit costs, unless otherwise noted.

[b]Based on 4-door sedan driven an assumed life-span of 10 years and 100,000 miles from 1960 and 1974 data published by the Federal Highway Administration (9).

[c]Assumed to be same as experienced by passenger cars.

[d]Assumed to be same as experienced by 3-S2 diesel trucks, because of difficulty in selecting a single-unit truck similar to that used by Winfrey (7).

[e]Developed from Winfrey's (7) running costs tables, where the individual unit costs were applied to four uniform speeds (5,30,50, and highest miles per hour) and averaged for each vehicle type.

per hour for 3-S2 trucks (3-axle truck-tractor pulling a 2-axle simi-trailer.)

Due to similarities in vehicle characteristics, the updated running costs for Vehicle Types 1 and 2 are based on the weighted average cost increase for passenger cars, as shown in Table 4. The updated costs for Vehicle Types 3 and 6 are based on the weighted average cost increase for single-unit trucks. The updated costs for Vehicle Types 4 and 5 are based on the weighted average cost increase for 3-S2 trucks.

The updated running costs for each vehicle type used on freeways by level of service and average running speed are shown in Tables 5 through 9. These costs replace those reported by McCasland (10), which were developed from basic cost data published by AASHO (2) and Winfrey (7). The running costs reported by McCasland reflect a 25 percent increase in Winfrey's values to account for speed distributions, non-alerted drivers, and non-tuned vehicles as is done in the AASHO study.

The updated running costs for vehicles using city streets by vehicle type and uniform speed are shown in Table 10. Also, the updated excess running costs due to speed cycle changes on city streets by vehicle type, initial speed, and speed reduced to and returned from are shown in Tables 11 through 15. These costs, too, replace those reported by McCasland. Finally, updated idling costs by type of vehicle are shown in Table 16.

Table 5

Running Costs for Vehicle Type 1 on Freeways, by Level of Service and Running Speed[a]

Average Running Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	----------Cents per Vehicle Mile[c]--------					
5						27.10
10						15.38
15						11.62
20						9.87
25						8.84
30					6.25	8.33
35				6.26	6.30	
40			6.38	6.44		
45		6.39	6.30	6.71		
50	6.38	6.61	6.87	7.08		
55	6.60	6.90	7.23			
60	6.93	7.27				
65	7.38					
70	7.95					

[a]Update of costs in Table 6.8 of McCasland Study (10) using the weighted average cost increase for passenger cars shown in Table 4.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by .6214.

Table 6

Running Costs for Vehicle Type 2 on Freeways, by Level of Service and Running Speed[a]

Average Running Speed	Level of Service					
	A	B	C	D	E	F
Miles Per Hour[b]	Cents Per Vehicle Mile[c]					
5						39.29
10						20.42
15						14.85
20						12.15
25					6.96	10.89
30					7.06	9.94
35				7.04	7.19	
40			7.20	7.28		
45		7.31	7.55	7.68		
50	7.43	7.71	8.00	8.25		
55	7.85	8.22	8.63			
60	8.52	8.95				
65	9.51					
70	10.80					

[a]Update of costs in Table 6.9 of McCasland Study (10) using the weighted average cost increase for passenger cars shown in Table 4.

[b]To convert from miles per hour to kilometer per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by .6214.

Table 7

Running Costs for Vehicle Types 3 and 6, on Freeways, by Level of Service and Running Speed[a]

Average Running Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	Cents Per Vehicle Mile[c]					
5						64.05
10						34.94
15						24.88
20						20.51
25						18.50
30					12.62	17.47
35				13.24	13.00	
40			13.71	13.89		
45		14.08	14.53	14.82		
50	14.37	14.91	15.50	15.99		
55	15.29	15.99	16.77			
60	16.43	17.17				
65	17.77					
70	19.31[d]					

[a]Update of costs in Table 6.10 of McCasland Study (10) using the weighted average cost increase for single-unit trucks shown in Table 4.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometers, multiply by .6214.

[d]Estimated.

Table 8

Running Costs for Vehicle Type 4 on Freeways, by Level of Service and Running Speed[a]

Average Running Speed	Level of Service A	B	C	D	E	F
Miles Per Hour[b]	Cents Per Vehicle Mile[c]					
5						206.40
10						96.85
15						61.36
20						46.66
25						39.61
30					21.37	34.39
35				21.59	21.53	
40			22.31	22.72		
45		23.20	24.11	24.68		
50	24.16	25.23	26.40	27.38		
55	26.64	28.10	29.73			
60	30.06	31.71				
65	34.41[d]					
70	39.68[d]					

[a]Update of costs in Table 6.11 of McCasland Study (10) using the weighted average cost increase for 3-S2 trucks shown in Table 4.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by .6214.

[d]Estimated.

Table 9

Running Costs for Vehicle Type 5 on Freeways, by Level of Service and Running Speed[a]

Average Running Speed	Level of Service A	B	C	D	E	F
Mile Per Hour[b]	-----------Cents Per Vehicle Mile[c]---------------					
5						195.27
10						81.73
15						52.74
20						40.50
25					19.37	35.45
30					19.87	31.56
35				20.07	21.00	
40			20.92	21.48		
45		22.07	22.92	23.59		
50	22.94	24.01	25.22	26.20		
55	25.14	26.64	28.32			
60	27.51	29.01				
65	30.10[d]					
70	32.87[d]					

[a]Update of costs in Table 6.12 of McCasland Report (10) using the weighted average cost increase for 3-S2 trucks shown in Table 4.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[c]To convert from cents per mile to cents per kilometer, multiply by .6214.

[d]Estimated

Table 10

Running Costs on City Streets, by Vehicle Type and Uniform Speed[a]

Uniform Speed	Vehicle Type 1	2	3[b]	4	5
Miles Per Hour[c]	Cents Per Vehicle Mile[d]				
5	11.80	12.78	21.56	53.43	38.55
10	8.94	9.84	16.90	34.37	27.81
15	7.90	8.78	15.14	27.79	23.92
20	7.38	8.22	14.34	24.77	22.16
25	7.08	7.93	14.08	23.40	21.50
30	6.93	7.82	14.16	23.01	21.52
35	6.92	7.81	14.49	23.33	22.00
40	6.96	7.92	14.98	24.18	23.09
45	7.08	8.12	15.63	25.53	24.48
50	7.27	8.44	16.44	27.45	26.27

[a]Update of costs in Table 6.15 of McCasland Report (10) using the appropriate weighted average cost increases shown in Table 4.

[b]Use these values for buses (Type 6).

[c]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

[d]To convert from cents per mile to cents per kilometer, multiply by .6214.

Table 11

Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 1, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned from (MPH)[b]				
	Stop	10	20	30	40
Miles Per Hour[b]	---------- Cents per Cycle Change ---------				
5	0.17				
10	0.37				
15	0.65	0.24			
20	0.99	0.52			
25	1.38	0.92	0.35		
30	1.86	1.38	0.80		
35	2.43	1.96	1.37	0.54	
40	3.13	2.64	2.04	1.22	
45	3.98	3.48	2.86	2.04	0.81
50	4.99	4.50	3.86	3.02	1.78

[a]Update of costs in Table 6.16 of McCasland Report (10) using weighted average cost increase for passenger cars shown in Table 4.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 12

Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 2, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned from (MPH)[b]				
	Stop	10	20	30	40
Miles Per Hour[b]	-----------Cents per Cycle Change----------				
5	0.21				
10	0.43				
15	0.73	0.27			
20	1.13	0.64			
25	1.59	1.07	0.41		
30	2.16	1.61	0.94		
35	2.85	2.27	1.56	0.60	
40	3.69	3.08	2.35	1.37	
45	4.69	4.05	3.29	2.29	0.89
50	5.90	5.23	4.42	3.39	1.97

[a]Update of costs in Table 6.17 of McCasland Report (10) using weighted average cost increase for passenger cars shown in Table 4.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 13

Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 3, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned from (MPH)[b]				
	Stop	10	20	30	40
Miles Per Hour[b]	-----------Cents per Cycle Change----------				
5	0.42				
10	1.03				
15	1.81	0.64			
20	2.73	1.50			
25	3.85	2.56	0.99		
30	5.17	3.85	2.24		
35	6.75	5.41	3.78	1.48	
40	8.68	7.31	5.62	3.31	
45	10.98	9.57	7.85	5.50	2.19
50	13.73	12.28	10.51	8.13	4.79

[a]Update of costs in Table 6.18 of McCasland Report (10) using weighted average cost increase for single-unit trucks shown in Table 4. Also, use these costs for buses (Vehicle Type 6).

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 14

Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 4, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned from (MPH)[b]				
	Stop	10	20	30	40
Miles Per Hour[b]	----------------Cents per Cycle Change----------------				
5	1.70				
10	3.66				
15	6.22	2.57			
20	9.49	6.57			
25	13.62	9.75	4.07		
30	18.72	14.73	9.01		
35	24.96	20.92	15.08	6.11	
40	32.63	28.55	22.57	13.52	
45	41.90	37.72	31.69	22.20	8.97
50	53.10	48.84	42.68	33.47	19.81

[a]Update of costs in Table 6.19 of McCasland Report (10) using weighted average cost increased for 3-S2 trucks shown in Table 4.

[b]To convert from miles per hour to kilometer per hour, multiply by 1.609344.

Table 15

Excess Running Costs of Speed Cycle Changes on City Streets for Vehicle Type 5, by Initial Speed[a]

Initial Speed	Speed Reduced to and Returned from (MPH)[b]				
	Stop	10	20	30	40
Miles Per Hour[b]	------------Cents per Cycle Change--------------				
5	2.11				
10	4.87				
15	7.97	5.03			
20	12.14	8.16			
25	17.28	12.10	4.92		
30	23.64	18.35	11.08		
35	31.47	26.05	18.70	7.64	
40	41.16	35.65	28.12	17.02	
45	53.06	47.34	39.70	28.49	11.62
50	67.60	61.72	53.87	42.46	25.49

[a]Update of costs in Table 6.19 of McCasland Report (10) using weighted average cost increase for 3-S2 trucks shown in Table 4.

[b]To convert from miles per hour to kilometers per hour, multiply by 1.609344.

Table 16

Idling Costs, by Type of Vehicle

Vehicle Type	Idling Cost[a]
	-----Cents per Hour-----
1	22.83
2	26.34
3	43.51
4	57.69
5	45.39
6	43.51

[a] Based on Winfrey's Costs (7), which were increased by 25 percent to account for non-alert drivers and non-tuned vehicles. Then these values were updated by using the appropriate factors shown in Table 4.

Accident Costs

The literature review reveals no basic accident cost data which should take the place of these reported by Burke (8) in 1969. Burke developed a method for estimating Texas accident costs utilizing direct involvement cost data from studies completed by the States of Massachusetts, Illinois, Utah, and New Mexico.

The direct involvement cost elements approximate the out-of-pocket expenses incurred by accident victims but do not include, for example, overhead costs of insurance, loss of future earnings because of death, traffic delay and congestion costs, and costs associated with accident investigation or prevention programs. Also, involvement costs reflect only the costs which are associated with a single vehicle and its occupants involved in an accident. For multi-vehicular accidents, the total accident cost is the involvement cost of the applicable type of accident (fatal, injury, or property damage) multiplied by the number vehicles involved in the accident.

The particular involvement cost data updated in this report are the same as those reported by McCasland (10), which in turn were based on Burke's study. Updated average direct costs per fatal involvement in urban areas by vehicle type and accident type are presented in Table 17. The updated costs reflect a 33 percent increase in medical care costs from 1969 to 1975 as indicated by the Consumer Price Index for Medical Care published by the U.S. Bureau of Labor Statistics. These indexes are used since a state index is not available.

Since the updated fatal involvement costs shown in Table 17 do not include the loss of future earnings for persons killed in accidents, the following updated values by sex are given:

Male	$67,348
Female	$49,617
Average	$61,984

Table 17

Direct Cost Per Fatal Involvement Per Vehicle in Urban Areas, by Vehicle Type and Accident Type[a]

Accident Type	Vehicle Type: Passenger Car[b]	Single-Unit Truck[c]	Combination Truck[d]
	---------- Dollars Per Involvement Per Vehicle		
Multi-Vehicle			
Head-on	8,068	2,038	4,628
Rear End	6,702	3,067	-
Angle	8,890	6,706	1,971
Sideswipe	9,035	487	-
Turning	4,087	1,576	3,669
Parking	-	-	-
Other	5,674	564	-
Single-Vehicle			
Pedestrian	7,814	7,375	5,126
Train	9,396	13,098	-
Bicycle	6,811	7,113	3,995
Animal	4,220	-	-
Fixed-Object	4,734	14,606	-
Other-Object	-	-	-
Non-Collision	4,886	4,187	22,440
All	7,288	6,703	5,776

[a]Update of Table 6.21 in McCasland Study (10) using a 33 percent increase in costs from 1969 to 1975 as indicated by Consumer Price Index for Medical Care published by the U.S. Bureau of Labor Statistics.

[b]Use for Vehicle Types 1 and 2.

[c]Use for Vehicle Type 3.

[d]Use for Vehicle Types 4 and 5.

The updated values reflect a 49 percent increase in the per capita gross income for Texas from 1969 to 1975, as indicated by U.S. Bureau of Census data.

The updated average direct costs per injury involvement in urban areas by vehicle type and accident type are presented in Table 18. The Consumer Price Index for Medical Care is also used to update injury involvement costs.

Updated average direct costs per property damage involvement in urban areas by vehicle type and accident type are presented in Table 19. The updated costs reflect a 48 percent increase in automobile repair and maintenance costs from 1969 to 1975, as indicated by the Consumer Price Index for Automobile Repair and Maintenance.

The above tables present accident cost data for three basic vehicle types. As in the case with vehicle running costs, the updated accident involvement costs for passenger cars are applicable to vehicle Types 1 and 2. The updated costs for single-unit trucks are applicable for vehicle Type 3, and those for combination trucks are applicable to vehicle Types 4 and 5. The latest direct costs per involvement for buses (Type 6) should be obtained directly from transit records, due to the lack of statistically reliable estimates of bus accident costs. For 1966, Smith (11) gives a value of $600 per injured person. However, this value is not based on transit riders. Updating this value by the Consumer Price Index for Medical Care gives a value of $800.

The updated accident costs presented in the section are based on reported accidents. Curry and Anderson (12) suggest that a multiplying factor of at least 2.5 should be applied to property damage costs based on reported accidents to account for unreported accidents.

Table 18

Direct Cost Per Injury Involvement Per Vehicle in Urban Areas, by Vehicle Type and Accident Type[a]

Accident Type	Vehicle Type: Passenger Car[b]	Single-Unit Truck[c]	Combination Truck[d]
	--------- Dollars Per Involvement		
Multi-Vehicle			
Head-on	1,184	1,277	7,898
Rear End	1,148	548	640
Angle	1,208	870	648
Sideswipe	588	1,028	452
Turning	988	625	2,520
Parking	657	426	884
Other	998	525	346
Single-Vehicle			
Pedestrian	1,914	1,875	1,962
Train	2,421	1,964	10,714
Bicycle	1,383	849	390
Animal	2,059	-	-
Fixed-Object	2,725	1,893	2,157
Other-Object	1,265	-	286
Non-Collision	1,584	1,347	1,684
All	1,290	891	1,504

[a]Update of Table 6.22 in McCasland study (10) using a 33 percent increase in costs from 1969 to 1975 as indicated by Consumer Price Index for Medical Care published by the U.S. Bureau of Labor Statistics.

[b]Use for Vehicle Types 1 and 2.

[c]Use for Vehicle Type 3.

[d]Use for Vehicle Types 4 and 5.

Table 19

Direct Cost Per Property Damage Involvement Per Vehicle in Urban Areas, by Vehicle Type and Accident Type[a]

Accident Type	Vehicle Type: Passenger Car[b]	Single-Unit Truck[c]	Combination Truck[d]
	--------- Dollars Per Involvement Per Vehicle		
Multi-Vehicle			
Head-On	302	265	977
Rear End	209	136	130
Angle	297	237	284
Sideswipe	188	101	70
Turning	215	147	130
Parking	95	90	24
Other	184	129	31
Single-Vehicle			
Pedestrian	47	-	-
Train	104	895	1,670
Bicycle	90	56	-
Animal	397	266	-
Fixed-Object	324	675	1,430
Other-Object	127	98	215
Non-Collision	303	688	2,443
All	222	182	306

[a]Update of Table 6.23 in McCasland Study (10) using a 48 percent increase in costs from 1969 to 1975 as indicated by Consumer Price Index for Automobile Repairs and Maintenance published by the U.S. Bureau of Labor Statistics.

[b]Use for Vehicle Types 1 and 2.

[c]Use for Vehicle Type 3.

[d]Use for Vehicle Types 4 and 5.

Finally, the updated accident costs presented here do not include vehicle insurance overhead. Again, Curry and Anderson (12) suggest that a multiplying factor of 1.4 should be applied to direct accident costs.

IMPACT OF ENERGY SHORTAGE

Another task of this study is to analyze the impact of the energy shortage on the results of benefit-cost analyses.

The recent energy shortage, created by the Arab oil embargo, produced various actions by the federal and state governments, such as speed limit reductions, fuel allocations, Sunday closings of gas stations, gasoline price controls, partial deregulation of domestic crude oil prices and import tariff on foreign crude oil. Also, the public has been asked to conserve fuel by commuting in carpools, buses, or trains in lieu of private automobiles.

Crisis situations, such as the oil embargo, require at least temporary mandatory controls or adjustments. When such controls are in effect, current market prices are not a good measure to allocate resources efficiently among alternative uses. Short-run market aberrations in supply, demand, and prices of resources must be ignored in long-run planning decisions that commit capital to highway improvement projects.

Some of the controls considered to be appropriate for short-run adjustments in the supply and demand of motor vehicle fuel are as follows:

(1) Sunday closing of gas stations

(2) Lowering speed limits

(3) Reduction in automobile trips

(4) Temporary price control, either at producer or consumer level

Lowering of the speed limit can become a long-term control device which will affect decisions committing capital to highway projects, especially in rural areas. However, the complexity of the situation makes it difficult to say how this control measure should influence the results of benefit-cost analyses. If all petroleum could be produced domestically, there probably would be less emphasis on non-market conservation devices, such as lowering of the speed limit to 55 miles per hour. Even if the 55 miles per hour speed limit becomes a long-run conservation device, it probably will not have much influence on the findings of benefit-cost analyses on urban highway projects since most urban travel is not affected by the 55 miles per hour speed limit.

Price controls can also become intermediate to long-term conservation devices. If long-term, they will have an influence on the findings of benefit-cost analyses. The price of "old" crude petroleum, which is a significant percent of all petroleum produced in this country, is set well below the current world price. The long-run outlook is that price controls of old crude and natural gas will be removed, allowing the market price to be a more realistic allocator of resources.

To the extent that the prices of fuel become permanently altered in relation to the prices of other things, long-term adjustments will be made. Long-term adjustments, such as changes in vehicle sizes, changes in type of fuel used, and location of homes and businesses will result from changes in the real prices of fuel. An examination of Figure 1 illustrates the relationship between the real price of motor fuel and the size (weight) of motor vehicles over time (generalized). As the real price of fuel declined prior to 1973, the average size of motor vehicles increased. Also, during this same period (Figure 1), real incomes increased so that people could afford to buy heavier and less fuel-efficient automobiles. In fact, the real running costs for a standard size automobile declined slightly during this period (9).

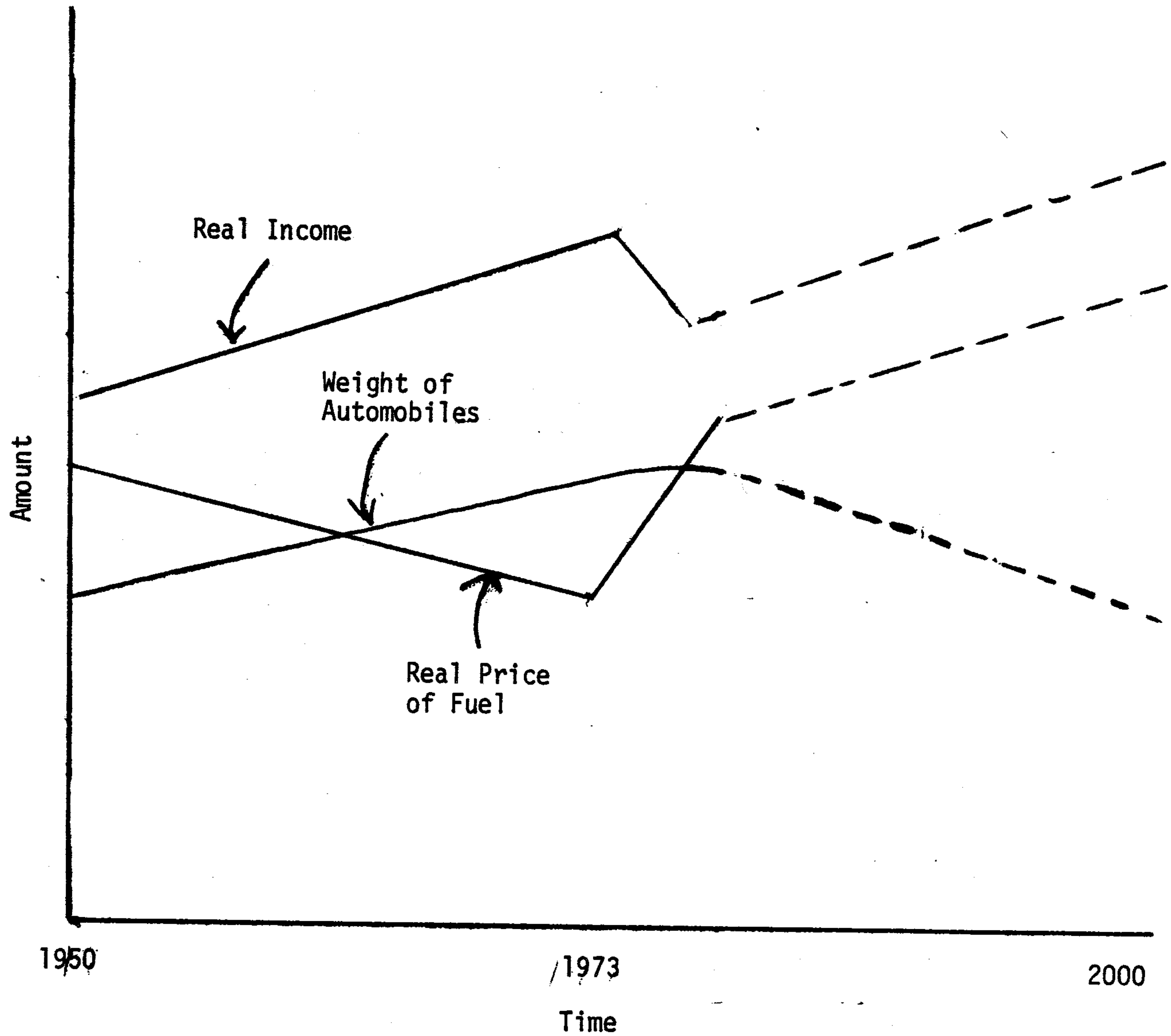

Figure 1. Trends in Real Income, Real Price of Fuel, and Weight of Automobiles Over Time. (Generalized).

Since 1973, the real price of fuel has increased considerably and is expected to continue to rise (Figure 1). Also, real income has declined. Therefore, increasing real running costs of automobiles and decreasing real incomes have led to a downward adjustment in the size of automobiles. Assuming that real fuel prices continue to rise relative to real income, long-term adjustments in vehicle characteristics and types of fuels used are expected to occur.

Benefit-cost analyses for highway decisionmaking are criticized on the grounds that the value of travel time has played too great a role in determining whether to commit capital to highway improvement projects. However, the change in the relationship between real income and real vehicle running costs, as a result of the fuel shortage, indicates that the value of time will play a lesser role than in the past in allocating resources through future benefit-cost analyses. Even before the fuel shortage, a recent series of 117 highway economy studies (chiefly for new freeways) resulted in almost all of the projects being economically attractive solely on the basis of savings in vehicle running costs before inclusion of time savings which added even more to their attractiveness (1). Assuming that the new relation ship between real income and real vehicle running costs continues for the long term, there seems to be little need to start arbitrarily discounting the value of time in benefit-cost analyses. The benefit-cost analysis is still a practical method of assessing the economic feasibility of highway projects, including freeway traffic control projects. However, prior to making the decision to commit funds to a particualr highway project, non-user costs and benefits and socio-environmental impacts must be given proper consideration.

RECOMMENDED ANALYTICAL PROCEDURE

One of the key tasks of this study is to recommend an analytical procedure that is best suited for evaluating alternative freeway surveillance and traffic control systems. This section briefly outlines the recommended procedure that uses the benefit-cost or cost-effectiveness approach. Such a procedure provides a method of considering both private and social benefits and costs, including user and non-user impacts. Not all of these impacts can be measured in dollars but can be measured to some extent in other quantifiable units.

Determination of User Benefits

User benefits are determined by estimating the reduction in the following user costs: (1) travel time costs, (2) vehicle running costs, (3) accident costs, and (4) other costs. It is conceivable that negative benefits may accrue from a proposed freeway control system. The updated costs, presented in this report are applicable here.

As indicated in the introduction of this report, the benefit-cost or cost-effectiveness approach requires that an analysis period must be selected to measure annual benefits resulting from a project. For the cost-effectiveness approach, one year before and after construction or implementation of a project is an acceptable period in which to estimate the annual reduction in user costs. For the benefit-cost approach, a base year and all relevant future years after implementation of the project should be used.

The reduction in user costs should be estimated for the peak periods of travel on the freeways or streets being evaluated, because the greatest potential for user savings occurs during these periods. There are 250 non-holiday weekdays per year, giving 250 morning and 250 afternoon peak periods per year.) Of course, reductions in user costs for off-peak periods should be estimated too.

Time and Vehicle Running Costs

The level of service concept is utilized in calculating savings in vehicle running costs on freeways. According to the 1965 Highway Capacity Manual (13), level of service is defined as a qualitative measure which denotes any one of an infinite number of differing combinations of operating conditions that may occur on a given freeway or land when it is accommodating various traffic volumes. Volume/capacity ratios generally reflect levels of service. Through use of the Highway Capacity Manual, McCasland (10) developed running costs for six levels of service at selected running speeds by vehicle type (Table 1). The updated values are given in (Tables 5-9). To calculate the average running speed for each freeway condition (level of service) the operating speed (OS) is calculated using the average highway speed (AHS) in the following formula:

$$OS = \frac{AHS}{2} [1 \pm (1 - \frac{v}{c})^n]$$

where $\frac{v}{c}$ is the prevailing effective volume/capacity ratio and "n" is given in Table 20. Then, the average running speed (ARS) is calculated using:

$$ARS = OS - 0.1AHS\ (1 - \frac{v}{c})$$

By applying the running costs given in Tables 5-9 to the average running speed, level of service, and miles per vehicle type, the total vehicle operating costs are calculated for the base year and one or more control years. By applying time costs given in Table 3 to the average running speed and miles per vehicle type, the total time costs are calculated for the base year and one or more control years. The decrease in time and vehicle operating costs that can be attributed to the control project on freeways then are calculated. Estimates should be made for peak-hour as well as non-peak-hour traffic.

To calculate time and vehicle running costs on city streets or freeway frontage roads, it is required that information be developed by type of vehicle on uniform (spot) speeds, on the total numbers of stops and other speed changes from different uniform speeds, and on the total idling time due to stops. The uniform (spot) speeds should be estimated at locations where vehicles are neither accelerating or decelerating, but rather where they are operating at their maximum speeds before making speed changes. Also, the number of vehicle miles and days of travel for the different operating conditions for the relevant years must be determined.

To obtain the annual travel time costs for stops and speed changes from different uniform speeds and for idling time, the estimated travel times for each of the basic vehicle types are multiplied by the appropriate values of time given in Table 2.

To obtain the estimated annual running costs, two separate calculations must be made. First, the estimated miles of travel at the derived uniform speed for each vehicle type are multiplied by the appropriate running costs in Table 10. Use Vehicle Type 3 values for buses (Vehicle Type 6). Second, the estimated numbers of stops and speed changes at the derived uniform speed for each vehicle type are multiplied by the appropriate running costs in Tables 11 through 15. The amount of idling time (hours) associated with stops by vehicle type are multiplied by the appropriate idling costs in Table 16. The running costs for the three sets of calculations are added together to obtain the total annual running costs.

Table 20

Values of Exponent "n" by Average Highway Speed and Number of Lanes

Average Highway Speed	Number of Lanes	Exponent "n"
70	4	0.73
70	6	0.59
70	8	0.51
60	4	0.71
60	6	0.70
60	8	0.68
50	4,6,8	0.82

The net travel time and running cost savings (could be negative) for projects on city streets or freeway frontage roads are obtained by subtracting the control year(s) costs from the base year costs.

Accident Costs

The suggested procedure for obtaining estimates of dollar savings accruing from accident reduction on freeways and city streets is presented below.

For each year of the analysis period, the number of accident involvements (number of vehicles involved) by type of involvement, type of accident, and type of vehicle must be estimated. Involvements can be of three types: (1) fatal involvement--where at least one person is killed in vehicle, (2) injury involvement--where at least one person is injured in vehicle, and (3) property damage involvement--where no persons are killed or injured in vehicle which incurred damages.

The accident types can be identified as follows: (1) multi-vehicle collision--where vehicles collide head-on, rear end, angle, sideswipe, turning, parking, or other; (2) single-vehicle collision--where vehicle collides with pedestrian, train, bicycle, animal, fixed object, or other object; (3) non-collision--where no object is struck by vehicle.

The vehicle(s) involved can be designated as one of the three following types: (1) passenger car (including pick-ups and panel trucks); (2) single-unit trucks; and (3) combination trucks (including all combinations of trucks or truck tractors pulling trailers or semi-trailers).

The numbers of involvements, vehicles involved in each type of accident (fatal, injury, or property damage), for each year in the study period are multiplied by the appropriate direct cost per involvement per vehicle in Tables 17 through 19 to obtain estimated annual accident costs.

The direct costs per bus involvement are estimated directly from transit records and accident files. First, an estimate must be made of the number of bus accidents, bus riders injured, and dollar damages to buses for each of the years under study. The estimated number of injured riders is multiplied by $798 per person to give the direct costs due to injuries. Second, the estimated number of buses are multiplied by the estimated damages per bus.

Indirect accident costs such as loss of future earnings because of death and overhead costs of insurance are estimated. The number of expected deaths by sex is multiplied by the appropriate values as follows: (1) males - $67,348 and (2) females - $49, 617. If the number by sex cannot be estimated, then an average value of $61,984 can be used. The amount of overhead costs are estimated by applying a factor of 1.4 to all direct accident costs.

Finally, the accident costs involving non-reported accidents are estimated by multiplying the estimated direct costs due to property damage by a factor of 2.5.

By subtracting the estimated base year accident costs from the estimated control year(s) accident costs, the total dollar savings accruing to accident reduction are estimated.

Other Costs

Reduction in other user costs, such as parking costs, can result from a highway improvement project. New park-and-ride improvements can affect parking fees and volume of cars parked in the central business district (CBD) immediately or in the short-run and affect the number of parking spaces in the long-run. Although it is improbable that an exclusive cause and effect relationship between control projects and parking fees and available parking spaces exists, certain data are required to evaluate the indicated relationship. The following data should be collected from at least a random sample of parking lots, both public and private:

(1) volume of cars parked per day

(2) average parking charge per car per day

(3) number of existing parking spaces

A change in any of these three measures will be reflected in total parking revenues, and a reduction in such revenues can be considered as out-of-pocket savings to users. Other savings may result from a reduction in off-street parking. However, these savings, if any, will be reflected as time, running, or accident cost savings on city streets.

Another user cost is the cost of discomfort associated with making speed changes and driving in congested traffic. Unfortunately, there currently exists no economic coefficients for estimating the cost of discomfort. The best that can be done is to measure those physical characteristics, such as speed changes and acceleration noise, that are believed to affect comfort, and to use these as measures of effectiveness.

Determination of Non-User Benefits

Certain types of freeway control and surveillance projects can have a considerable impact on non-users of freeways by changing air and noise pollution levels, land values, business receipts, employment levels, etc. To the extent that a freeway project reduces the measured levels of air and/or noise pollution, this is considered a benefit to those living and working in and around the freeway. If the project increases pollution, it is considered a negative benefit or cost. The same is true if a freeway project increases or decreases land values, business receipts and employment. Suggested procedures for measuring each of these impacts are disscussed below.

Air Pollution

Roadside measurements of pollutants from motor vehicle emissions before and after implementation of freeway improvements can be made by appropriate instrumentation located at critical points along the freeway. An alternate method is to estimate the emissions from vehicles before and after project implementation by using emission rates developed from other studies.

Figures 2 and 3 illustrate the 1968 emission rates of hydrocarbons and carbon monoxide by uniform speed and speed stopped, respectively, as reported by Anderson and Curry (12). Although not shown here, Cesario (14) reports that the 1970 emission rates for nitrogen oxides start increasing with speed at about 25 miles per hour and approach 0.01 pounds per vehicle mile at 60 miles per hour. Emission rates for vehicles using gasoline for a fuel vary according to vehicle type. The emission rates for trucks (Types 3, 4, and 5) and buses (Type 6) are from 2.0 to 2.5 times (12, 19) the emission rates for passenger cars (Type 1) and light trucks (Type 2). Diesel trucks have low emissions of the above pollutants. Smoke is the primary pollutant emitted from diesel engines. Also, carbon monoxide and hydrocarbon emission rates are significantly greater for vehicles starting cold and running for the first two minutes than for vehicles starting hot or running for more than two minutes (19). The 1975 cars are expected to emit 90 percent of their carbon monoxide and 80 percent of their hydrocarbons during the first two minutes of a typical cold start trip (19). Nitrogen oxide emission rates do not vary significantly due to cold starts.

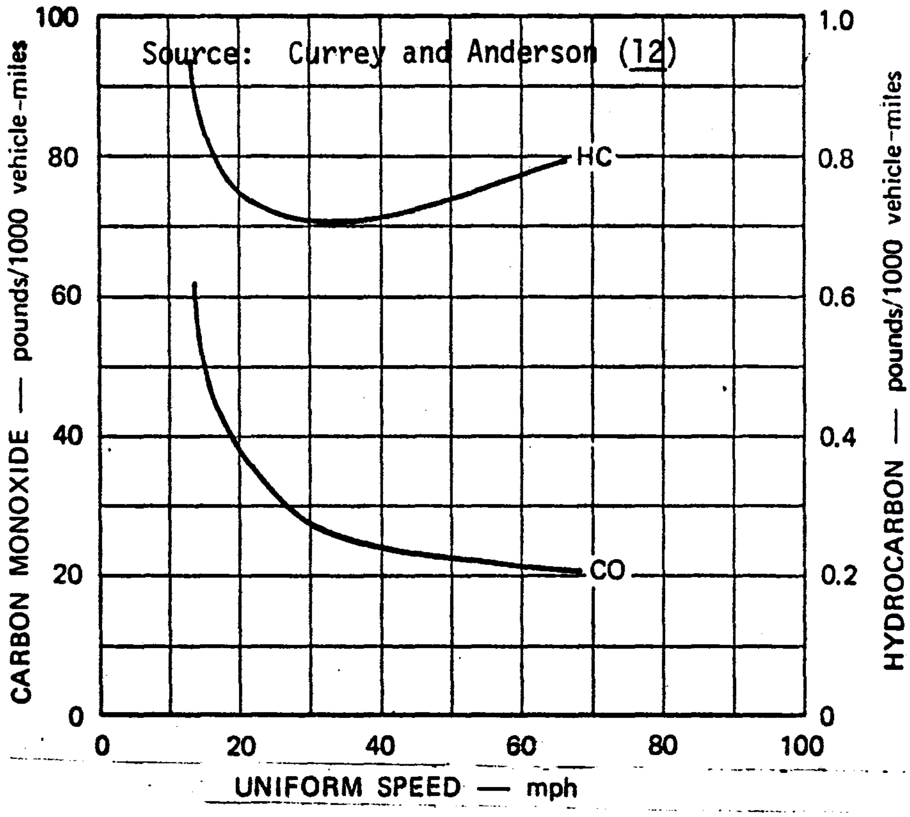

Figure 2. Hydrocarbon and Carbon Monoxide Emissions per 1,000 Miles of Driving at Uniform Speed (Reference Automobile)

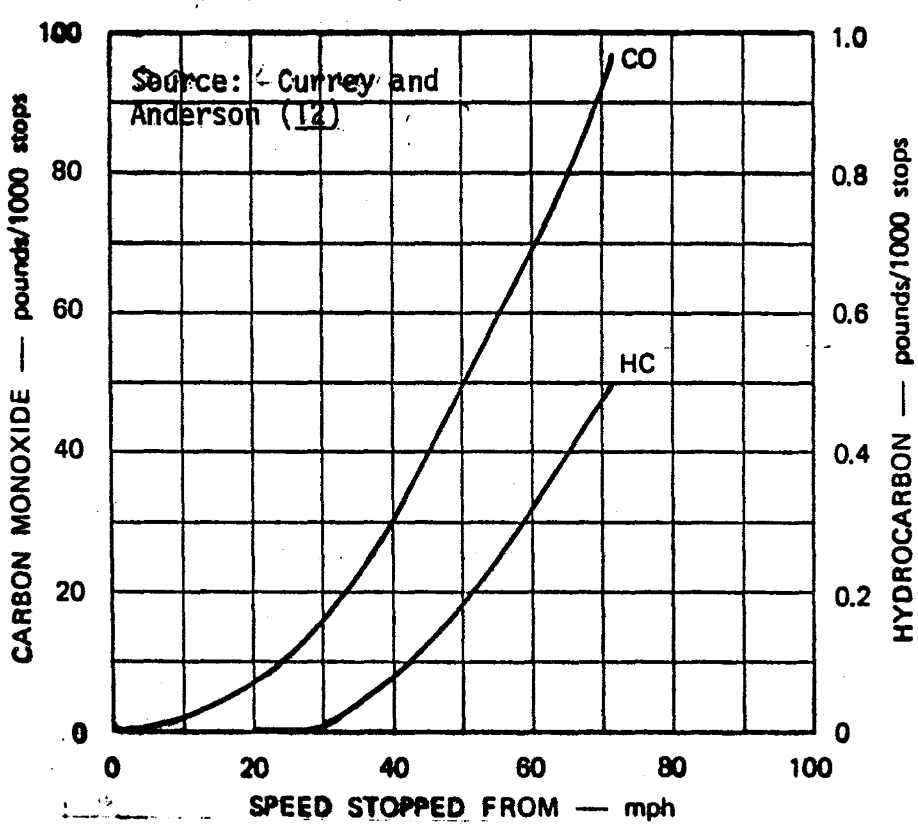

Figure 3. Hydrocarbon and Carbon Monoxide Emissions Added per 1,000 Stops (Reference Automobile)

Since the emission standards, vehicle maintenance practices, and the mix of old and new vehicles are changing rapidly, the emission rates for the base and control years of study must be adjusted by some factor. Figure 4 shows the factor to convert the reference year (1968) automobile emission rates to emissions in year Y, taking into account the above changes (12). However, the factor in Figure 4 does not take into consideration the changes in cold start and hot start emission rates. Unfortunately the proposed emission control devices are not as effective to reduce cold start emissions as to reduce hot start emissions (19). Therefore, post 1975 cars are expected to emit an even greater proportion of their carbon monoxide and hydrocarbon pollulants due to cold starts.

The levels of lead and smoke particulate emissions as a function of driving conditions are not yet determined. However, the levels of lead emission can be approximated, given the average lead content per gallon of gasoline and the percentage of lead exhausted from the tailpipe for the base and control years. For example, the average lead content in gasoline in 1970 is given as two grams per gallon and 80 percent given as the exhaust rate (12). Both the lead content and exhaust rate are declining rapidly due to EPA standards.

The equipment being used to control air pollution, such as the catalytic converter, is emitting acid into the environment, offsetting some of the gains made in reducing other air pollutants. If the majority of motor vehicles become equipped with catalytic converters, the level of acid emission may become a serious problem.

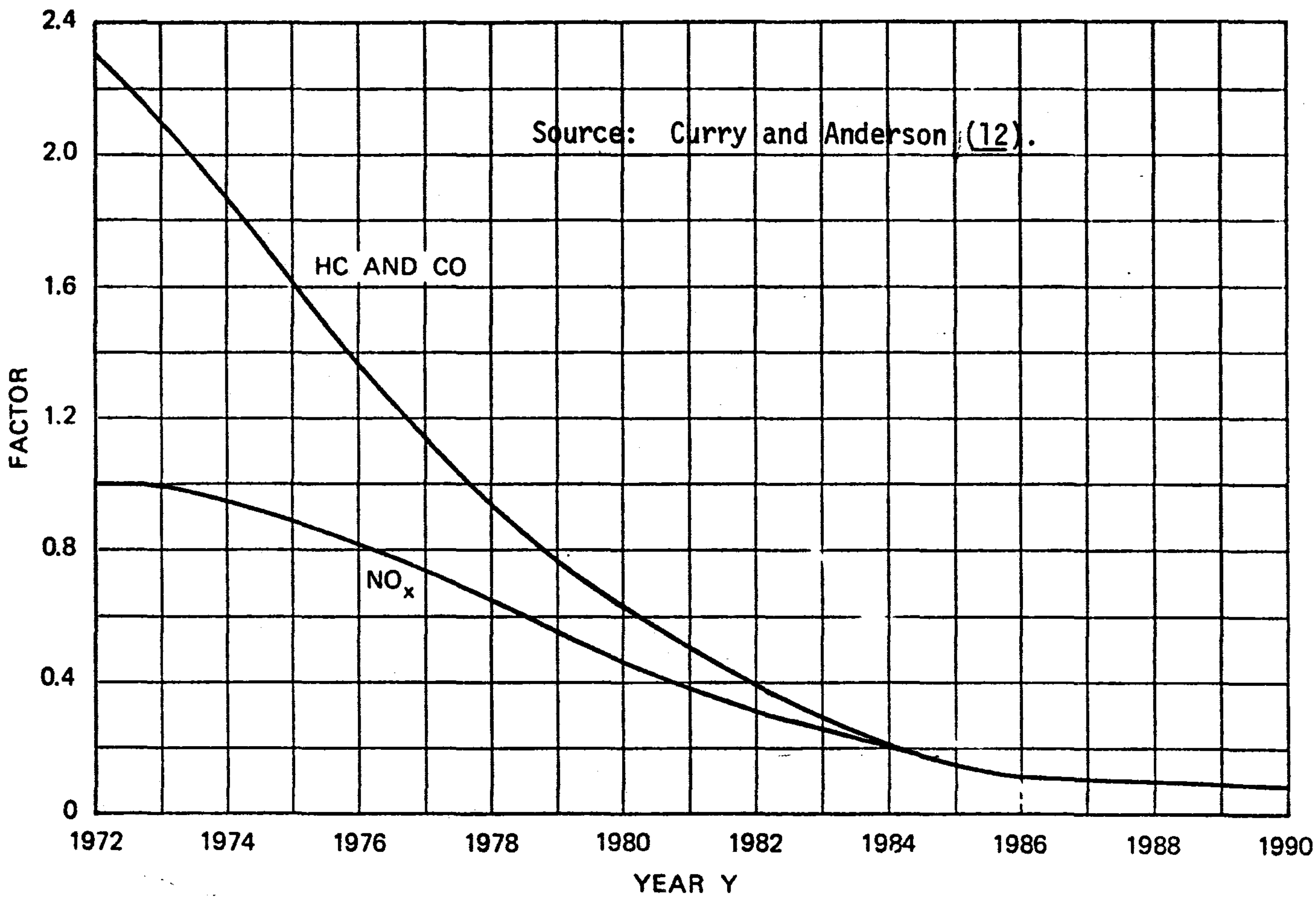

Figure 4. Factor to Convert Reference Year Emissions to Emissions in Year Y

Noise Pollution

The A-scale noise level in decibels (dBA) of a precision sound level meter has been found to be an accurate and practical measure of highway noise. The decibel is used to measure the physical effects of noise even though it is not a direct measure of loudness. However, the A-scale measurements correlate highway noises with human acceptance of those noises very well, and a number of good instruments are available for making base and control year(s) measurements.

Predicting the noise levels is an alternate procedure. In such cases, those factors which have an effect on highway noise levels must be considered. According to Young and Woods (16), traffic density, speed, and composition account for most of the variations in the noise level. Figure 5 illustrates the mean noise level in dBA's at 100 feet from a lane by density of automobiles per mile for selected speeds. Figure 6 indicates the mean noise level at 100 feet by density of vehicles per mile for selected traffic mixes of cars and diesel trucks.

According to data presented in two studies (12, 15) vehicle noise levels also vary according to the basic design of freeways and the presence or absence of sound barriers. Therefore, if the new freeway improvement involves a design change, with or without sound barriers, the predicted noise levels can be based on the results shown in Figure 7.

Finally, Young and Woods (16) indicate that the detrimental effects of vehicle noise vary according to the land use activities along a freeway. Table 21 gives the recommended noise levels for various land use activities by time of day.

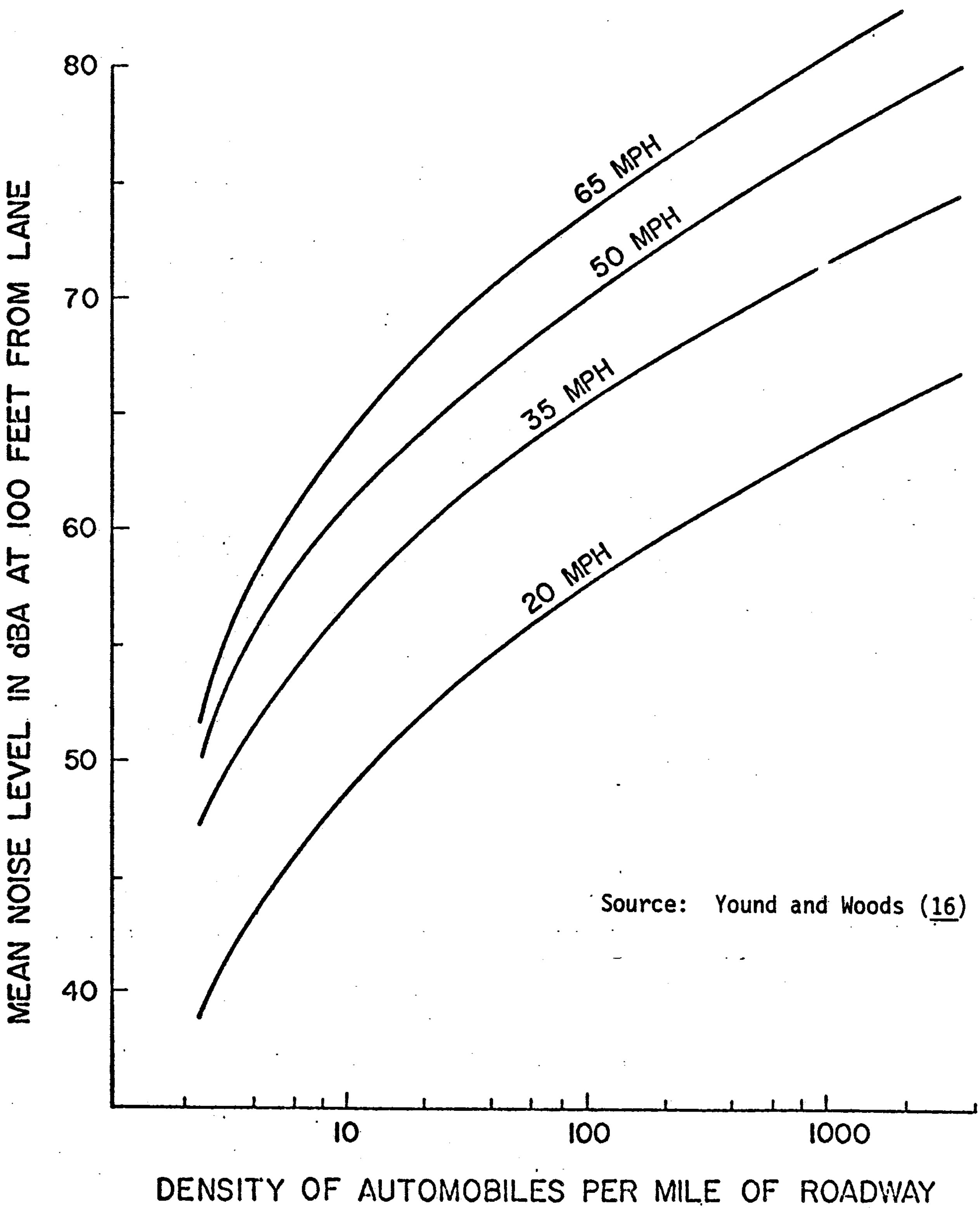

Figure 5. Mean Noise Level at 100 Feet from a Lane, by Density of Automobiles per Mile of Roadway for Selected Speeds.

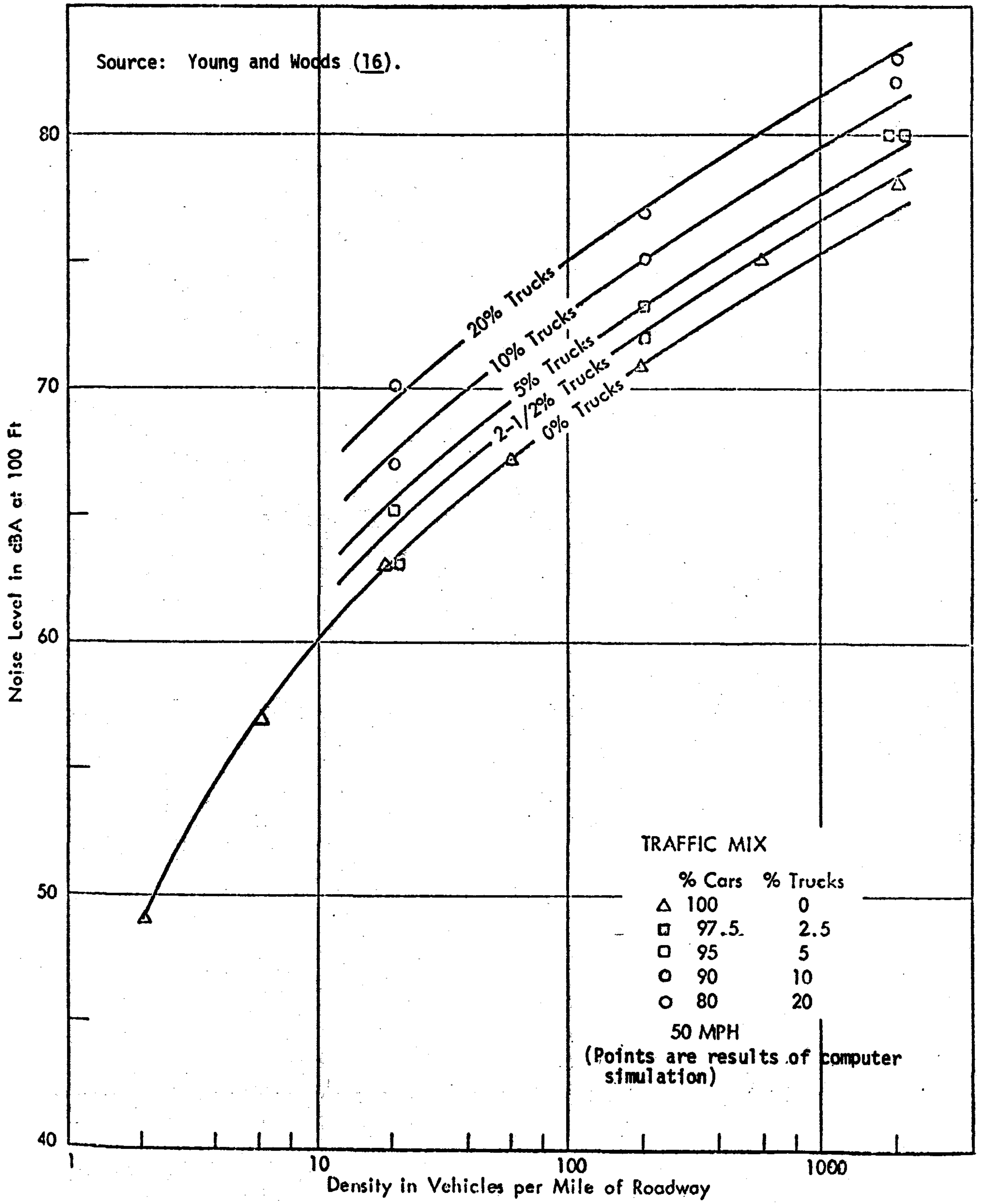

Figure 6. Curves for Estimation of Mean Noise Level in dBA at 100 Feet Distance From a Lane (or Single-Lane-Equivalent) of Mixed Car and Diesel Truck Traffic.

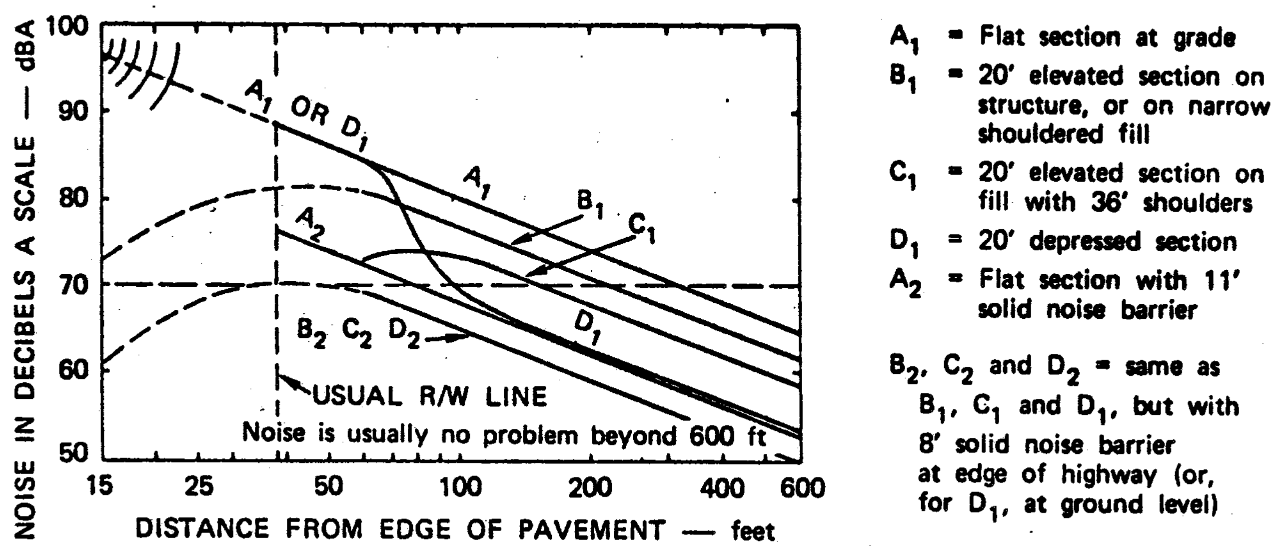

Figure 7. Noise Comparison Chart for Different Highway Designs.

Source: Beaton and Bourget (15), as presented by Curry and Anderson (12).

Table 21

Recommended Noise Levels for Various Land Use Activities

Land Use Activity	Time of Day	Recommended Maximum Mean Sound Pressure Level (dBA)	
		At Property Line	Inside a Structure
Residential (Single and Multiple Family)	Day	70	65
	Night	65	55[a]
Business (Commercial and Industrial)	All	75	65
Educational Institutions	All	70	60
Hospitals and Rest Homes	Day	60[b]	55
	Night	50[b]	45
Public Parks	All	70	55

[a]Air conditioning systems commonly operate at 55 dBA. For non-air conditioned residential structures, it may be desirable to reduce this value by 5 dBA.

[b]Expected ambient noise level.

Source: Young and Woods Study (16).

The predicted noise levels resulting from a freeway improvement can be correlated with existing land use activities in assessing the detrimental effects of such an improvement. However, it is very difficult to measure these effects in dollars.

Other Impacts

An attempt should be made to quantify other non-user impacts resulting from a new freeway improvement project.

Base and control year(s) data on abutting land values, business receipts, and employment levels can be collected from pilot demonstration projects. Otherwise, the impact on these factors can be estimated by studying changes in the volume, pattern, and composition of traffic resulting from project implementation. According to Babcock and Khasnabis (17), the types and densities of abutting land uses are impacted significantly by the traffic generating characteristics of a freeway. Table 22 summarizes the general conclusions relative to traffic generation characteristics by land use activity.

Changes in land values, business receipts, employment, etc. created by a new freeway traffic control system are not restricted to only land and businesses abutting the freeway, but also include those in the general area. However, the changes in the general area are affected by many factors other than the new project. Therefore, care must be exercised not to expand the study area to the point that localized effects of the new project cannot be precisely measured. Also, care should be exercised to avoid double counting of effects.

Table 22

Traffic Generation Characteristics Along Freeways or Interstate Highways, by Land Use Activity

Land Use Activity	Traffic Generation Characteristics[a]
Service Stations	Generate 4 to 13 trips (one-way) leaving freeway per average hour, with 80 to 90 percent of vehicles returning.
Industrial Developments	Generate 5 to 50 percent of vehicles using freeway at shift change.
Motels	Generate about one vehicle moving from freeway for every 6 rooms in motel per daytime hour.
Apartment Complexes	Generate one vehicle for every 5 housing units making use of a beltline type freeway.
Shopping Centers	Generate up to 50 percent of traffic coming from freeway or 25 percent of traffic using shopping center.

[a]Where service roads exist, connecting the freeway interchanges, between one-third and one-half of all of the service road traffic comes from or goes to the freeway.

Source: Babcock and Khasnabis (17).

Determination of Project Costs

The preceding sections have dealt with the measurement of private and social user and non-user costs in order to determine the measurable benefits resulting from a freeway project. This section considers the information requirements for determining freeway project costs (both initial and annual recurring), as well as the estimated life and salvage value of the project elements or hardware. Included are all costs required to obtain user or non-user savings.

The initial project costs should include the following:

(1) Project administration.

(2) System planning, designing, and testing.

(3) Equipment, materials, supplies, and installation services.

(4) Land and Buildings.

(5) Site preparation.

(6) Miscellaneous initial costs.

The annual recurring costs should include the following:

(1) Operation, maintenance, and repair.

(2) Damage or loss of property (not including user accident costs).

(3) Services.

(4) Miscellaneous recurring costs.

The estimated life of a project element is the length of time that it remains useful without requiring major reconstruction. This period may also be called the analysis period when it is the estimated life of the overall project.

The salvage value of a project improvement is the value of the usable materials and equipment less the cost of making them usable or disposing of them. The salvage value is negative when materials and equipment must be removed and their value in their new use is less than the cost of their removal. To some extent, the estimates of life and net salvage value are based on value judgements.

Comparison of Benefits With Costs

After all of the annual benefits and the annual costs affecting users and non-users have been quantified, only a few calculations remain before an assessment of the economic feasibility or cost-effectiveness of a highway project can be made.

Since the dollar costs and benefits are annualized for evaluation, some discount or interest rate is needed. Generally, the rates recommended for public projects range from 6 to 10 percent (12). A rate of 8 percent is recommended for this analysis since it represents a compromise between the two extremes. The interest rate is used in this analysis only to indicate that project funds have an opportunity cost for alternative uses. The interest rate gives an indication of the expected rate of return for these alternative uses.

The economic feasibility of a project can be partially determined by dividing the discounted present value of annualized dollar benefits by the discounted present value of the annualized dollar costs (reduced to account for salvage value) to give a ratio of benefits to costs.

The full economic feasibility of a project is determined after considering all other measurable benefits and costs together with those making up the benefit-cost ratio. At this point, the decisionmaker, must resort to value judgments when considering or weighing the benefits and costs that are not quantifiable into dollars before reaching a decision on the project. The literature contains various rating or weighting schemes that can be employed (18).

The alternative procedure is to use the cost-effectiveness approach where the annualized user benefits are added together and used with the quantified measures of other impacts to determine the effectiveness of a project. One advantage that the effectiveness analysis has over the benefit-cost analysis is that the decisionmaker can compare projects on the basis of their effects, measured in various units (including dollar), and their respective costs. Of course, the benefit-cost ratios for alternative projects can be compared to reach a decision on which project to select.

The benefit-cost analysis has weaknesses other than those previously recognized. Haney (19) mentions the following factors that produce potential uncertainties in the results or conclusions based on the benefit-cost analysis: (1) forecasts of the future, (2) computer analyses to estimate actual travel conditions, and (3) value measurement procedures that are approximate at best.

Haney says that one way to indicate the uncertainty of results derived from a benefit-cost analysis is to make estimates of the important variables not only on a most likely basis, but also on a 10 percent-90 percent basis (values for which there is only a 10 percent probability that the actual value will be greater or less than the estimated value). Then, there are three estimates from which to draw conclusions.

APPLICATION OF RECOMMENDED PROCEDURE

Various freeway surveillance and traffic control projects can be employed on existing freeways to accomplish one or more of the following goals:

(1) Increase capacity.

(2) Increase speed (save time)

(3) Increase safety.

(4) Increase transit usage.

(5) Increase economic development.

(6) Reduce fuel consumption.

(7) Reduce air and noise pollution.

These goals are established at the national, state, or local level, and they may be supported at one or more levels. Conservation of fuel is clearly a national goal, while to increase economic development and to increase capacity of freeways are state and local goals.

As time passes, the importance and priority of goals change resulting in a conflicting set of goals. For instance, the goal to increase speed (save time) conflicts, to some extent, with the goal to reduce fuel consumption. Also, those at the various levels of government or in different regions of the country may differ on the importance of a goal. The goal given the highest priority usually depends upon the level of government and the level of legal and financial support. For example, the national government is giving strong legal support to the goal of reducing air and noise pollution and it is giving strong support to fuel conservation. The latter goal seems to be receiving a higher priority than the former goal, because federal pollution reduction standards (which increase fuel consumption) have been relaxes or their effective dates have been extended. In short, when goals conflict, someone must rank them in the order of their importance to the national welfare. This is especially true when means cannot be found to accomplish competing goals at the same time. Fortunately, a reduction in air pollution and fuel consumption can be achieved by reducing automobile travel and increasing carpool and transit bus ridership.

There may be more than one freeway surveillance and traffic control project that will accomplish a particular goal or set of goals. The most commonly mentioned projects to accomplish one or more of the above listed goals on the existing freeways in Texas are as follows:

(1) Reserved lane for buses and/or carpool vehicles.

(2) Contraflow lane for buses and/or carpool vehicles.

(3) Exclusive busway.

(4) Congestion by-pass and priority entry system.

(5) Bus entry ramps on metered freeway.

(6) Park-and-ride system.

Which project(s), if any, should be implemented to accomplish a particular goal or set of goals? With the help of the analytical procedure discussed in the previous section, this question can be more satisfactorily answered. Briefly, the following steps should be taken. The <u>first step</u> is to conduct a benefit-cost or cost-effectiveness analysis on each of the alternative projects. Immediately those projects that are not economically justified can be eliminated from further consideration. The <u>second step</u> is to construct a value matrix, as described in detail by Carter, Hall and Haefner (18), that selects the best alternative project to meet a particular set of goals. The number of projects and goals can vary. The principal advantage of the value matrix technique is its ability to handle a mixture of subjective measures and values in a systematic framework using mathematical techniques. To construct the value matrix, the following steps must be taken:

(1) Assign a weight (or utility value) to each goal that reflects the values of the local community, the state and the nation. The most important goal receives the highest weight. The group that assigns these weights should be decisionmakers and experts (public and private) at all three levels of authority.

(2) Assign a weight to each project that indicates how well a goal will be accomplished. Again, the project that best meets the goal receives the highest weight. A parameter that best measures each goal must be selected from the benefit-cost analysis. For instance, the parameter for the goal to reduce fuel consumption could be measured by gallons of fuel saved. The assigned weights should represent relative differences in the values of each goal's parameter among projects, i.e., be based on a linear scale.

(3) Multiply the weight of each goal by the weight of each project (based on parameter values) and sum the new array of values for each project to determine the project that best meets the set of goals.

The above procedure is flexible, but the most difficult task would be the assigning of weights to the goals used in the analysis. But, this seems to be a very necessary and logical step to take in determining which freeway control project(s) should be used on our freeways in Texas. The procedure does not take into consideration budget constraints which always have to be considered. However, this constraint could easily be worked into the first step.

In conclusion, the real test of the procedure outlined in this report is to apply it to real world problem situations in the urban areas of Texas. Only then can the detailed data requirements and limitations of the procedure be identified. Consequently, it is recommended that Texas Transportation Institute coordinate with the State Department of Highways and Public Transportation officials to collect the necessary data on pilot projects and to conduct a critical evaluation of the procedure. For example, an evaluation could be made of alternate bus transit systems, such as reserved lanes flowing with the traffic versus reserved lanes flowing against (contra-flow) the traffic. Another evaluation could be made of park-and-ride facilities as a part of bus transit systems.

The end product of the above testing should be a refined evaluation procedure that is practical and reliable for providing answers to these problem areas.

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