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COOPERATIVE
RESEARCH

A MODEL TO CALCULATE DELAY SAVINGS FOR HIGHWAY IMPROVEMENT PROJECTS

in cooperation with the
Department of Transportation
Federal Highway Administration

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16. Abstract This report presents a computerized delay savings model which can be used to calculate the delay savings resulting from an improvement of an existing highway facility. The delay savings come as a result of the increased average speed along the improved facility, which is converted into dollars of delay savings, calculated for each year through a 20-year planning horizon, and discounted to the present.

The model also calculates a delay savings ratio, which is the ratio of the total discounted delay savings and the estimated construction cost. The ratio measures the amount of delay savings per dollar construction cost. These delay savings ratios are then ranked, with the highest being first and the others following in order. The cumulative construction cost is also shown so that if a specific budget amount is available, the projects with the highest delay savings ratios within that budget can be identified.

The model incorporates recent data concerning the relationship between average speeds and hourly traffic volumes for several facility types. The model provides a quick and simple method to compute delay savings and compare projects on that basis.

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A MODEL TO CALCULATE DELAY SAVINGS FOR HIGHWAY IMPROVEMENT PROJECTS

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The contents of this report reflect the views of the authors who are responsible for the facts and accuracy of the data presented herein. The contents do not necessary reflect the views or policies of the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

SUMMARY

This report examines a model to calculate the delay savings resulting from a capacity improvement to an existing facility. The model is designed to minimize the information required about each project so that the program can be quickly and easily used with little or no additional data collection necessary. Just as important, is the capability to quickly and consistently compare a large number of projects on the same basis, namely the amount of delay savings generated over the planning horizon per dollar construction cost.

The major characteristics of the model include:

1. The only traffic volume required for each project is the current ADT. A projected ADT can also be specified, but if one is not given, then the program will generate its own ADT projection, using either a low, medium, or high ADT growth formula. The particular growth category can be specified if desired, otherwise the medium growth formula will be used.
2. Certain characteristics of the existing highway, as well as the proposed highway are needed. These include the location (rural or urban), highway type, number of lanes, and length of road section. In addition the estimated construction cost must be specified. Other characteristics can also be specified, if desired, such as speed limit, shoulders, left-turn median, and number of traffic signals per mile.
3. ADT is converted into hourly traffic volumes using average K factors for rural conditions and urban conditions. There is no further breakdown into direction of travel and variations within the hour, though there is an adjustment for those factors in the capacity parameters.
4. Average speeds, as a function of hourly volumes, are taken from recent data collected at several sites in Texas.

5. In order to make all projects directly comparable, the construction year is assumed to be the year following the current year.
6. The discounted delay savings are calculated over the planning horizon, and then ranked using the delay savings ratio, which is the delay savings divided by the construction cost. The cumulative construction cost is also provided to aid in project selection with a budget constraint.
7. The program can process up to 9999 projects at one time.

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INTRODUCTION

For most highway projects designed to increase the capacity of an existing facility, the single, most important benefit is the reduction in delay, termed delay savings. That savings is readily apparent on heavily congested routes for which additional capacity can have a dramatic impact if that congestion is significantly reduced or eliminated. However delay savings can result, even if no congestion is present, by increasing the average speed along the facility. Thus rural routes, with low traffic volumes, can be analyzed.

Calculation of delay savings is not a new concept. It has been generally recognized for several years that a large portion of benefits generated by an improved highway network comes from reduced time costs. Many manuals and computer programs include an analysis of delay savings. One widely used manual method is contained in AASHTO's A Manual for User Benefit Analysis of Highway and Bus Transit Improvements (1). The manual is commonly referred to as the Redbook, and contains nomographs and tabular data which can be used to calculate delay savings. However the process can be very tedious and time consuming, especially if a large number of projects are to be analyzed.

The revised Highway Economic Evaluation Model (HEEM-II) (2) is a computer program which can also be used to calculate delay savings, though its primary output are the overall user benefits, including delay savings. It calculates benefits over a planning horizon for given projected traffic volumes within a corridor. The major drawbacks in using HEEM-II are the use of ADT directly to calculate an average daily speed, rather than converting the ADT to hourly volumes and using the hourly volumes to calculate average speeds. That also creates a problem in handling times during the day when demand exceeds capacity, and a queue forms. HEEM-II does not have any explicit mechanism to handle the queue conditions or the dissipation of the queue.

This report presents a computerized model to calculate delay savings which is simple to use, requires a relatively small amount of data, and incorporates recently collected data on average speeds along Texas highways. Delay savings are calculated for each year of the planning horizon, discounted, and summed to give the total discounted delay savings for the project. The projects are then ranked by delay savings per dollar construction cost to indicate the relative merits of each project using the delay savings criteria.

CHARACTERISTICS OF MODEL

The calculation of delay savings in the model is based upon the projected ADT, which can be given in the input data or calculated within the program. In either case an ADT is then calculated for each year between the current year and the projected year. The next step is to convert each ADT into hourly volumes. This is accomplished using K-factors within the program. There is a separate peaking pattern for rural projects and for urban projects.

The next major step is to calculate an average speed for each hourly traffic volume. This is based upon four basic highway types, undivided, divided, freeway, and busway, with other characteristics such as the presence of shoulders, and left-turn medians. When vehicle demand exceeds capacity, a queue is assumed to form and the speed declines as the average queue length increases. The queue is carried over into each succeeding hour until the queue dissipates.

Delay cost, in dollars, is then calculated and the difference between the proposed facility and the existing facility becomes the delay savings as a result of the improvement. The calculations for a busway on an existing freeway and new location construction are slightly more complicated because the proposed facility does not replace the existing facility. In that case, when the proposed facility is built, part of the traffic will use the new facility (busway), while the rest remain on the existing facility. That split must be specified as part of the input data, or a fifty percent split of persons in assumed.

The input and output data for the model are presented in Table 1. Details are provided in the section entitled "Use of the Model." As can be seen in the table, very little data are required to analyze a project, the current ADT,

Table 1. Input and Output Data for the Delay Savings Model

Input Data

Required

- Current Year
- Problem Number
- Current ADT
- For the Existing and Proposed Facilities,
  - Location (Rural or Urban)
  - Highway Type
  - Number of Lanes
  - Length of Road Section
- Construction Cost

Optional

- Percentage Trucks
- Value of Time for Cars, Trucks
- Discount Rate
- Planning Horizon
- Projected ADT for Planning Horizon
- For the Existing and Proposed Facilities,
  - Speed Limit
  - Shoulders
  - Left-Turn Median
  - Number of Traffic Signals Per Mile
  - Category of Area Development
- Percentage Persons to Use Proposed Facility
- Problem Description

Output Data

- Ranking
- Discounted Delay Savings
- Delay Savings Ratios
- Cumulative Construction Cost

construction cost, and some basic information on the existing and proposed facilities. These data should be readily available and greatly reduce the time and effort required to obtain an estimate of delay savings.

If a more complete analysis is desired, then other data can be given, at the option of the program user. Four different highway types can be specified, an undivided highway, a divided highway, a freeway, and a busway on a freeway. Such things as adding shoulders to a rural 2-lane highway, or improving the geometrics so the speed limit can be increased, or putting a continuous left-turn median in an undivided city arterial are some of the problems which can be analyzed with the optional data. The number of traffic signals per mile are included in the optional data, even though they are not currently incorporated into the program. This is in anticipation of data available at a future time on the effect of traffic signals on urban arterials which could then be incorporated into the computer calculations.

Another important aspect of the optional data is the ability to specify a projected ADT at the end of the planning horizon, or if the projected ADT is not available, then a category of future ADT growth can be specified. If the projected ADT is not given in the input data, the program will calculate a projected ADT internally, for any of three categories of future development, low, medium, or high. The traffic growth for each category is treated separately for both rural and urban areas. If the growth category is not specified, then the medium category is used.

The speed limit can also be specified as part of the optional data. This allows not only for comparison of highways with different speed limits, but highways with atypical speeds. The default value for the speed limit in the program is 55 mph, and the initial or highest speed (the speed at zero traffic volume) will be 5 mph higher, or 60 mph. If a speed limit is provided in the input data, then the initial speed will be 5 mph higher. All other speeds assumed in the speed/volume relationship are adjusted accordingly. If a particular initial speed were desired, that desired speed, minus 5, should be input as the speed limit.

The program also allows the user to include a short problem description. Such information as highway number, location, etc., can be included.

The program has constant or default values built into the model for all optional inputs. If the user does not specify values for the optional inputs, the program automatically uses its preset values. These program constant default values are presented in later sections of the report. Details of the delay savings calculations are continued in Appendix A.

USE 3F THE MODEL

The input data consists of one card which contains the current year and assumptions to be used for all problems. The input data for problems are each contained on a separate card and up to 9999 problems can be handled at one time.

Card 1 (initial assumptions)

Card columns

*5-8	current year
9-13	percentage trucks (default = 8)
14-18	value of car time per hour (default = 10.20)
19-23	value of truck time per hour (default = 19.20)
24-28	discount rate (default = 8)
29-31	planning horizon (default = 20)

Problem Card (one card for each problem)

Card columns

*1-4	problem number (1 to 9999)
*5-10	current ADT
11-16	projected ADT at end of planning horizon
	Existing Facility
*17	location (R-rural, U-urban)
*18	highway type (U-undivided, D-divided, F-freeway, B-busway on an existing freeway)
*19-20	number of lanes in both directions
*21-24	length of road section in miles
25-26	speed limit (default = 55)

27 shoulder switch (0 or blank-shoulders, 1-no shoulders)

28 left-turn median (0 or blank-yes, 1-no)

29-30 number of signals per mile (default = 0)

31 category of future development (1-fast growing, 2-medium growing, 3-slow growing)

Proposed Facility

*32 location (R-rural, U-urban)

*33 highway type (U-undivided, D-divided, F-freeway, B-busway on an existing freeway)

*34-35 number of lanes in both directions

*36-39 length of road section in miles

40-41 speed limit (default = 55) (must be between 15 and 70)

42 shoulder switch (0 or blank-shoulders, 1-no shoulders)

43 left-turn median (0 or blank-yes, 1-no)

44-45 number of signals per mile (default = 0)

46 category of future development (1-fast growing, 2-medium growing, 3-slow growing)

47 buildover switch (0 or blank-proposed replaces existing, 1-proposed does not replace existing)

48-50 percentage persons to use proposed facility if the existing is not builtover (default = 50)

*51-56 construction cost (thous. $)

57-80 problem description

* indicates required data which must be supplied

The data deck consists of one initial assumptions card and one card for each problem. The problem numbers do not have to be in order, but they should not be duplicated. There are no implied decimals in any of the fields so if a decimal is wanted, it must be placed in the data. For any optional data, if the field is left blank, then the default values are used.

EXAMPLES OF THE MODEL'S USE

Several hypothetical examples were used to test the model. The summary of those test problems are presented in Table 2. For each problem, the total discounted delay savings of the proposed project are presented, along with the construction cost. The ratio of those two numbers, the delay savings ratio, is also given. This measures the delay savings per dollar construction cost for each project. The projects are ranked by the highest delay savings ratio. The cumulative construction cost is also shown to aid in project selection with a limited construction budget. For example, to build the first 5 projects would cost 128.35 million dollars. It should be emphasized that these projects are strictly hypothetical. Table 2 does not imply anything about the relative merits of different types of projects. A copy of the program and complete output are presented in Appendix B.

A Manual Method to Calculate Delay Savings

The delay savings model was also used to generate delay savings ratios for several types of projects, given different current ADT's and assumptions concerning the growth of future ADT. The first of these is a 2-lane rural highway without shoulders, improved to add wide surfaced shoulders. Table 3 gives the results for several levels of current ADT. The numbers were calculated assuming a project one mile long and $100,000 construction cost. The three categories of projected ADT's are the ADT's generated within the program. Figure 1 presents the same results graphically.

Table 4 and Figure 2 present similar results for a 2-lane rural highway with shoulders, improved to a 4-lane rural highway without shoulders. The results for a 2-lane rural highway with shoulders improved to a 4-lane rural highway with shoulders are presented in Table 5 and Figure 3. The results for a

Table 2. *** PROBLEM DELAY SAVINGS ***
RANKED BY HIGHEST DELAY SAVINGS
PER DOLLAR CONSTRUCTION COST
(DELAY SAVINGS RATIO)

RANKING	PROBLEM NUMBER	DESCRIPTION	DISCOUNTED DELAY SAVINGS ($000)	CONSTRUCTION COST ($000)	DELAY SAVINGS RATIO	CUMULATIVE CONSTRUCTION COST ($000)
1	6	2LN UNDVD TO 4LN DVD	449651.2	10800.0	41.63	10800.0
2	5	4LN DVD TO 8LN FRWY	152926.2	5000.0	30.59	15800.0
3	16	BUSWAY FOR 8LN FRWY	366732.5	23250.0	15.77	39050.0
4	13	ODD LANE FREEWAY	106632.4	10300.0	10.35	49350.0
5	8	4LN FRWY TO 10LN FRWY	523635.7	79000.0	6.63	128350.0
6	14	4LN FRWY TO 8LN FRWY	126032.1	20100.0	6.27	148450.0
7	11	4LN UNDVD TO SHLD/+SPL	7480.3	1500.0	4.99	149950.0
8	1	IMPROVE FRWY 6/8 LANES	156558.1	40000.0	3.91	189950.0
9	9	4LN UNDIV TO DVD	26086.2	7000.0	3.73	196950.0
10	3	BUSWAY FOR 6LN FRWY	47773.9	20000.0	2.39	216950.0
11	15	4LN FRWY NEW LOCATION	66365.4	50000.0	1.33	266950.0
12	12	2LN W/SHLD TO 4LN W/O	814.4	700.0	1.16	267650.0
13	7	2LN DVD TO 4LN DVD	3873.9	6000.0	0.65	273650.0
14	2	U4LN UNDIV. TO DIVIDED	907.6	2500.0	0.36	276150.0
15	4	SHOULDERS ON RURAL HWY	484.7	1500.0	0.32	277650.0
16	10	6LN DVD TO 4LN FRWY	3632.7	16000.0	0.23	293650.0

Table 3. Delay Savings Ratios for a 2-Lane Rural Highway, Improved from no Shoulders to Shoulders

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*
1,000	1.412	0.10	1,893	0.15	2,374	0.20
2,000	2,824	0.40	3,786	0.61	4,748	0.87
3,000	4,236	0.93	5,679	1.44	7,122	2.07
4,000	5,648	1.72	7,572	2.70	9.497	4.52
5,000	7,060	2.79	9.465	5.19	11,871	26.01
6,000	8,471	4.28	11,358	20.51	14,245	144.44
7,000	9.883	9.46	13,251	101.62	16,619	369.28
8,000	11,295	30.27	15,144	298.24	18,993	601.35

* Discounted Delay Savings per $100,000 construction cost per mile

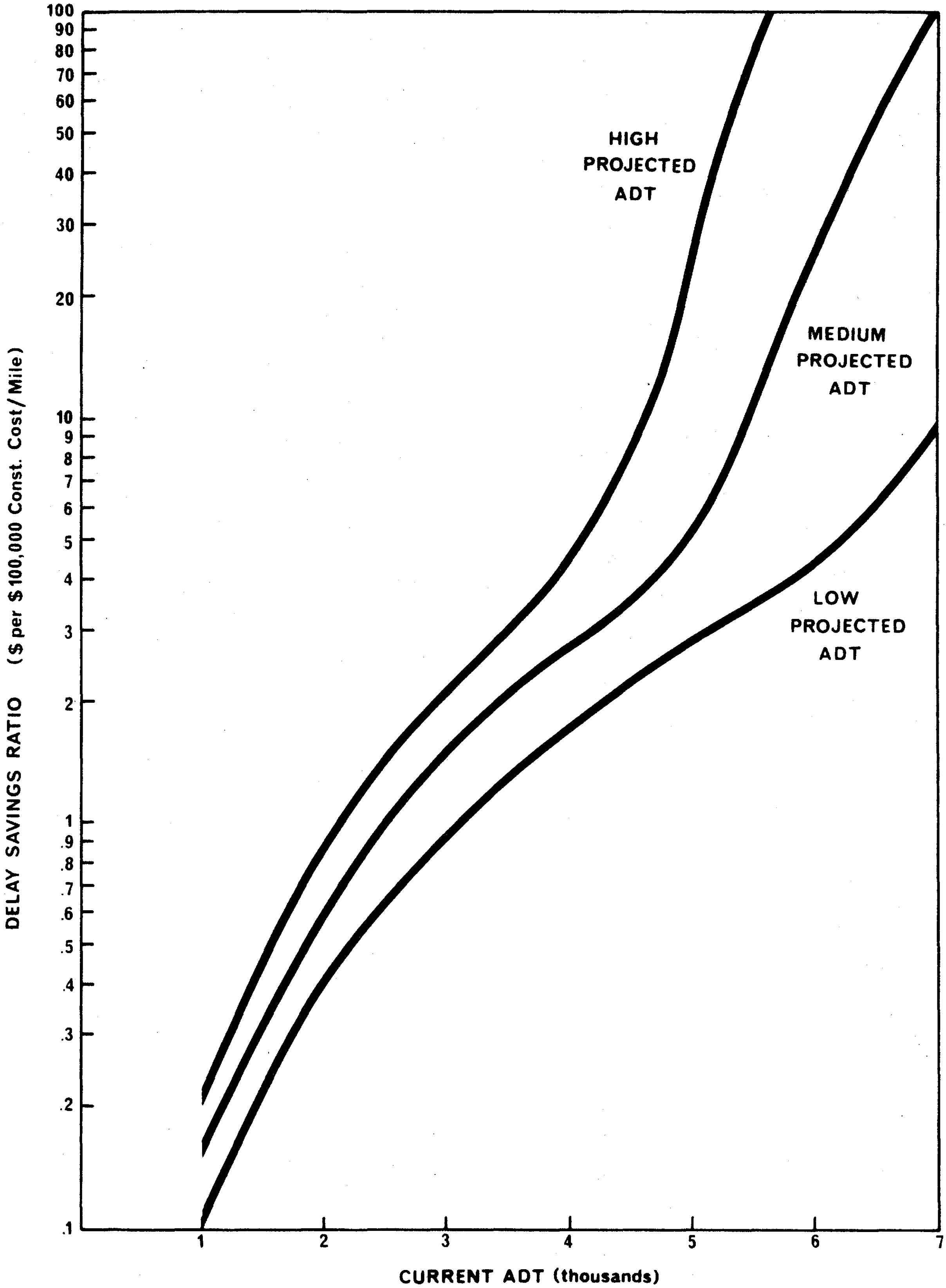

Figure 1. Delay Savings Ratios for a 2-Lane Rural Highway, Improved from No Shoulders to Shoulders

Table 4. Delay Savings Ratios for a 2-Lane Rural Highway with Shoulders Improved to a 4-Lane Rural Highway with Shoulders

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*
1,000	1,412	0.08	1,893	0.12	2,374	0.17
2,000	2,824	0.32	3,786	0.49	4,748	0.68
3,000	4,236	0.73	5,679	1.12	7,122	1.57
4,000	5,648	1.32	7,572	2.02	9,497	2.84
5,000	7,060	2.09	9,465	3.21	11,871	4.56
6,000	8,471	3.05	11,358	4.70	14,245	9.06
7,000	9,883	4.21	13,251	7.18	16,619	28.53
8,000	11,295	5.58	15,144	16.74	18,993	110.05
9,000	12,707	7.65	17,036	47.84	21,367	287.94
10,000	14,119	13.68	18,929	138.71	23,742	539.35
11,000	16,943	30.27	20,822	314.58	26,116	836.96

* Discounted Delay Savings per $100,000 construction cost per mile

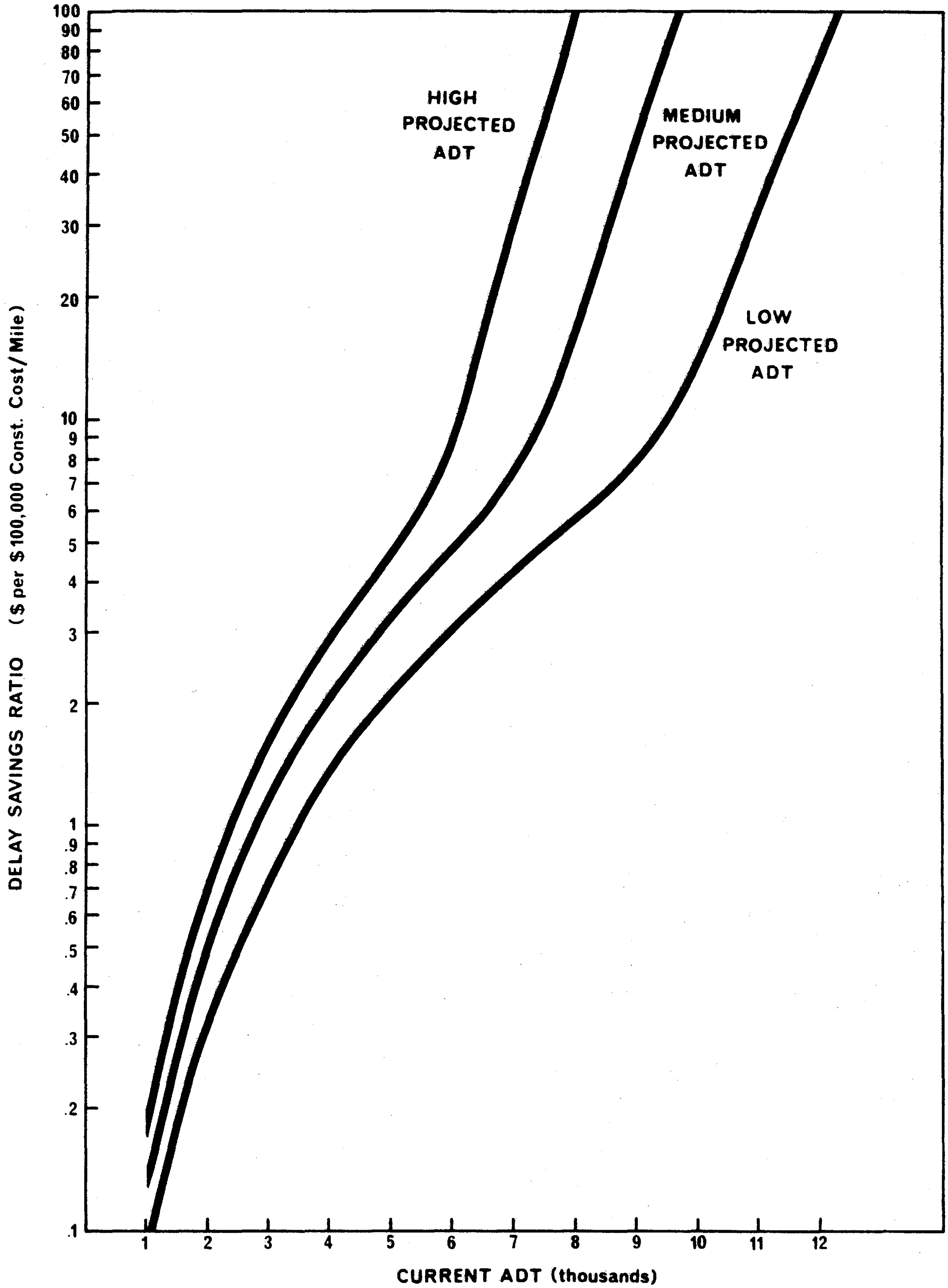

Figure 2. Delay Savings Ratios for a 2-Lane Rural Highway with Shoulders, Improved to a 4-Lane Rural Highway without Shoulders

Table 5. Delay Savings Ratios for a 2-Lane Rural Highway with Shoulders Improved to a 4-Lane Rural Highway with Shoulders

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*
1,000	1,412	0.08	1,893	0.12	2,374	0.17
2,000	2,824	0.33	3,786	0.50	4,748	0.69
3,000	4,236	0.74	5,679	1.13	7,122	1.59
4,000	5,648	1.34	7,572	2.05	9,497	2.89
5,000	7,060	2.12	9,465	3.26	11,871	4.63
6,000	8,471	3.10	11,358	4.78	14,245	9.16
7,000	9,883	4.28	13,251	7.28	16,619	28.67
8,000	11,295	5.67	15,144	16.87	18,993	110.23
9,000	12,707	7.76	17,036	48.00	21,367	288.16
10,000	14,119	13.81	18,929	138.91	23,742	539.63
11,000	15,531	30.43	20,822	314.83	26,116	837.30

* Discounted Delay Savings per $100,000 construction cost per mile

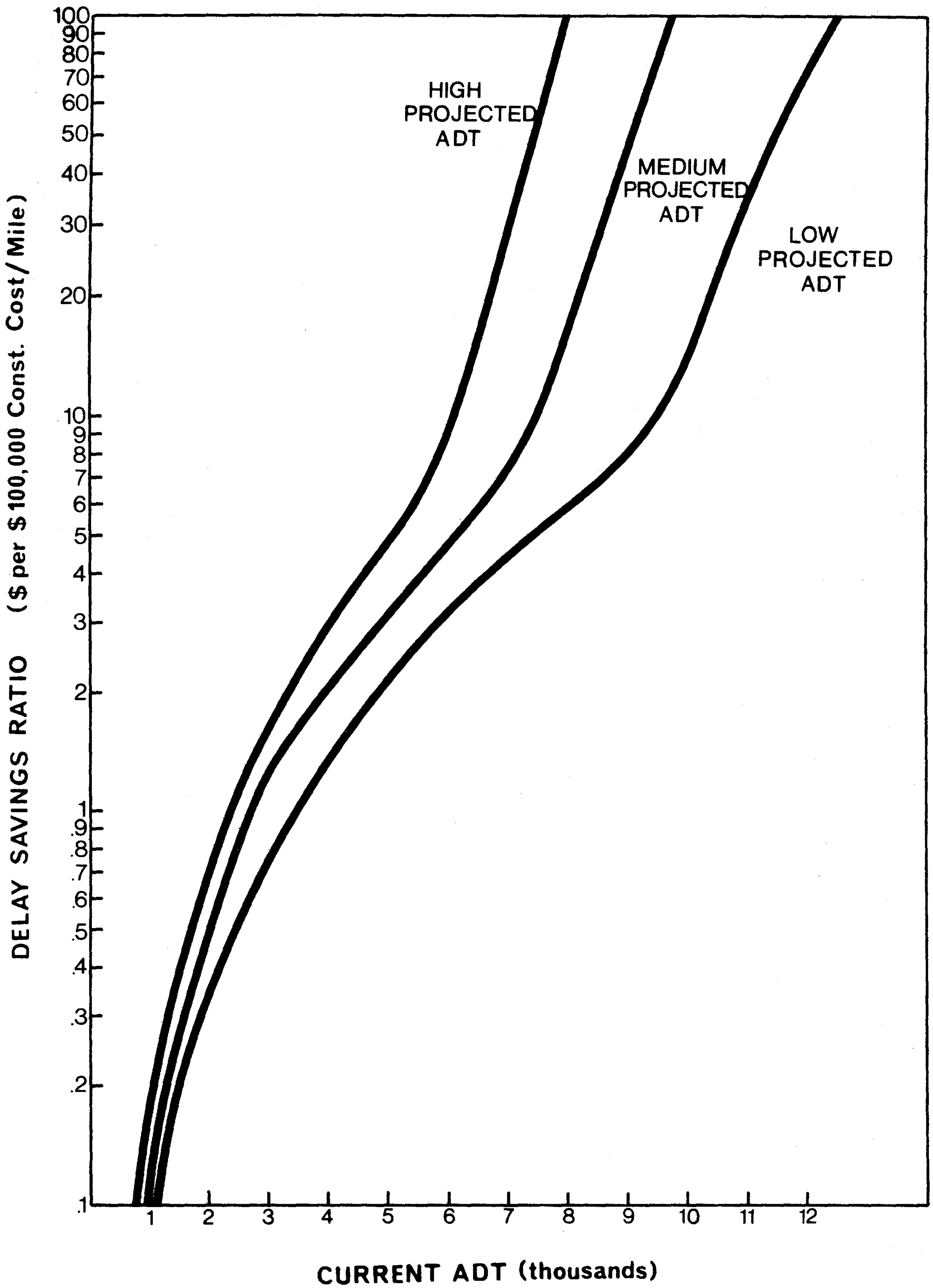

Figure 3. Delay Savings Ratios for a 2-Lane Rural Highway, Improved to a 4-Lane Rural Highway

2-lane urban undivided street improved to a 4-lane undivided street are presented in Table 6 and Figure 4. Also, Table 7 and Figure 5 present the results for a 4-lane undivided highway improved to include a left-turn median. Similar assumptions were made for these other projects, including a one mile project with a $100,000 construction cost. The reason for making the length and construction cost assumptions is to facilitate the use of the tables and graphs for manual calculations of delay savings. The formula for using the tables and graphs is given below,

$$DSR = D_N \times 100{,}000 \times L \div CST$$

where DSR = calculated delay savings ratio for the project

L = project length in miles

D_N = delay savings ratio from Tables 3-7, or Figures 1-5

CST = estimated construction cost

For example, suppose a project is proposed to add shoulders along a 2 mile stretch of a 2-lane rural highway. The estimated construction cost is $150,000, and current ADT is 3000, with average future traffic growth. From Table 3, the delay savings ratio is 1.44, so applying the formula,

$$DSR = 1.44 \times 100{,}000 \times 2 \div 150{,}000 = 1.92$$

This project is estimated to generate $1.92 in delay savings per dollar construction cost. The total discounted delay savings can be obtained by multiplying the delay savings ratio by the construction cost,

or DS = DSR x CST = 1.92 x 150,000 = $288,000.

A similar analysis was also performed for freeways. The results of a 4-lane urban highway with left-turn median improved to a 4-lane freeway are

Table 6. Delay Savings Ratios for a 2-Lane Urban Highway without Shoulders or Left Turn Median, Improved to a 4-Lane Urban Highway without Shoulders or Left Turn Median

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*
1,000	1,876	0.24	2,516	0.38	3,154	0.54
2,000	3,753	1.02	15,031	1.59	16,308	2.29
3,000	5,629	2.39	17,547	3.79	19,462	5.64
4,000	7,505	4.43	10,062	8.17	12,616	33.16
5,000	9,382	7.38	12,578	38.75	15,770	184.08
6,000	11,258	22.35	15,093	167.87	18,925	473.73
7,000	13,134	74.73	17,609	414.45	22,079	842.22

* Discounted Delay Savings per $100,000 construction cost per mile

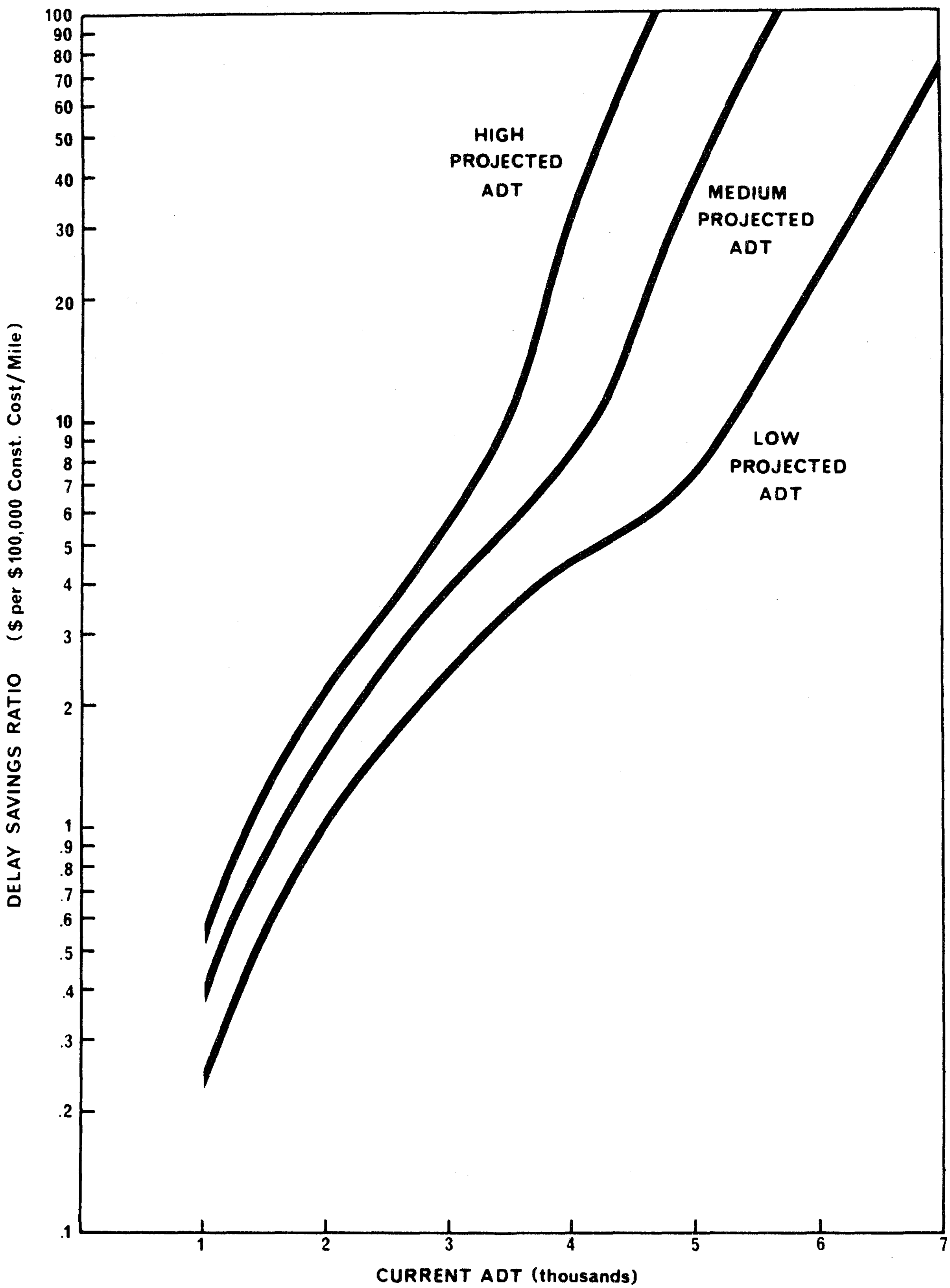

Figure 4. Delay Savings Ratios for a 2-Lane Urban Highway without Shoulders or L.T. Median, Improved to a 4-Lane Urban Highway without Shoulders or L.T. Median

Table 7. Delay Savings Ratios for a 4-Lane Urban Highway without Shoulders or Left Turn Median, Improved to a 4-Lane Urban Highway with Left Turn Median

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*
3,000	5,629	0.10	7,547	0.16	9,462	0.22
4,000	7,505	0.18	10,062	0.28	12,616	0.40
5,000	9,382	0.29	12,578	0.45	15,770	0.63
6,000	11,258	0.42	15,093	0.65	18,925	0.93
7,000	13,134	0.57	17,609	0.90	22,079	1.29
8,000	15,010	0.76	20,124	1.19	25,233	1.72
9,000	16,887	0.97	22,640	1.53	28,387	3.70
10,000	18,763	1.21	25,155	1.92	31,541	15.33
11,000	20,639	1.49	27,671	3.18	34,695	40.96
12,000	22,516	1.79	30,187	10.53	37,849	92.79
13,000	24,392	2.13	32,702	27.84	41,003	196.31
14,000	26,268	2.60	35,218	57.78	44,157	349.79
15,000	28,145	4.80	37,733	110.76	47,311	533.89
16,000	30,021	13.32	40,249	204.08	50,465	725.76
17,000	31,897	29.67	42,764	339.42	53,619	898.04

* Discounted Delay Savings per $100,000 construction cost per mile

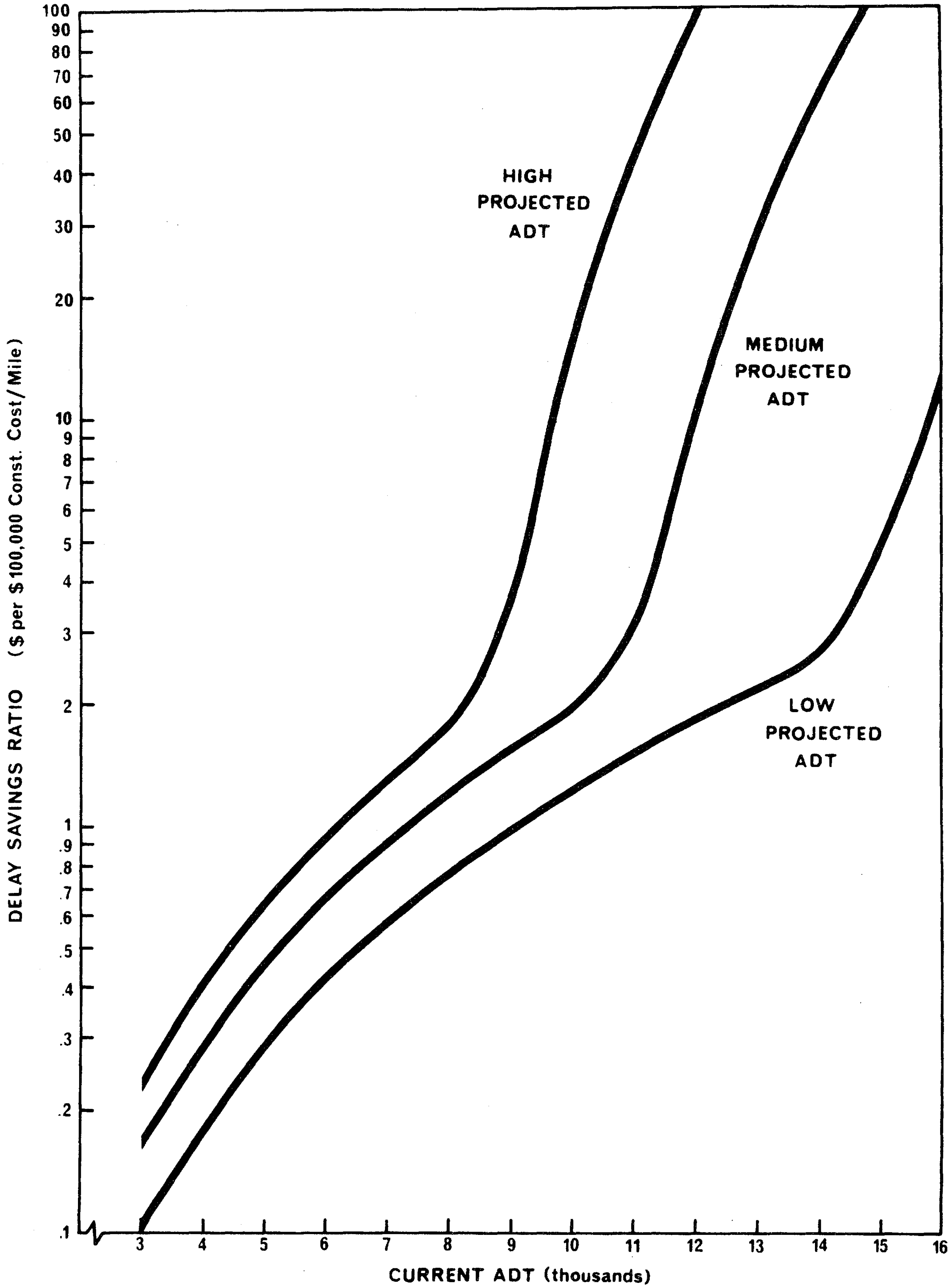

Figure 5. Delay Savings Ratios for a 4-Lane Urban Highway without Shoulders or L.T. Median, Improved to a 4-Lane Urban Highway with L.T. Median

presented in Table 8 and Figure 6. The results of a 4-lane freeway improved to a 6-lane freeway are presented in Table 9 and Figure 7. Due to the higher cost of freeway construction, these numbers are in terms of one million dollars of construction cost, instead of $100,000 of construction cost. Therefore the formula for calculating the delay savings ratio for this particular type of freeway improvement is given as,

$$DSR = D_F \times 1{,}000{,}000 \times L \div CST$$

where D_F = freeway delay savings ratio from Table 6 or Figure 4

As an example, suppose a project is proposed to expand a 4-lane urban freeway to 6 lanes. The proposed project is 3 miles long with an estimated construction cost of $15 million, and a current ADT of 35,000 with high expected future ADT growth. From Table 6, the delay savings ratio is 20.29, therefore the delay savings ratio for the project can be calculated as,

$$DSR = 20.29 \times 1{,}000{,}000 \times 3 \div 15{,}000{,}000 = 4.06$$

This project is estimated to generate $4.06 in delay savings per dollar construction cost.

The tables and figures presented in this section to manually calculate the delay savings ratio can become dated as time passes due to changes in the assumed values of time in the future. For that reason, tables and figures are presented in Appendix C which are calculated in terms of hours of delay savings so different values of time can be used to manually calculate the delay savings ratio.

Comparison of the Delay Savings Model to HEEM-II

The delay savings model was also tested against the Revised Highway Economic Evaluation Model (HEEM-II) (1). The two models were tested on the same

Table 8. Delay Savings Ratios for a 4-Lane Urban Highway with Left Turn Median, Improved to a 4-Lane Freeway

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*
5,000	9,382	0.09	12,578	0.14	15,770	0.20
7,500	14,072	0.21	18,867	0.33	23,656	0.47
10,000	18,763	0.38	25,155	0.60	31,541	0.85
12,500	23,454	0.61	31,444	0.95	39,426	2.25
15,000	28,145	0.89	37,733	1.84	47,311	10.22
17,500	32,835	1.23	44,022	6.68	55,196	39.63
20,000	37,526	2.16	50,311	21.30	63,082	95.74
22,500	42,217	6.33	56,600	58.49	70,967	170.89
25,000	46,908	15.87	62,889	115.16	78,852	258.25
27,500	51,598	37.68	69,178	185.53	86,737	354.54
30,000	56,289	79.02	75,466	264.64	94,623	454.15

* Discounted Delay Savings per $1,000,000 construction cost per mile

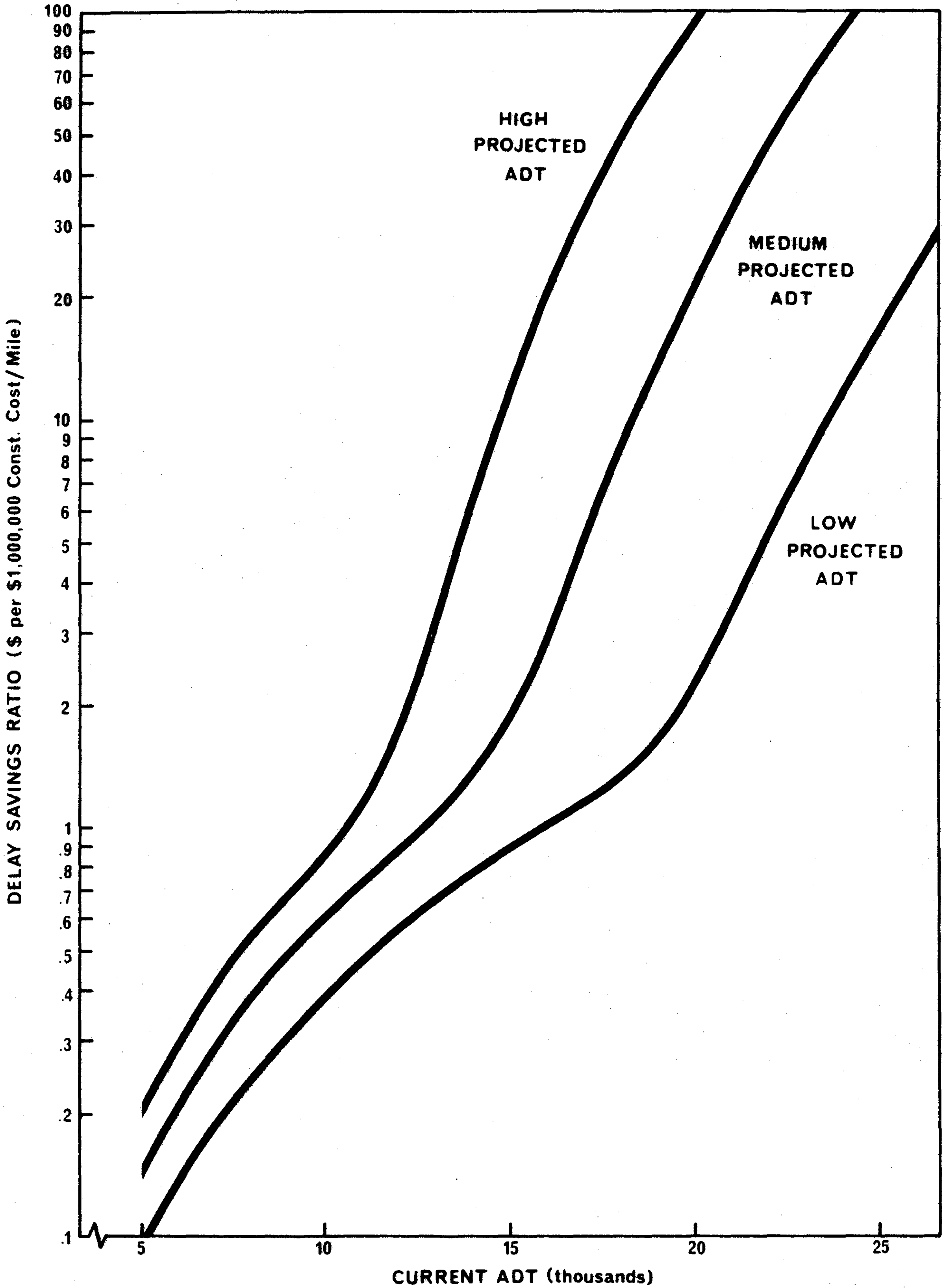

Figure 6. Delay Savings Ratios for a 4-Lane Urban Highway with L.T. Median, Improved to a 4-Lane Freeway

Table 9. Delay Savings Ratios for a 4-Lane Urban Freeway Improved to a 6-Lane Urban Freeway

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*	Projection	Delay Savings Ratio*
20,000	37,526	0.10	50,311	0.15	63,082	0.22
25,000	46,908	0.16	62,889	0.24	78,852	0.36
30,000	56,289	0.23	75,466	0.35	94,623	3.98
35,000	65,671	0.31	88,044	1.70	110,393	20.29
40,000	75,052	0.41	100,622	9.73	126,163	74.32
45,000	84,434	1.05	113,200	31.50	141,934	171.74
50,000	93,815	6.12	125,777	88.98	157,704	296.38
55,000	103,197	17.86	138,355	180.02	173,475	429.72
60,000	112,578	42.41	150,933	293.63	189,245	546.36

* Discounted Delay Savings per $1,000,000 construction cost per mile

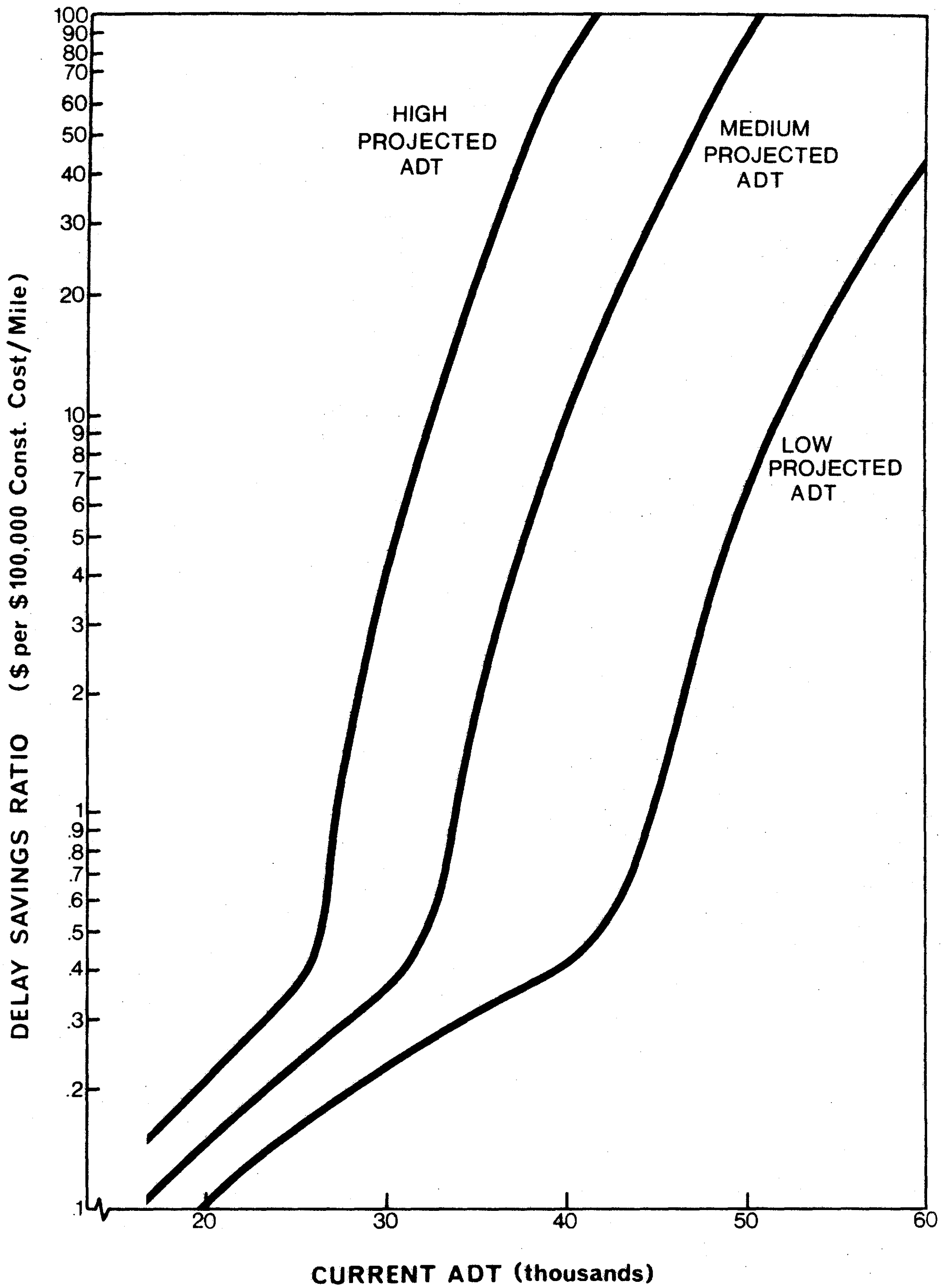

Figure 7. Delay Savings Ratios for a 4-Lane Urban Freeway, Improved to a 6-Lane Urban Freeway

freeway project described above, namely an improvement of a 4-lane urban freeway to 6 lanes per million dollars construction cost per mile. The results are presented in Table 10. The results are similar for lower ADT's, but begin to diverge as the ADT's increase, with the numbers from the delay savings model going up faster than the numbers from HEEM-II. The major difference in the numbers probably is a result of different treatments and assumptions regarding congestion, queues and diversion of traffic in queues. However the relative merits of specific projects should be about the same for both programs. Another interesting point is the relationship between the delay savings ratio and the overall benefit-cost ratio in the HEEM. For low traffic volumes, the benefit-cost ratio is relatively much larger than the delay savings ratio, but that difference goes down and almost disappears as traffic volumes increase.

Table 10. Comparison of Delay Saving Model Estimates to HEEM for a 4-Lane Urban Freeway Improved to a 6-Lane Urban Freeway

	Delay Savings Model	HEEM-II	
Current ADT	Delay Savings Ratio*	Delay Savings Ratio*	Benefit-Cost Ratio
	Low Projected ADT		
20,000	0.10	0.16	1.09
25,000	0.16	0.25	1.67
30,000	0.23	0.36	2.38
35,000	0.31	0.50	3.19
40,000	0.41	0.66	4.13
45,000	1.05	1.54	5.68
50,000	6.12	4.03	8.52
	Medium Projected ADT		
20,000	0.15	0.24	1.64
25,000	0.24	0.39	2.52
30,000	0.35	0.57	3.58
35,000	1.70	1.72	5.49
40,000	9.73	4.99	9.16
45,000	31.50	11.03	15.24
50,000	88.98	19.19	22.99
	High Projected ADT		
20,000	0.22	0.35	2.26
25,000	0.36	0.62	3.53
30,000	3.98	2.60	6.25
35,000	20.29	7.68	11.64
40,000	74.32	15.75	19.46
45,000	171.74	20.62	22.15

* delay savings ratio is per million dollars of construction cost per mile.

CONCLUSION

This report presents a model to calculate the delay savings generated by a highway improvement. The model goes through a number of calculations to estimate the hourly speed, congestion, and delay over a specified planning horizon. These delays are then summed, and the reduction in delay due to the proposed improvement is compared to the estimated construction costs to rank projects according to the delay savings ratio.

The biggest advancement of the delay savings model is the incorporation of recent field data on the speed-volume relationships on Texas highways. These improved data should prove valuable in improving the accuracy of delay savings estimates for proposed highway improvement projects.

Additional work needs to be done in this area in order to improve the accuracy of the delay savings generated by highway projects. Some effects of specific projects on highway speeds and capacity are not well defined. That is especially the case for assumed traffic volumes near to or even greater than capacity. The specific interaction of motorists in the queue is not yet well defined. Another aspect of the same problem is diversion. When a major change along a facility occurs, whether it be improved capacity, or severe congestion if nothing is done, will typically cause diversion to take place. The delay savings model, presented here, does not currently incorporate any explicit diversion mechanism. In some circumstances, the accuracy of the model could be improved by including these types of factors.

REFERENCES

1. J. L. Memmott and J. L. Buffington, Revised Highway Economic Evaluation Model (HEEM-II), Research Report 225-28F, Texas Transportation Institute, Texas A&M University, College Station, Texas, October 1983.

2. Multisystems, Inc. (modified by W. Smith and Assoc.), Highway Investment Analysis Package (HIAP): Vol II, Technical Manual Federal Highway Administration, June 1979.

3. M. K. Chui, J. L. Memmott, and J. L. Buffington, Predicting the Effects of Roadway Improvements on Land Use and Traffic Volumes, Research Report 225-27, Texas Transportation Institute, Texas A&M University, College Station, Texas, July 1983.

4. T. Urbanik, Speed/Volume Relationships on Texas Highways, Research Report 327-2F, Texas Transportation Institute, Texas A&M University, College Station, Texas, October 1983.

APPENDIX A

DELAY SAVINGS CALCULATIONS

The calculation of delay savings in this model follows, in most respects, the methods used in other models. Some differences and improvements are incorporated in the program generated projected ADT and in the calculation of average speeds for congested periods.

Calculation of the Projected Traffic Volume

One of the critical aspects of the desirability of a proposed highway project is the current traffic on the facility, and along with that, an estimate of future conditions. An important measurement of those conditions is the ADT, both current and projected.

Nearly all computerized models to calculate benefits of highway projects require the projected ADT as part of the input data. That is the case for both the HEEM-II (1) and the HIAP (2). However when comparing large numbers of projects, traffic projections to the same year may not be readily available for all projects and the projections may not be consistent with far different methods used to make the projections. For those reasons the delay savings model incorporates a traffic projection mechanism, so that if a traffic projection is not given in the input data, one will be generated within the program.

The equations used to make traffic projections within the model are taken from empirical research concerning traffic growth in TTI Research Report 225-27 (3) by Chui, Memmott and Buffington. This report examines the traffic growth on several highways throughout Texas as a function of several variables, including adjacent lane development, highway type, location, capacity changes, and median treatments. A total of 187 count stations over a ten year period were used to estimate coefficients in a linear regression model. The equations used in the delay savings model are derived from the results presented in that report. The projected ADT is calculated using the following equation,

$$ADT_p = ADT_c(T+1)^r$$

where ADT_p = projected ADT to year T

ADT_c = current ADT, year 1

T = year at end of planning horizon

r = coefficient, taken from Table 8

As can be seen in Table 11, there are six possible different ADT projections. They are divided between rural and urban areas, and each of three categories of ADT growth; low, medium, and high. The specific coefficient used is determined by the input data on the project. When the projected ADT is determined, ADT for each year during the planning horizon using the following equation,

$$ADT_t = ADT_c(t+1)^e$$

where ADT_t = estimated ADT for year t

$e = (\ln ADT_p - \ln ADT_c)/\ln T$

Calculation of Average Speed

After the ADT for each year has been calculated, the ADT must be converted into hourly traffic volumes. The percentages of daily traffic for each hour, used in the delay savings model, are listed in Table 12. These are taken from TTI Research Report 327-2F (4) and are intended to reflect typical or average situations in urban and rural areas.

The calculation of average speed is based upon recent field data collected as part of this project, reported in TTI Research Report 327-2F (4). There are four assumed critical points along the speed-volume curve which are used to

Table 11. Coefficients for ADT Projection Equation

	ADT Growth Category		
	Low	Medium	High
Rural Areas	.1139	.2096	.2840
Urban Areas	.2067	.3030	.3773

Table 12. Hourly Traffic Volume as Percent of ADT

Hour	Urban Areas[1]	Rural Areas[2]
1	0.913	0.864
2	0.500	0.485
3	0.394	0.485
4	0.298	0.105
5	0.391	0.169
6	1.768	0.485
7	6.316	1.875
8	7.683	6.783
9	6.016	6.994
10	5.122	5.393
11	4.915	5.456
12	5.114	5.941
13	5.124	6.236
14	5.275	6.151
15	5.710	6.214
16	7.117	6.720
17	7.870	7.478
18	7.629	8.784
19	5.695	6.552
20	4.417	4.950
21	3.187	3.623
22	3.302	3.960
23	3.373	2.928
24	1.871	1.559

[1] taken from IH 610, Station 5166
[2] taken from SH 336, Station 5069

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[1] taken from IH 610, Station 5166
[2] taken from SH 336, Station 5069

derive the average speed for any hourly traffic volume. The highest average speed at zero traffic volume, the point where traffic begins to congest at LOS D/E, capacity at the beginning of LOS F, and a point where a minimum congested average speed is reached. These points are illustrated in Figure 8. The speeds and volumes, depicted in Figure 8, are calculated from the field data in TTI Research Report 327-2F (4) given in Table 13. The speeds and volumes are calculated as follows,

SP_0 = SPL + 5 where SPL = speed limit

$SP_1 = SP_0 - SLP(V_1)$ where SLP and V_1 are from Table 13 and with $SP_1 \geq 28.5$

$SP_2 = SP_1/2.28$ with $SP_2 \geq 15$

$V_2 = 1.2(V_1)$

$SP_3 = SP_1/3.8$ with $SP_3 \geq 10$

$V_3 = 2.0(V_1)$

For any volumes greater than V_1 a queue is assumed to form consisting of the volume in excess of V_1. When a queue is present during the hour, the average speed is determined using V_1 plus the average number of vehicles in the queue during the hour. In the hour the queue dissipates, two calculations are made, for both the congested and uncongested portions of the hour.

V_1 is used as the point where the queue is assumed to begin forming instead of V_2 for two reasons. First, changes in directional split during the day are not incorporated into the model, a 50/50 split is being assumed. Secondly variability of traffic volumes within the hour can cause congestion even if the overall hourly volume is below capacity. For those reasons V_1 was chosen as the point where the queue begins to form in an attempt to adjust for those factors.

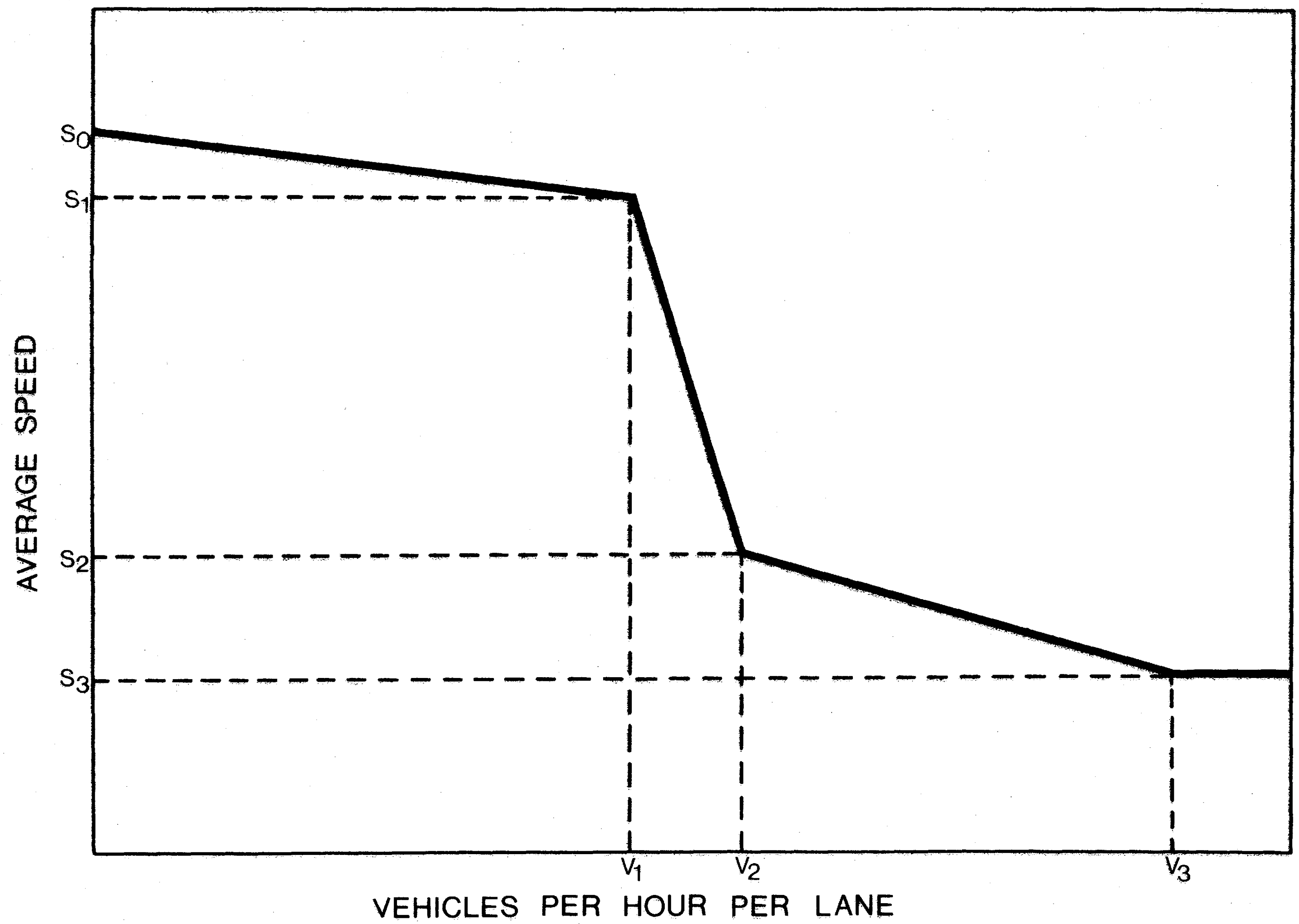

Figure 8. Assumed Speed - Volume Curve

Table 13. Coefficients for Speed-Volume Calculations

Facility	Slope (SLP)	Volume per Lane at LOS D/E(V_1)
2-Lane Rural no shoulders	.035	350
2-Lane Rural with shoulders	.017	500
2-Lane Urban no shoulders	.040	350
2-Lane Urban with shoulders	.020	500
4+ Lane Rural no shoulders	.0035	1000
4+ Lane Rural with shoulders	.003	1000
4+ Lane Urban no shoulders, no L. T. median	.015	500
4+ Lane Urban with shoulders, no L. T. median	.014	500
4+ Lane Urban no shoulders, with L. T. median	.012	650
4+ Lane Urban with shoulders, with L. T. median	.010	650
Freeway	.002	1500

Calculation of Delay Savings

Hourly delay can be calculated using the following equation,

$$DLY = L(V)/SP$$

where DLY = total hourly delay

L = length of project in miles

SP = calculated average speed

If the queue has not dissipated at the end of the 24 hour period, then an additional delay is added to the last hour for the delay to dissipate the remaining queue during the next hour. A warning is printed out if the queue does not dissipate for any year on the proposed route, indicating the projected ADT may be too high. The additional delay of a residual queue at the end of the day, is calculated as,

$$DQUE = QUE/2$$

where DQUE = additional delay to dissipate queue

QUE = number of vehicles in queue at the end of the 24 hour period

The dollar cost of the delay can then be calculated as,

$$CDLY = DLY[(1-PT)VT_C + (PT)VT_T]$$

where CDLY = hourly delay cost

PT = proportion trucks

VT_C = value of time, cars ($/hr)

VT_T = value of time, trucks ($/hr)

Each hour can then be summed to give a daily delay cost, converted to a yearly cost, and discounted to the present.

$$DCST = (COST)(365)/(1+R)^T$$

where DCST = discounted yearly delay cost

COST = daily delay cost

R = discount rate

T = length of planning horizon

Delay savings are simply the difference in delay costs between the existing alternative and the improved alternative, summed over the planning horizon

$$DSV = \sum_{t=1}^{T} (DCST_{Et} - DCST_{Pt})$$

where DSV = total discounted delay savings

$DCST_{Et}$ = discounted yearly delay cost on the existing route in year t

$DCST_{Pt}$ = discounted yearly delay cost on the proposed route in year t

If the existing route is not builtover with the proposed, which would be the case with a new location costruction or a busway, the above equation for delay savings is slightly more complicated, because the existing route must be calculated a second time for the portion of traffic left after the proposed is built. That cost also must be subtracted to determine the delay savings attributable to the proposed project.

APPENDIX B

PROGRAM DOCUMENTATION

Program Description

The delay savings model is a computerized program written in FORTRAN IV and designed for batch input. The program can run on both a WATFIV compiler and the IBM Fortran-VS compiler. The program uses about 400K of memory, .13 seconds compile time, and 23.55 seconds execution time to process 210 problems on the WATFIV compiler. The source code is 448 lines long. There are no subroutines in the program.

This Appendix contains a computer generated flow chart, a variable dictionary, a program listing, and sample output.

```
E=ENTRY, T=TERMINAL, C=CALL, R=READ, W=WRITE

                        C
                        C      DELAY SAVINGS MODEL  WRITTEN BY JEFFERY L. MEMMOTT
                        C
                        C      DATA INPUT CONSISTS OF ONE HEADER CARD WHICH CONTAINS THE CURRENT
                        C      YEAR AND INITIAL ASSUMPTIONS.  EACH OF THE OTHER DATA CARDS
                        C      IDENTIFY A SEPARATE PROJECT.  DATA INCLUDES A PROBLEM NUMBER,
                        C      CURRENT AND PROJECTED ADT, DESCRIPTIONS OF BOTH EXISTING AND
                        C      PROPOSED ROUTES, AND CONSTRUCTION COST.
                        C

                               DIMENSION LOC(2),IHWY(2),LN(2),DT(2),SPL(2),ISH(2),LFT(2),
                              *ISIG(2),IDEV(2),DES(6),ISW(2),ILC(2),IHY(4),IHT(2),TRAF(24,2),
                              *SLP(11),CAP(11),IT(2),DCST(2,2,41),DSV(9999),CON(9999),
                              *INDX(9999),DSRP(6,9999),ADT(41),OCP(2)
                               DATA ISW/'R','U'/
                               DATA IHY/'U','D','F','B'/
                               DATA TRAF/.00864,.00485,.00295,.00105,.00169,.00485,.01875,.06783,
                              *.06994,.05393,.05456,.05941,.06236,.06151,.06214,.0672,.07478,
                              *.08784,.06552,.0495,.03623,.0396,.02928,.01559,.00913,.005,.00394,
                              *.00298,.00391,.01768,.06316,.07683,.06016,.05122,.04915,.05114,
                              *.05124,.05275,.0571,.07117,.0787,.07629,.05695,.04417,.03187,
                              *.03302,.03373,.01871/
                               DATA SLP/.035,.017,.040,.020,.0035,.003,.015,.014,.0120,.0100,
                              *.002/
                               DATA CAP/350.,500.,350.,500.,1000.,1000.,500.,500.,650.,650.,
                              *1500./
                       EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
I----------------------        DO 98 JJ=1,9999                                                        E
I                      EEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEEE
I                                                            I
I                      ..........................................................................
I                      .       DSV(JJ)=0.                                                        .
I                      .       CON(JJ)=0.                                                        .
I                      ..........................................................................
I                                                            I
I                      ..........................................................................
----------------------*    98 CONTINUE                                                            .
                       ..........................................................................
                                                             I
                        C      SET END FLAG AND PROBLEM COUNT TO ZERO
                                                             I
                       ..........................................................................
                       .       IEND=0                                                            .
                       .       IPROB=0                                                           .
                       .       ICT=0                                                             .
                       .       N=0                                                               .
                       .       TCST=0.                                                           .
                       ..........................................................................
                                                             I
                        C      READ IN FIRST CARD
                                                             I
                       RRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRR
                       R       READ (5,5,END=100) IYR,PT,VTC,VTT,DR,IPL                      *-----------------------------------V
                       RRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRRR                                     I
                                                             I                                                                   I
1 2 3 4 5 6 7 8 9 0                                                                            . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
```

```
      5 FORMAT (4X,I4,4(F5.0),I3)

.       GOTO 110

 C      NO DATA CARDS

                                                OK

W   100 WRITE (6,10)                                                        W

     10 FORMAT (//2X,'NO DATA GIVEN FOR ANALYSIS, JOB ENDED')

.       GOTO 600

 C      SET DEFAULT ASSUMPTIONS

                                                OK

.   110 IF (PT.EQ.0.) PT=8.                                                 .
.       IF (VTC.EQ.0.) VTC=10.2                                             .
.       IF (VTT.EQ.0.) VTT=19.2                                             .
.       IF (DR.EQ.0.) DR=8.                                                 .
.       IF (IPL.EQ.0) IPL=20                                                .

 C      PRINT OUT ASSUMPTIONS

W       WRITE (6,15) IYR,PT,VTC,VTT,DR,IPL                                  W

     15 FORMAT ('1',51X,'*** DELAY SAVINGS MODEL ***'////4X,
       *'CURRENT YEAR',23X,I4//4X,'ASSUMPTIONS'/6X,'PERCENTAGE TRUCKS',
       *13X,F7.2/6X,'VALUE OF TIME, CARS ($/HR)',4X,F7.2/6X,
       *'VALUE OF TIME, TRUCKS ($/HR)',2X,F7.2/6X,'DISCOUNT RATE (%)',
       *13X,F7.2/6X,'PLANNING HORIZON (YEARS)',7X,I3/'1',51X,
       *'*** PROBLEM INPUT DATA ***'/)

.       PT=PT/100.                                                          .
.       DR=DR/100.                                                          .
```

```
C      ZERO OUT PROBLEM ARRAYS
                                                OK
  115 IFLAG=0
      IBLD=0
      PBLD=0.
      LQUE=0
      DO 116 I=1,2
      DO 116 I1=1,2
      DO 116 IY=1,41
      DCST(I,I1,IY)=0.
  116 CONTINUE
C      READ IN PROBLEM CARD
      IPROB=IPROB+1
      READ (5,20,END=120) KPROB,CADT,PADT,(LOC(I),IHWY(I),LN(I),DT(I),
     *SPL(I),ISH(I),LFT(I),ISIG(I),IDEV(I),I=1,2),IBLD,PBLD,CST,
     *(DES(J),J=1,6)
   20 FORMAT (I4,2(F6.0),2(A1),I2,F4.0,F2.0,2(I1),I2,I1,2(A1),I2,
     *F4.0,F2.0,2(I1),I2,2(I1),F3.0,F6.0,6(A4))
      GOTO 130
C      ALL PROBLEMS READ, GO TO SORTING
```

```
                                   OK
                                   I
  120 IEND=1
                                   I
      GOTO 497

C     CHECK PROBLEM NUMBER

                                   OK
                                   I
  130 IF (KPROB.GT.0) GOTO 135
                                   I
      WRITE (6,25) IPROB
                                   I
   25 FORMAT (//2X,'PROBLEM NUMBER MUST BE POSITIVE, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
                                   I
      GOTO 115

C     CHECK IF VALID LOCATION

                                   OK
                                   I
  135 IPROB=KPROB
                                   I
      DO 140 I=1,2
                                   I
      IF (LOC(I).EQ.ISW(1).OR.LOC(I).EQ.ISW(2)) GOTO 140
                                   I
      IFLAG=1
                                   I
```

47

```
1 2 3 4 5 6 7 8 9 0                    PAGE  5                         . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
                                          OK---------------------------------------O

 -------------------*   140 CONTINUE

        .      IF (IFLAG.NE.1) GOTO 150                                *-----------------V

        C      ERROR IN LOCATION

 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
 W             WRITE (6,30) IPROB                                              W
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW

            30 FORMAT (//2X,'INVALID LOCATION, ',
              *'PROBLEM NUMBER ',I4,' SKIPPED'//)

        .      GOTO 115                                                *-----------------I---I---A

        C      SET RURAL-URBAN SWITCH

                                          OK---------------------------------------O

 I--------------------   150 DO 160 I=1,2

        .      IF (LOC(I).EQ.ISW(1)) ILC(I)=1
        .      IF (LOC(I).EQ.ISW(2)) ILC(I)=2

 --------------------*   160 CONTINUE

        C      CHECK HIGHWAY TYPE

 I--------------------       DO 180 I=1,2

        .      IHT(I)=0

1 2 3 4 5 6 7 8 9 0                                                    . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
```

PAGE 6

```
      DO 170 J=1,4
      IF (IHWY(I).EQ.IHY(J)) IHT(I)=J
  170 CONTINUE
      IF (IHT(I).GT.0) GOTO 180
C     INVALID HIGHWAY TYPE
      WRITE (6,35) IPROB
   35 FORMAT (//2X,'INVALID HIGHWAY TYPE,
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
      GOTO 115
                                  OK
  180 CONTINUE
C     CHECK NUMBER OF LANES
      DO 190 I=1,2
      IF (LN(I).GE.1.OR.LN(I).LE.20) GOTO 190
C     INVALID NUMBER OF LANES
      WRITE (6,40) IPROB
```

```
I                                             I                                         I   I   I   I
I            40 FORMAT (//2X,'INVALID NUMBER OF LANES, MUST BE 1-20,                    I   I   I   I
I              *'PROBLEM NUMBER ',I4,' SKIPPED'//)                                      I   I   I   I
I                                             I                                         I   I   I   I
I          ..............................................................               I   I   I   I
I          .      GOTO 115                                              *---------------I---I---A   I
I          ..............................................................               I   I   I   I
I                                                                                       I   I   I   I
I                                                                                       I   I   I   I
I                                                                                       I   I   I   I
I                                             OK----------------------------------------O   I   I   I
I                                             I                                             I   I   I
I          ..............................................................                   I   I   I
-----------*   190 CONTINUE                                             .                   I   I   I
           ..............................................................                   I   I   I
                                              I                                             I   I   I
           C      CHECK SPEED LIMIT                                                         I   I   I
                                              I                                             I   I   I
           ..............................................................                   I   I   I
I-----------      DO 200 I=1,2                                          .                   I   I   I
I          ..............................................................                   I   I   I
I                                             I                                             I   I   I
I          ..............................................................                   I   I   I
I          .      IF (SPL(I).EQ.0.) SPL(I)=55.                          .                   I   I   I
I          ..............................................................                   I   I   I
I                                             I                                             I   I   I
I          ..............................................................                   I   I   I
I          .      IF (SPL(I).GE.15..AND.SPL(I).LE.70.) GOTO 200         *---------------V   I   I   I
I          ..............................................................               I   I   I   I
I                                             I                                         I   I   I   I
I          C      INVALID SPEED LIMIT                                                   I   I   I   I
I                                             I                                         I   I   I   I
I          WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW               I   I   I   I
I          W      WRITE (6,45) IPROB                                    W               I   I   I   I
I          WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW               I   I   I   I
I                                             I                                         I   I   I   I
I            45 FORMAT (//2X,'INVALID SPEED LIMIT, MUST BE 15-70, ',                    I   I   I   I
I              *'PROBLEM NUMBER ',I4,' SKIPPED'//)                                      I   I   I   I
I                                             I                                         I   I   I   I
I          ..............................................................               I   I   I   I
I          .      GOTO 115                                              *---------------I---I---A   I
I          ..............................................................               I   I   I   I
I                                                                                       I   I   I   I
I                                                                                       I   I   I   I
I                                                                                       I   I   I   I
I                                             OK----------------------------------------O   I   I   I
I                                             I                                             I   I   I
I          ..............................................................                   I   I   I
-----------*   200 CONTINUE                                             .                   I   I   I
           ..............................................................                   I   I   I
                                              I                                             I   I   I
           C      CHECK SHOULDER SWITCH                                                     I   I   I
                                              I                                             I   I   I
           ..............................................................                   I   I   I
I-----------      DO 210 I=1,2                                          .                   I   I   I
I          ..............................................................                   I   I   I
I                                             I                                             I   I   I
I                                             I                                             I   I   I
```

```
      IF (ISH(I).EQ.0.OR.ISH(I).EQ.1) GOTO 210
C     INVALID SHOULDER SWITCH
      WRITE (6,50) IPROB
   50 FORMAT (//2X,'INVALID SHOULDER SWITCH, MUST BE 0 OR 1, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
      GOTO 115
                                  OK
  210 CONTINUE
C     CHECK LEFT TURN SWITCH
      DO 220 I=1,2
      IF (LFT(I).EQ.0.OR.LFT(I).EQ.1) GOTO 220
C     INVALID LEFT TURN SWITCH
      WRITE (6,55) IPROB
   55 FORMAT (//2X,'INVALID LEFT TURN SWITCH, MUST BE 0 OR 1, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
      GOTO 115
                                  OK
```

```
      220 CONTINUE
C     CHECK PROJECTED ADT GROWTH CATEGORY
      DO 230 I=1,2
      IF (IDEV(I).EQ.0) IDEV(I)=2
      IF (IDEV(I).GT.0.AND.IDEV(I).LE.3) GOTO 230
C     INVALID PROJECTED ADT GROWTH CATEGORY
      WRITE (6,57) IPROB
   57 FORMAT (//2X,'INVALID PROJECTED ADT GROWTH CODE, MUST BE 1-3, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
      GOTO 115
      230 CONTINUE
C     CHECK BUILDOVER SWITCH
      IF (IBLD.EQ.0.OR.IBLD.EQ.1) GOTO 240
C     INVALID BUILDOVER SWITCH
      WRITE (6,60) IPROB
   60 FORMAT (//2X,'INVALID BUILDOVER SWITCH, MUST BE 0 OR 1, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
      GOTO 115
C     CHECK PERCENTAGE PERSONS USING PROPOSED FACILITY
```

```
  220 CONTINUE

C     CHECK PROJECTED ADT GROWTH CATEGORY

      DO 230 I=1,2

      IF (IDEV(I).EQ.0) IDEV(I)=2

      IF (IDEV(I).GT.0.AND.IDEV(I).LE.3) GOTO 230

C     INVALID PROJECTED ADT GROWTH CATEGORY

      WRITE (6,57) IPROB

   57 FORMAT (//2X,'INVALID PROJECTED ADT GROWTH CODE, MUST BE 1-3, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)

      GOTO 115

                                   OK

  230 CONTINUE

C     CHECK BUILDOVER SWITCH

      IF (IBLD.EQ.0.OR.IBLD.EQ.1) GOTO 240

C     INVALID BUILDOVER SWITCH

      WRITE (6,60) IPROB

   60 FORMAT (//2X,'INVALID BUILDOVER SWITCH, MUST BE 0 OR 1, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)

      GOTO 115

C     CHECK PERCENTAGE PERSONS USING PROPOSED FACILITY
```

```
                                        OK-----------------------------------------------------------O
                                        I
. 240 IF (IBLD.EQ.0) GOTO 245                                                  *---------------------V
                                        I
.     IF (PBLD.EQ.0.) PBLD=50.                                                 .
                                        I
.     IF (PBLD.GT.0..AND.PBLD.LT.100.) GOTO 245                                *---------------------V
                                        I
C     INVALID PERCENTAGE PERSONS
                                        I
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W     WRITE (6,65) IPROB                                                      W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                        I
   65 FORMAT (//2X,'WHEN EXISTING ROUTE IS NOT BUILTOVER, PERCENTAGE ',
     *'PERSONS USING PROPOSED FACILITY MUST BE 1-99, ',
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
                                        I
.     GOTO 115                                                                 *---------------------I---I---A

C     CHECK CONSTRUCTION COST

                                        OK-----------------------------------------------------------O
                                        I
. 245 IF (CST.GT.0.) GOTO 250                                                  *---------------------V
                                        I
C     INVALID CONSTRUCTION COST
                                        I
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W     WRITE (6,66) IPROB                                                      W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                        I
   66 FORMAT (//2X,'CONSTRUCTION COST MUST BE POSITIVE,
     *'PROBLEM NUMBER ',I4,' SKIPPED'//)
                                        I
.     GOTO 115                                                                 *---------------------I---I---A

1 2 3 4 5 6 7 8 9 0                                                     . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
```

```
C     CALCULATE PROJECTED ADT IF NECESSARY

                                OK

  250 PYR=IPL+1

      IF (PADT.GT.0.) GOTO 290

      IF (ILC(1).EQ.1) GOTO 282

      IF (IDEV(1)-2) 260,270,280

  260 PADT=CADT*(PYR**.3773)

      GOTO 290

                                OK

  270 PADT=CADT*(PYR**.3030)

      GOTO 290

                                OK

  280 PADT=CADT*(PYR**.2067)

      GOTO 290
```

```
  282 IF (IDEV(1)-2) 284,286,288

  284 PADT=CADT*(PYR**.2840)

      GOTO 290

  286 PADT=CADT*(PYR**.2096)

      GOTO 290

  288 PADT=CADT*(PYR**.1133)

C     CALCULATE ADT FOR EACH YEAR

  290 EXPNT=(ALOG(PADT)-ALOG(CADT))/ALOG(PYR)
      IPN=IPL+1

      DO 300 IY=1,IPN

      ADT(IY)=CADT*(IY**EXPNT)
```

```
                                   OK
  282 IF (IDEV(1)-2) 284,286,288
  284 PADT=CADT*(PYR**.2840)
      GOTO 290
                                   OK
  286 PADT=CADT*(PYR**.2096)
      GOTO 290
                                   OK
  288 PADT=CADT*(PYR**.1133)
C     CALCULATE ADT FOR EACH YEAR
                                   OK
  290 EXPNT=(ALOG(PADT)-ALOG(CADT))/ALOG(PYR)
      IPN=IPL+1
      DO 300 IY=1,IPN
      ADT(IY)=CADT*(IY**EXPNT)
```

57

```
  300 CONTINUE
C     PRINT OUT INPUT DATA
      ICT=ICT+1
      IF (ICT.LT.5) GOTO 302
      ICT=1
      WRITE (6,64)
   64 FORMAT ('1')
                                                          OK
  302 WRITE (6,70) IPROB,(DES(J),J=1,6)
   70 FORMAT (///4X,'PROBLEM NUMBER ',I4,5X,6(A4))
      WRITE (6,71) CADT,PADT
   71 FORMAT (/6X,'CURRENT ADT',4X,F7.0/6X,'PROJECTED ADT  ',F7.0)
      WRITE (6,72)
   72 FORMAT (/6X,'FACILITY DESC.',3X,'LOC.',3X,'HWY TYPE',3X,
     *'NO. LANES',3X,'LENGTH',3X,'SPD LMT',3X,'SHOULDERS',3X,
     *'L.T. MEDIAN',3X,'SIGNALS/MI.',3X,'ADT GROWTH')
      DO 380 I=1,2
      IF (I.GT.1) GOTO 305
```

```
1 2 3 4 5 6 7 8 9 0                         PAGE 13                       . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1

WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W      WRITE (6,68)                                                        W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                       I
    68 FORMAT (8X,'EXISTING')
                                       I
............................................................................
.      GOTO 307                                                            *-------------------V
............................................................................

                                       OK----------------------------------------------------I---O
                                       I
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W  305 WRITE (6,69)                                                        W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                       I
    69 FORMAT (8X,'PROPOSED')
                                       I
                                       OK----------------------------------------------------O
                                       I
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W  307 WRITE (6,73) LOC(I),IHWY(I),LN(I),DT(I),SPL(I)                      W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                       I
    73 FORMAT ('+',T25,A1,9X,A1,9X,I2,7X,F5.1,6X,F3.0)
                                       I
............................................................................
.      IF (ISH(I).GT.0) GOTO 310                                           *----------------------V
............................................................................
                                       I
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W      WRITE (6,74)                                                        W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                       I
    74 FORMAT ('+',T76,'YES')
                                       I
............................................................................
.      GOTO 320                                                            *-------------------V
............................................................................

                                       OK----------------------------------------------------I---O
                                       I
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
W  310 WRITE (6,75)                                                        W
WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                                       I
    75 FORMAT ('+',T77,'NO')
                                       I
                                       I
                                       I
                                       I
                                       I
                                       I
1 2 3 4 5 6 7 8 9 0                                                       . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
```

```
                              OK----------------------------------------O
                               I
 .............................................................
 .  320 IF (LFT(I).GT.0) GOTO 330                              *--------------------V
 .............................................................
                               I
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
 W      WRITE (6,76)                                          W
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                               I
     76 FORMAT ('+',T89,'YES')
                               I
 .............................................................
 .      GOTO 340                                               *----------------V
 .............................................................

                              OK----------------------------------------I---O
                               I
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
 W  330 WRITE (6,77)                                          W
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                               I
     77 FORMAT ('+',T90,'NO')
                               I
                              OK----------------------------------------O
                               I
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
 W  340 WRITE (6,78) ISIG(I)                                  W
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                               I
     78 FORMAT ('+',T103,I2)
                               I
 .............................................................
 .      IF (IDEV(I)-2) 350,360,370                             *--------------------V
 .                                                             *----------------V
 .............................................................
                               I
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
 W  350 WRITE (6,79)                                          W
 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW
                               I
     79 FORMAT ('+',T116,'HIGH')
                               I
 .............................................................
 .      GOTO 380                                               *------------V
 .............................................................

                              OK------------------------------------I---I---O
                               I
                               I
                               I
                               I
                               I
```

```
1 2 3 4 5 6 7 8 9 0                         PAGE 15                              . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
I                                              I                                                I   I       I   I   I
I                 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW           I   I       I   I   I
I                 W  360 WRITE (6,80)                                             W            I   I       I   I   I
I                 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW           I   I       I   I   I
I                                              I                                                I   I       I   I   I
I                     80 FORMAT ('+',T115,'MEDIUM')                                             I   I       I   I   I
I                                              I                                                I   I       I   I   I
I                 ...................................................................           I   I       I   I   I
I                 .       GOTO 380                                                   *--------------V   I       I   I   I
I                 ...................................................................           I   I       I   I   I
I                                                                                               I   I       I   I   I
I                                             OK------------------------------------------------I---O       I   I   I
I                                              I                                                I           I   I   I
I                 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW           I           I   I   I
I                 W  370 WRITE (6,81)                                             W            I           I   I   I
I                 WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW           I           I   I   I
I                                              I                                                I           I   I   I
I                     81 FORMAT ('+',T116,'LOW')                                                I           I   I   I
I                                              I                                                I           I   I   I
I                                             OK------------------------------------------------O           I   I   I
I                                              I                                                            I   I   I
I                 ...................................................................                       I   I   I
-------------------*  380 CONTINUE                                                  .                       I   I   I
                  ...................................................................                       I   I   I
                                               I                                                            I   I   I
                  WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW                      I   I   I
                  W       WRITE (6,91)                                            W                        I   I   I
                  WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW                      I   I   I
                                               I                                                            I   I   I
                      91 FORMAT (1X,' ')                                                                    I   I   I
                                               I                                                            I   I   I
                  ...................................................................                       I   I   I
                  .       IF (IBLD.EQ.0) GOTO 390                                    *-----------------------V   I   I   I
                  ...................................................................                   I   I   I   I
                                               I                                                        I   I   I   I
                  ...................................................................                   I   I   I   I
                  .       IF (IHT(2).EQ.4) GOTO 385                                  *------------------V   I   I   I   I
                  ...................................................................               I   I   I   I   I
                                               I                                                    I   I   I   I   I
                  WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW              I   I   I   I   I
                  W       WRITE (6,63) PBLD                                       W                I   I   I   I   I
                  WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW              I   I   I   I   I
                                               I                                                    I   I   I   I   I
                      63 FORMAT (6X,'PROPOSED DOES NOT BUILDOVER EXISTING. ',F5.2,                  I   I   I   I   I
                        *' PERCENT PERSONS TO USE PROPOSED FACILITY')                               I   I   I   I   I
                                               I                                                    I   I   I   I   I
                  ...................................................................               I   I   I   I   I
                  .       GOTO 387                                                   *--------------V   I   I   I   I   I
                  ...................................................................           I   I   I   I   I   I
                                                                                                I   I   I   I   I   I
1 2 3 4 5 6 7 8 9 0                                                              . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
```

```
                                        OK--------------------------------------------I---O
W  385 WRITE (6,82) PBLD                                                            W

    82 FORMAT (6X,'PROPOSED DOES NOT BUILDOVER EXISTING. ',F5.2,
      *' PERCENT PERSONS FROM EXISTING FACILITIY PASSENGER CARS ',
      *'TO USE PROPOSED FACILITY')
                                        OK--------------------------------------------O

.  387 PBLD=PBLD/100.                                                               .

                                        OK-------------------------------------------------O

W  390 WRITE (6,83) CST                                                             W

    83 FORMAT (6X,'CONSTRUCTION COST ($000)',3X,F7.0)

 C      DETERMINE APPROPRIATE HIGHWAY TYPE FOR SPEED CALCULATION

I-------------------  392 DO 479 I=1,2                                               .

.       IT(I)=11                                                                    .

.       IF (IHT(I).GE.3) GOTO 397                                                   *--------------------V

.       IF (LN(I).GT.2) GOTO 395                                                    *----------------V

.       IF (ILC(I).EQ.1.AND.ISH(I).EQ.1) IT(I)=1                                    .
.       IF (ILC(I).EQ.1.AND.ISH(I).EQ.0) IT(I)=2                                    .
.       IF (ILC(I).EQ.2.AND.ISH(I).EQ.1) IT(I)=3                                    .
.       IF (ILC(I).EQ.2.AND.ISH(I).EQ.0) IT(I)=4                                    .

.       GOTO 397                                                                    *----------------I---V
```

```
      OK
  395 IF (ILC(I).EQ.1.AND.ISH(I).EQ.1) IT(I)=5
      IF (ILC(I).EQ.1.AND.ISH(I).EQ.0) IT(I)=6
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.1.AND.LFT(I).EQ.1) IT(I)=7
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.0.AND.LFT(I).EQ.1) IT(I)=8
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.1.AND.LFT(I).EQ.0) IT(I)=9
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.0.AND.LFT(I).EQ.0) IT(I)=10
C     SET OCCUPANCY RATES
      OK
  397 IF (IHT(I).EQ.4) GOTO 398
      OCP(I)=1.3-.3*PT
      GOTO 399
      OK
  398 OCP(I)=14.
C     SET UP CALCULATION FOR EXISTING/PROPOSED
      OK
  399 IF (I.GT.1) GOTO 401
      J1=1
      J2=1
      GOTO 404
```

```
                  OK
401 IF (IBLD.EQ.0) GOTO 403

      J1=1
      J2=2

      GOTO 404

                  OK
403 J1=2
      J2=2
                  OK
404 DO 478 I1=J1,J2

C     CALCULATE SPEED AND DELAY FOR EACH HOUR AND YEAR

      DO 477 IY=2,IPN

      QUE=0.
      COST=0.

      DO 476 KH=1,24

      PQE=0.
      DLY=0.
      DQUE=0.
```

```
C     CALCULATE HOURLY VEHICLE DEMAND AND CAPACITY

      TCAP=CAP(IT(I1))*LN(I1)

      IF (I.EQ.2.AND.IBLD.EQ.1) GOTO 445

      VEH=ADT(IY)*TRAF(KH,ILC(I))

      GOTO 455

                                        OK
  445 IF (IHT(2).EQ.4) GOTO 447

      VEH=ADT(IY)*TRAF(KH,ILC(I1))*(2.-I1+(2.*I1-3)*PBLD)

      GOTO 455

                                        OK
  447 VEH=ADT(IY)*TRAF(KH,ILC(I1))*(2.-I1-PBLD*(1.-PT)*(2.-I1-1.3*
     *(I1-1)/OCP(I1)))
                                        OK
  455 IF (VEH.LE.TCAP.AND.QUE.EQ.0.) GOTO 462

C     CALCULATE VEHICLES IN QUEUE

      QUE1=QUE
      QUE=QUE+VEH-TCAP
      PQE=1.
```

```
      IF (QUE.GT.0.) GOTO 460

C     CALCULATE PROPORTION OF HOUR QUEUE PRESENT

      PQE=QUE1/(TCAP-VEH)
      QUE=0.

C     CALCULATE AVERAGE QUEUE
                                             OK

  460 AQUE=(QUE1+QUE)/2.

      IF (LQUE.EQ.1.OR.QUE.EQ.0..OR.KH.LT.24.OR.I1.EQ.1) GOTO 462

      LQUE=1
      IQYR=IYR+IY-1

C     CALCULATE AVERAGE SPEED
                                             OK

  462 SINT=SPL(I1)+5.

      IF (QUE.GT.0.) GOTO 467

      SPD=SINT-SLP(IT(I1))+VEH/LN(I1)
      IF (SPD.LT.28.5) SPD=28.5

C     CALCULATE DELAY

      DLY=DT(I1)+VEH/SPD

      IF (PQE.EQ.0.) GOTO 470
```

```
C     CALCULATE CAPACITY SPEED

  467 CSPD=SINT-SLP(IT(I1))*CAP(IT(I1))
      IF (CSPD.LT.28.5) CSPD=28.5

C     CALCULATE QUEUE SPEED

      RSPD=CSPD/2.28
      IF (RSPD.LT.15.) RSPD=15.
      ESPD=CSPD/3.8
      IF (ESPD.LT.10.) ESPD=10.
      PCAP=CAP(IT(I1))
      RCAP=PCAP*1.2
      TVEH=PCAP+AQUE/LN(I1)

      IF (TVEH.GT.RCAP) GOTO 468

      QSPD=CSPD-(CSPD-RSPD)*(TVEH-PCAP)/(RCAP-PCAP)

      GOTO 469

  468 QSPD=RSPD-(RSPD-ESPD)*(TVEH-RCAP)/(2.*PCAP-RCAP)
      IF (QSPD.LT.ESPD) QSPD=ESPD

C     CALCULATE QUEUE DELAY

  469 DQUE=DT(I1)*VEH/QSPD

C     IF QUEUE NOT DISSIPATED AT END OF DAY, ADD DELAY TO DISSIPATE QUE

      IF (QUE.GT.0..AND.KH.EQ.24) DQUE=DQUE+QUE/2.
```

```
C     CALCULATE DELAY COST
  470 IF (IHT(I1).EQ.4) GOTO 473
      IF (PBLD.LT.1.) GOTO 471
      APT=1.
      GOTO 472
  471 APT=PT/((1.-PBLD)*(1.-PT)+PT)
  472 CDLY=(PQE*DQUE+(1.-PQE)*DLY)*(APT*VTT+(1.-APT)*VTC)
      GOTO 475
  473 CDLY=(PQE*DQUE+(1.-PQE)*DLY)*VTC*OCP(I1)/1.3
C     ACCUMULATE FOR DAILY COST
  475 COST=COST+CDLY
```

```
  476 CONTINUE
C     CALCULATE DISCOUNTED YEARLY DELAY COST
      DCST(I,I1,IY)=COST*365./(1.+DR)**(IY-1)
  477 CONTINUE
  478 CONTINUE
  479 CONTINUE
C     CALCULATE DELAY SAVINGS
      DO 480 IY=2,IPN
      DSV(IPROB)=DSV(IPROB)+DCST(1,1,IY)-DCST(2,1,IY)-DCST(2,2,IY)
  480 CONTINUE
      DSV(IPROB)=DSV(IPROB)/1000.
C     SAVE CONSTRUCTION COST AND DESCRIPTION
      CON(IPROB)=CST
      DO 490 J=1,6
      DSRP(J,IPROB)=DES(J)
```

```
1 2 3 4 5 6 7 8 9 0                               PAGE 24                          . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
I                                                    I                                                       I    I    I
I                                                                                                            I    I    I
--------------------*   490 CONTINUE                                          .                              I    I    I
                                                     I                                                       I    I    I
                    .       N=N+1                                             .                              I    I    I
                    .       INDX(N)=IPROB                                     .                              I    I    I
                                                     I                                                       I    I    I
                     C      PRINT WARNING IF QUEUE NOT DISSIPATED AT END OF DAY                              I    I    I
                                                     I                                                       I    I    I
                    .       IF (LQUE.LT.1) GOTO 495                           *-----------------------V      I    I    I
                                                     I                                                I      I    I    I
                    WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW                       I      I    I    I
                    W       WRITE (6,84) IQYR                                 W                       I      I    I    I
                    WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW                       I      I    I    I
                                                     I                                                I      I    I    I
                        84 FORMAT (2X,'*** WARNING ***  EST. QUEUE NOT DISSIPATED AT ',               I      I    I    I
                          *'END OF DAY ON PROPOSED ROUTE, BEG. IN ',I4,'.',                           I      I    I    I
                          *'  CHECK PROJ. ADT, MAY BE TOO HIGH.')                                     I      I    I    I
                                                     I                                                I      I    I    I
                     C      PROCESS NEXT PROBLEM                                                      I      I    I    I
                                                     I                                                I      I    I    I
                                                     OK-----------------------------------------------O      I    I    I
                                                     I                                                       I    I    I
                    .   495 GOTO 115                                          *------------------------------I----A    I
                                                                                                             I         I
                     C      SORT DELAY SAVINGS/CONSTRUCTION COST RATIOS                                      I         I
                                                                                                             I         I
                                                     OK------------------------------------------------------O         I
                                                     I                                                                 I
                    .   497 M=N                                               .                                        I
                                                     I                                                                 I
                                                     OK-----------------------------------------------------------O    I
                                                     I                                                            I    I
                    .   500 M=M/2                                             .                                   I    I
                                                     I                                                            I    I
                    .       IF (M.LT.1) GOTO 540                              *------------------------------V    I    I
                                                     I                                                       I    I    I
                    .       K=N-M                                             .                              I    I    I
                    .       JA=1                                              .                              I    I    I
                                                     I                                                       I    I    I
                                                     I                                                       I    I    I
1 2 3 4 5 6 7 8 9 0                                                            . 9 . 8 . 7 . 6 . 5 . 4 . 3 . 2 . 1
```

```
         OK
  510 IA=JA
         OK
  520 L=IA+M
        IF (DSV(INDX(IA))/CON(INDX(IA)).GT.DSV(INDX(L))/CON(INDX(L)))
       *GOTO 530
        T=INDX(IA)
        INDX(IA)=INDX(L)
        INDX(L)=T
        IA=IA-M
        IF (IA.GE.1) GOTO 520
         OK
  530 JA=JA+1
        IF (JA.GT.K) GOTO 500
        GOTO 510

 C      PRINT OUT SORTED VALUES

         OK
  540 WRITE (6,85)
```

```
   85 FORMAT ('1',50X,'*** PROBLEM DELAY SAVINGS ***'/49X,
     *'RANKED BY HIGHEST DELAY SAVINGS'/50X,'PER DOLLAR CONSTRUCTION
     *'COST'/54X,'(DELAY SAVINGS RATIO)')

      MX=N/50+1

      DO 580 IN=1,MX

      IF (IN.EQ.1) GOTO 560

      WRITE (6,86)

   86 FORMAT ('1')

                             OK

  560 WRITE (6,87)

   87 FORMAT (//6X,'RANKING',6X,'PROBLEM',14X,'DESCRIPTION',13X,
     *'DISCOUNTED',8X,'CONSTRUCTION',10X,'DELAY',10X,'CUMULATIVE')

      WRITE (6,88)

   88 FORMAT (19X,'NUMBER',38X,'DELAY SAVINGS',10X,'COST',13X,
     *'SAVINGS',8X,'CONSTRUCTION')

      WRITE (6,89)

   89 FORMAT (53X,2(13X,'($000)'),13X,'RATIO',9X,'COST ($000)'/)

C     SET LOWER AND UPPER RANGE OF PROBLEM OUTPUT

      IL=50*IN-49
       IU=50*IN
      IF (IU.GT.N) IU=N
```

```
I                                                    I                                                     I
I                        .............................................................................    I
I I-------------------        DO 570 IX=IL,IU                                              .             I
I I                      .............................................................................    I
I I                                                    I                                                   I
I I                      .............................................................................    I
I I                      .      IP=INDX(IX)                                                .             I
I I                      .      TCST=TCST+CON(IP)                                          .             I
I I                      .      TRATIO=DSV(IP)/CON(IP)                                     .             I
I I                      .............................................................................    I
I I                                                    I                                                   I
I I                      WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW   I
I I                      W      WRITE (6,90) IX,IP,(DSRP(J,IP),J=1,6),DSV(IP),CON(IP),TRATIO,TCST W   I
I I                      WWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWWW   I
I I                                                    I                                                   I
I I                         90 FORMAT (7X,I4,9X,I4,9X,6(A4),5X,F12.1,8X,F9.1,8X,F10.2,8X,F12.1)           I
I I                                                    I                                                   I
I I                      .............................................................................    I
I ------------------*   570 CONTINUE                                                       .             I
I                        .............................................................................    I
I                                                      I                                                   I
I                        .............................................................................    I
-------------------*    580 CONTINUE                                                       .             I
                         .............................................................................    I
                                                       I                                                   I
                                                       OK--------------------------------------------------O
                                                       I
                         TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT
                         T  600 STOP                                                                  T
                         TTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTTT

                         .............................................................................
                         .      END                                                                   .
                         .............................................................................
```

Variable Dictionary

ADT(41)	ADT for each year during planning horizon
APT	adjusted proportion trucks, adjusted for busways which do not have truck delay costs
AQUE	average number of vehicles in queue during hour, used in delay cost calculation
CADT	current ADT from input data
CAP(11)	hourly vehicle capacity per lane for each program generated highway type
CDLY	hourly delay cost
CON(9999)	array to hold construction cost for each problem for output
COST	accumulated daily delay cost
CSPD	average speed at capacity, used in delay cost calculation
CST	construction cost ($1,000), from input data
DCST(2,2,41)	discounted yearly delay cost
DES(6)	problem description, from input data
DLY	hourly delay for uncongested conditions
DQUE	hourly delay for congested conditions
DR	discount rate from input data or default value, converted to decimal form after assumptions printed
DSPR(6,9999)	array to hold problem description for output
DSV(9999)	total discounted delay savings over planning horizon
DT(2)	length of the facility for the existing and proposed highways, from the input data
ESPD	average speed at vehicle volumes twice or greater capacity, used in delay cost calculation

EXPNT	exponent in calculation of ADT for each year from the current year through the planning horizon
I	index, I = 1 for rural location, I = 2 for urban location
I1	index to calculate delay costs, I1 = 1 for the existing highway, I1 = 2 for the proposed highway
IA	variable in sorting process for ranking problems
IBLD	buildover switch, from input data
ICT	counter, used to print four problems on each page before moving to next page
IDEV(2)	projected ADT growth category for generating projected ADT in program, from input data
IEND	end of file flag
IFLAG	error flag to skip processing of problem if an error is found in input data
IHT(2)	highway type for existing highway and proposed highway, generated within program
IHWY(2)	highway type for existing and proposed highways, from input data
IHY(4)	highway type variable for testing input data, IHY(1) = U, IHY(2) = D, IHY(3) = F, IHY(4) = B
IL	lower range for printing output on page
ILC(2)	rural-urban switch for existing and proposed highways, ILC = 1 for rural, ILC = 2 for urban
IN	counter for printing output heading
INDX(9999)	array to hold problem number for sorting and output
IP	index number of problem when the results are printed out
IPL	planning horizon from input data or default value

IPN	planning horizon plus 1, used as terminal value in loops to make calculations during planning horizon
IPROB	problem number
IQYR	first year when queue does not dissipate at end of day
ISH(2)	shoulder switch for existing and proposed highways, from input data
ISIG(2)	number of signals per mile for existing and proposed highways, from input data
ISW(2)	rural-urban variable for testing input data, ISW(1) = R, ISW(2) = U
IT(2)	program generated highway type index for existing and proposed highways
IU	upper range for printing output on page
IX	index for printing output
IY	index for year in delay cost calculation
IYR	current year from input data
J	index for each of the four highway types possible from input data
J1	index for lower bound on loop to calculate delay costs, J1 = 1 for do-nothing alternative or when the proposed highway does not replace the existing highway for the construct alternative, J1 = 2 when the proposed highway replaces the existing highway for the construct alternative
J2	index for upper hand on loop to calculate delay costs, J2 = 1 for the do-nothing alternative, J2 = 2 for the construct alternative
JA	variable in sorting process for ranking projects
JJ	index for problem number in arrays for sorting and output
K	variable in sorting process for ranking problems

KH	index for hour, used in delay cost calculation
KPROB	problem number from input data
L	variable in sorting process for ranking problems
LFT(2)	left-turn median switch for existing and proposed highways, from input data
LN(2)	number of lanes for existing and proposed highways, from input data
LOC(2)	location of facility, for existing route and proposed route, from input data
LQUE	index to indicate queue at end of day LQUE = 1 if queue at end of hour 24, LQUE = 0 otherwise
M	variable sorting process for ranking problems
MX	upper range of counter for printing output headings
N	counter for number of problems processed, used to sort delay savings ratios
OCP(2)	average occupancy rate for the existing highway and the proposed highway
PADT	projected ADT at end of planning horizon, from input data or calculated in the program
PBLD	percentage persons in passenger cars to use proposed facility if the existing facility is not buildover, from input data
PCAP	facility capacity per lane, used in delay cost calculation
PQE	proportion of hour queue is present during hour, used in hour queue dissipates for delay cost calculation
PT	percentage trucks from input data or default value, converted to decimal form after assumptions are printed
PYR	planning horizon plus 1, used in calculating projected ADT

QSPD	average speed during congested conditions, used in delay cost calculation
QUE	number of vehicles in queue at end of hour, used in delay cost calculation
QUE1	number of vehicles in queue at beginning of hour, used in delay cost calculation
RCAP	facility capacity per lane plus 20%, used in delay cost calculation
RSPD	average speed for vehicle volumes 20% greater than capacity, used in delay cost calculation
SINT	free-flow speed, equals speed limit plus five, used in delay cost calculation
SLP(11)	slope of hourly speed-volume curve for each highway type
SPD	average speed for uncongested conditions, used in delay cost calculation
SPL(2)	speed limit for the existing and proposed highways, from input data
T	variable in sorting process to rank problems
TCAP	total hourly vehicle capacity for all lanes on facility
TCST	cumulative construction cost
TRAF(24,2)	proportions to convert ADT into hourly traffic volumes, for each hour in rural areas, and each hour in urban areas
TRATIO	delay savings ratio
TVEH	number of vehicles per lane in congested conditions, used to determine average speed for delay cost calculation
VEH	hourly traffic volume, all lanes in both directions
VTC	value of time for cars ($/hr) from input data or default value
VTT	value of time for trucks ($/hr) from input data or default value

```
C
C      DELAY SAVINGS MODEL  WRITTEN BY JEFFERY L. MEMMOTT
C
C      DATA INPUT CONSISTS OF ONE HEADER CARD WHICH CONTAINS THE CURRENT
C      YEAR AND INITIAL ASSUMPTIONS.  EACH OF THE OTHER DATA CARDS
C      IDENTIFY A SEPARATE PROJECT.  DATA INCLUDES A PROBLEM NUMBER,
C      CURRENT AND PROJECTED ADT, DESCRIPTIONS OF BOTH EXISTING AND
C      PROPOSED ROUTES, AND CONSTRUCTION COST.
C
       DIMENSION LOC(2),IHWY(2),LN(2),DT(2),SPL(2),ISH(2),LFT(2),
      *ISIG(2),IDEV(2),DES(6),ISW(2),ILC(2),IHY(4),IHT(2),TRAF(24,2),
      *SLP(11),CAP(11),IT(2),DCST(2,2,41),DSV(9999),CON(9999),
      *INDX(9999),DSRP(6,9999),ADT(41),OCP(2)
       DATA ISW/'R','U'/
       DATA IHY/'U','D','F','B'/
       DATA TRAF/.00864,.00485,.00295,.00105,.00169,.00485,.01875,.06783,
      *.06994,.05393,.05456,.05941,.06236,.06151,.06214,.0672,.07478,
      *.08784,.06552,.0495,.03623,.0396,.02928,.01559,.00913,.005,.00394,
      *.00293,.00391,.01768,.06316,.07683,.06016,.05122,.04915,.05114,
      *.05124,.05275,.0571,.07117,.0787,.07629,.05695,.04417,.03187,
      *.03302,.03373,.01871/
       DATA SLP/.035,.017,.040,.020,.0035,.003,.015,.014,.0120,.0100,
      *.002/
       DATA CAP/350.,500.,350.,500.,1000.,1000.,500.,500.,650.,650.,
      *1500./
       DO 98 JJ=1,9999
       DSV(JJ)=0.
       CON(JJ)=0.
    98 CONTINUE
C      SET END FLAG AND PROBLEM COUNT TO ZERO
       IEND=0
       IPROB=0
       ICT=0
       N=0
       TCST=0.
C      READ IN FIRST CARD
       READ (5,5,END=100) IYR,PT,VTC,VTT,DR,IPL
     5 FORMAT (4X,I4,4(F5.0),I3)
       GOTO 110
C      NO DATA CARDS
   100 WRITE (6,10)
    10 FORMAT (//2X,'NO DATA GIVEN FOR ANALYSIS, JOB ENDED')
       GOTO 600
C      SET DEFAULT ASSUMPTIONS
   110 IF (PT.EQ.0.) PT=8.
       IF (VTC.EQ.0.) VTC=10.2
       IF (VTT.EQ.0.) VTT=19.2
       IF (DR.EQ.0.) DR=8.
       IF (IPL.EQ.0) IPL=20
C      PRINT OUT ASSUMPTIONS
       WRITE (6,15) IYR,PT,VTC,VTT,DR,IPL
    15 FORMAT ('1',51X,'*** DELAY SAVINGS MODEL ***'////4X,
      *'CURRENT YEAR',23X,I4//4X,'ASSUMPTIONS'/6X,'PERCENTAGE TRUCKS',
      *13X,F7.2/6X,'VALUE OF TIME, CARS ($/HR)',4X,F7.2/6X,
      *'VALUE OF TIME, TRUCKS ($/HR)',2X,F7.2/6X,'DISCOUNT RATE (%)',
      *13X,F7.2/6X,'PLANNING HORIZON (YEARS)',7X,I3/'1',51X,
      *'*** PROBLEM INPUT DATA ***'/)
       PT=PT/100.
       DR=DR/100.
```

```
C      ZERO OUT PROBLEM ARRAYS
   115 IFLAG=0
       IBLD=0
       PBLD=0.
       LQUE=0
       DO 116 I=1,2
       DO 116 I1=1,2
       DO 116 IY=1,41
       DCST(I,I1,IY)=0.
   116 CONTINUE
C      READ IN PROBLEM CARD
       IPROB=IPROB+1
       READ (5,20,END=120) KPROB,CADT,PADT,(LOC(I),IHWY(I),LN(I),DT(I),
      *SPL(I),ISH(I),LFT(I),ISIG(I),IDEV(I),I=1,2),IBLD,PBLD,CST,
      *(DES(J),J=1,6)
    20 FORMAT (I4,2(F6.0),2(A1),I2,F4.0,F2.0,2(I1),I2,I1,2(A1),I2,
      *F4.0,F2.0,2(I1),I2,2(I1),F3.0,F6.0,6(A4))
       GOTO 130
C      ALL PROBLEMS READ, GO TO SORTING
   120 IEND=1
       GOTO 497
C      CHECK PROBLEM NUMBER
   130 IF (KPROB.GT.0) GOTO 135
       WRITE (6,25) IPROB
    25 FORMAT (//2X,'PROBLEM NUMBER MUST BE POSITIVE,
      *'PROBLEM NUMBER ',I4,' SKIPPED'//)
       GOTO 115
C      CHECK IF VALID LOCATION
   135 IPROB=KPROB
       DO 140 I=1,2
       IF (LOC(I).EQ.ISW(1).OR.LOC(I).EQ.ISW(2)) GOTO 140
       IFLAG=1
   140 CONTINUE
       IF (IFLAG.NE.1) GOTO 150
C      ERROR IN LOCATION
       WRITE (6,30) IPROB
    30 FORMAT (//2X,'INVALID LOCATION, ',
      *'PROBLEM NUMBER ',I4,' SKIPPED'//)
       GOTO 115
C      SET RURAL-URBAN SWITCH
   150 DO 160 I=1,2
       IF (LOC(I).EQ.ISW(1)) ILC(I)=1
       IF (LOC(I).EQ.ISW(2)) ILC(I)=2
   160 CONTINUE
C      CHECK HIGHWAY TYPE
       DO 180 I=1,2
       IHT(I)=0
       DO 170 J=1,4
       IF (IHWY(I).EQ.IHY(J)) IHT(I)=J
   170 CONTINUE
       IF (IHT(I).GT.0) GOTO 180
C      INVALID HIGHWAY TYPE
       WRITE (6,35) IPROB
    35 FORMAT (//2X,'INVALID HIGHWAY TYPE,
      *'PROBLEM NUMBER ',I4,' SKIPPED'//)
       GOTO 115
   180 CONTINUE
C      CHECK NUMBER OF LANES
       DO 190 I=1,2
       IF (LN(I).GE.1.OR.LN(I).LE.20) GOTO 190
```

```
C       INVALID NUMBER OF LANES
        WRITE (6,40) IPROB
     40 FORMAT (//2X,'INVALID NUMBER OF LANES, MUST BE 1-20, ',
       *'PROBLEM NUMBER ',I4,' SKIPPED'//)
        GOTO 115
    190 CONTINUE
C       CHECK SPEED LIMIT
        DO 200 I=1,2
        IF (SPL(I).EQ.0.) SPL(I)=55.
        IF (SPL(I).GE.15..AND.SPL(I).LE.70.) GOTO 200
C       INVALID SPEED LIMIT
        WRITE (6,45) IPROB
     45 FORMAT (//2X,'INVALID SPEED LIMIT, MUST BE 15-70, ',
       *'PROBLEM NUMBER ',I4,' SKIPPED'//)
        GOTO 115
    200 CONTINUE
C       CHECK SHOULDER SWITCH
        DO 210 I=1,2
        IF (ISH(I).EQ.0.OR.ISH(I).EQ.1) GOTO 210
C       INVALID SHOULDER SWITCH
        WRITE (6,50) IPROB
     50 FORMAT (//2X,'INVALID SHOULDER SWITCH, MUST BE 0 OR 1, ',
       *'PROBLEM NUMBER ',I4,' SKIPPED'//)
        GOTO 115
    210 CONTINUE
C       CHECK LEFT TURN SWITCH
        DO 220 I=1,2
        IF (LFT(I).EQ.0.OR.LFT(I).EQ.1) GOTO 220
C       INVALID LEFT TURN SWITCH
        WRITE (6,55) IPROB
     55 FORMAT (//2X,'INVALID LEFT TURN SWITCH, MUST BE 0 OR 1, ',
       *'PROBLEM NUMBER ',I4,' SKIPPED'//)
        GOTO 115
    220 CONTINUE
C       CHECK PROJECTED ADT GROWTH CATEGORY
        DO 230 I=1,2
        IF (IDEV(I).EQ.0) IDEV(I)=2
        IF (IDEV(I).GT.0.AND.IDEV(I).LE.3) GOTO 230
C       INVALID PROJECTED ADT GROWTH CATEGORY
        WRITE (6,57) IPROB
     57 FORMAT (//2X,'INVALID PROJECTED ADT GROWTH CODE, MUST BE 1-3, ',
       *'PROBLEM NUMBER ',I4,' SKIPPED'//)
        GOTO 115
    230 CONTINUE
C       CHECK BUILDOVER SWITCH
        IF (IBLD.EQ.0.OR.IBLD.EQ.1) GOTO 240
C       INVALID BUILDOVER SWITCH
        WRITE (6,60) IPROB
     60 FORMAT (//2X,'INVALID BUILDOVER SWITCH, MUST BE 0 OR 1, ',
       *'PROBLEM NUMBER ',I4,' SKIPPED'//)
        GOTO 115
C       CHECK PERCENTAGE PERSONS USING PROPOSED FACILITY
    240 IF (IBLD.EQ.0) GOTO 245
        IF (PBLD.EQ.0.) PBLD=50.
        IF (PBLD.GT.0..AND.PBLD.LT.100.) GOTO 245
C       INVALID PERCENTAGE PERSONS
        WRITE (6,65) IPROB
     65 FORMAT (//2X,'WHEN EXISTING ROUTE IS NOT BUILTOVER, PERCENTAGE ',
       *'PERSONS USING PROPOSED FACILITY MUST BE 1-99, ',
       *'PROBLEM NUMBER ',I4,' SKIPPED'//)
```

```
            GOTO 115
      C     CHECK CONSTRUCTION COST
        245 IF (CST.GT.0.) GOTO 250
      C     INVALID CONSTRUCTION COST
            WRITE (6,66) IPROB
         66 FORMAT (//2X,'CONSTRUCTION COST MUST BE POSITIVE,
           *'PROBLEM NUMBER ',I4,' SKIPPED'//)
            GOTO 115
      C     CALCULATE PROJECTED ADT IF NECESSARY
        250 PYR=IPL+1
            IF (PADT.GT.0.) GOTO 290
            IF (ILC(1).EQ.1) GOTO 282
            IF (IDEV(1)-2) 260,270,280
        260 PADT=CADT*(PYR**.3773)
            GOTO 290
        270 PADT=CADT*(PYR**.3030)
            GOTO 290
        280 PADT=CADT*(PYR**.2067)
            GOTO 290
        282 IF (IDEV(1)-2) 284,286,288
        284 PADT=CADT*(PYR**.2840)
            GOTO 290
        286 PADT=CADT*(PYR**.2096)
            GOTO 290
        288 PADT=CADT*(PYR**.1133)
      C     CALCULATE ADT FOR EACH YEAR
        290 EXPNT=(ALOG(PADT)-ALOG(CADT))/ALOG(PYR)
            IPN=IPL+1
            DO 300 IY=1,IPN
            ADT(IY)=CADT*(IY**EXPNT)
        300 CONTINUE
      C     PRINT OUT INPUT DATA
            ICT=ICT+1
            IF (ICT.LT.5) GOTO 302
            ICT=1
            WRITE (6,64)
         64 FORMAT ('1')
        302 WRITE (6,70) IPROB,(DES(J),J=1,6)
         70 FORMAT (///4X,'PROBLEM NUMBER ',I4,5X,6(A4))
            WRITE (6,71) CADT,PADT
         71 FORMAT (/6X,'CURRENT ADT',4X,F7.0/6X,'PROJECTED ADT  ',F7.0)
            WRITE (6,72)
         72 FORMAT (/6X,'FACILITY DESC.',3X,'LOC.',3X,'HWY TYPE',3X,
           *'NO. LANES',3X,'LENGTH',3X,'SPD LMT',3X,'SHOULDERS',3X,
           *'L.T. MEDIAN',3X,'SIGNALS/MI.',3X,'ADT GROWTH')
            DO 380 I=1,2
            IF (I.GT.1) GOTO 305
            WRITE (6,68)
         68 FORMAT (8X,'EXISTING')
            GOTO 307
        305 WRITE (6,69)
         69 FORMAT (8X,'PROPOSED')
        307 WRITE (6,73) LOC(I),IHWY(I),LN(I),DT(I),SPL(I)
         73 FORMAT ('+',T25,A1,9X,A1,9X,I2,7X,F5.1,6X,F3.0)
            IF (ISH(I).GT.0) GOTO 310
            WRITE (6,74)
         74 FORMAT ('+',T76,'YES')
            GOTO 320
        310 WRITE (6,75)
         75 FORMAT ('+',T77,'NO')
```

```
  320 IF (LFT(I).GT.0) GOTO 330
      WRITE (6,76)
   76 FORMAT ('+',T89,'YES')
      GOTO 340
  330 WRITE (6,77)
   77 FORMAT ('+',T90,'NO')
  340 WRITE (6,78) ISIG(I)
   78 FORMAT ('+',T103,I2)
      IF (IDEV(I)-2) 350,360,370
  350 WRITE (6,79)
   79 FORMAT ('+',T116,'HIGH')
      GOTO 380
  360 WRITE (6,80)
   80 FORMAT ('+',T115,'MEDIUM')
      GOTO 380
  370 WRITE (6,81)
   81 FORMAT ('+',T116,'LOW')
  380 CONTINUE
      WRITE (6,91)
   91 FORMAT (1X,' ')
      IF (IBLD.EQ.0) GOTO 390
      IF (IHT(2).EQ.4) GOTO 385
      WRITE (6,63) PBLD
   63 FORMAT (6X,'PROPOSED DOES NOT BUILDOVER EXISTING. ',F5.2,
     *' PERCENT PERSONS TO USE PROPOSED FACILITY')
      GOTO 387
  385 WRITE (6,82) PBLD
   82 FORMAT (6X,'PROPOSED DOES NOT BUILDOVER EXISTING. ',F5.2,
     *' PERCENT PERSONS FROM EXISTING FACILITIY PASSENGER CARS ',
     *'TO USE PROPOSED FACILITY')
  387 PBLD=PBLD/100.
  390 WRITE (6,83) CST
   83 FORMAT (6X,'CONSTRUCTION COST ($000)',3X,F7.0)
C     DETERMINE APPROPRIATE HIGHWAY TYPE FOR SPEED CALCULATION
  392 DO 479 I=1,2
      IT(I)=11
      IF (IHT(I).GE.3) GOTO 397
      IF (LN(I).GT.2) GOTO 395
      IF (ILC(I).EQ.1.AND.ISH(I).EQ.1) IT(I)=1
      IF (ILC(I).EQ.1.AND.ISH(I).EQ.0) IT(I)=2
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.1) IT(I)=3
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.0) IT(I)=4
      GOTO 397
  395 IF (ILC(I).EQ.1.AND.ISH(I).EQ.1) IT(I)=5
      IF (ILC(I).EQ.1.AND.ISH(I).EQ.0) IT(I)=6
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.1.AND.LFT(I).EQ.1) IT(I)=7
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.0.AND.LFT(I).EQ.1) IT(I)=8
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.1.AND.LFT(I).EQ.0) IT(I)=9
      IF (ILC(I).EQ.2.AND.ISH(I).EQ.0.AND.LFT(I).EQ.0) IT(I)=10
C     SET OCCUPANCY RATES
  397 IF (IHT(I).EQ.4) GOTO 398
      OCP(I)=1.3-.3*PT
      GOTO 399
  398 OCP(I)=14.
C     SET UP CALCULATION FOR EXISTING/PROPOSED
  399 IF (I.GT.1) GOTO 401
      J1=1
      J2=1
      GOTO 404
  401 IF (IBLD.EQ.0) GOTO 403
```

```
      J1=1
      J2=2
      GOTO 404
  403 J1=2
      J2=2
  404 DO 478 I1=J1,J2
C     CALCULATE SPEED AND DELAY FOR EACH HOUR AND YEAR
      DO 477 IY=2,IPN
      QUE=0.
      COST=0.
      DO 476 KH=1,24
      PQE=0.
      DLY=0.
      DQUE=0.
C     CALCULATE HOURLY VEHICLE DEMAND AND CAPACITY
      TCAP=CAP(IT(I1))*LN(I1)
      IF (I.EQ.2.AND.IBLD.EQ.1) GOTO 445
      VEH=ADT(IY)*TRAF(KH,ILC(I))
      GOTO 455
  445 IF (IHT(2).EQ.4) GOTO 447
      VEH=ADT(IY)*TRAF(KH,ILC(I1))*(2.-I1+(2.*I1-3)*PBLD)
      GOTO 455
  447 VEH=ADT(IY)*TRAF(KH,ILC(I1))*(2.-I1-PBLD*(1.-PT)*(2.-I1-1.3*
     *(I1-1)/OCP(I1)))
  455 IF (VEH.LE.TCAP.AND.QUE.EQ.0.) GOTO 462
C     CALCULATE VEHICLES IN QUEUE
      QUE1=QUE
      QUE=QUE+VEH-TCAP
      PQE=1.
      IF (QUE.GT.0.) GOTO 460
C     CALCULATE PROPORTION OF HOUR QUEUE PRESENT
      PQE=QUE1/(TCAP-VEH)
      QUE=0.
C     CALCULATE AVERAGE QUEUE
  460 AQUE=(QUE1+QUE)/2.
      IF (LQUE.EQ.1.OR.QUE.EQ.0..OR.KH.LT.24.OR.I1.EQ.1) GOTO 462
      LQUE=1
      IQYR=IYR+IY-1
C     CALCULATE AVERAGE SPEED
  462 SINT=SPL(I1)+5.
      IF (QUE.GT.0.) GOTO 467
      SPD=SINT-SLP(IT(I1))*VEH/LN(I1)
      IF (SPD.LT.28.5) SPD=28.5
C     CALCULATE DELAY
      DLY=DT(I1)*VEH/SPD
      IF (PQE.EQ.0.) GOTO 470
C     CALCULATE CAPACITY SPEED
  467 CSPD=SINT-SLP(IT(I1))*CAP(IT(I1))
      IF (CSPD.LT.28.5) CSPD=28.5
C     CALCULATE QUEUE SPEED
      RSPD=CSPD/2.28
      IF (RSPD.LT.15.) RSPD=15.
      ESPD=CSPD/3.8
      IF (ESPD.LT.10.) ESPD=10.
      PCAP=CAP(IT(I1))
      RCAP=PCAP*1.2
      TVEH=PCAP+AQUE/LN(I1)
      IF (TVEH.GT.RCAP) GOTO 468
      QSPD=CSPD-(CSPD-RSPD)*(TVEH-PCAP)/(RCAP-PCAP)
      GOTO 469
```

```
  468 QSPD=RSPD-(RSPD-ESPD)*(TVEH-RCAP)/(2.*PCAP-RCAP)
      IF (QSPD.LT.ESPD) QSPD=ESPD
C     CALCULATE QUEUE DELAY
  469 DQUE=DT(I1)*VEH/QSPD
C     IF QUEUE NOT DISSIPATED AT END OF DAY, ADD DELAY TO DISSIPATE QUE
      IF (QUE.GT.0..AND.KH.EQ.24) DQUE=DQUE+QUE/2.
C     CALCULATE DELAY COST
  470 IF (IHT(I1).EQ.4) GOTO 473
      IF (PBLD.LT.1.) GOTO 471
      APT=1.
      GOTO 472
  471 APT=PT/((1.-PBLD)*(1.-PT)+PT)
  472 CDLY=(PQE*DQUE+(1.-PQE)*DLY)*(APT*VTT+(1.-APT)*VTC)
      GOTO 475
  473 CDLY=(PQE*DQUE+(1.-PQE)*DLY)*VTC*OCP(I1)/1.3
C     ACCUMULATE FOR DAILY COST
  475 COST=COST+CDLY
  476 CONTINUE
C     CALCULATE DISCOUNTED YEARLY DELAY COST
      DCST(I,I1,IY)=COST*365./(1.+DR)**(IY-1)
  477 CONTINUE
  478 CONTINUE
  479 CONTINUE
C     CALCULATE DELAY SAVINGS
      DO 480 IY=2,IPN
      DSV(IPROB)=DSV(IPROB)+DCST(1,1,IY)-DCST(2,1,IY)-DCST(2,2,IY)
  480 CONTINUE
      DSV(IPROB)=DSV(IPROB)/1000.
C     SAVE CONSTRUCTION COST AND DESCRIPTION
      CON(IPROB)=CST
      DO 490 J=1,6
      DSRP(J,IPROB)=DES(J)
  490 CONTINUE
      N=N+1
      INDX(N)=IPROB
C     PRINT WARNING IF QUEUE NOT DISSIPATED AT END OF DAY
      IF (LQUE.LT.1) GOTO 495
      WRITE (6,84) IQYR
   84 FORMAT (2X,'*** WARNING ***  EST. QUEUE NOT DISSIPATED AT ',
     *'END OF DAY ON PROPOSED ROUTE, BEG. IN ',I4,'.',
     *'  CHECK PROJ. ADT, MAY BE TOO HIGH.')
C     PROCESS NEXT PROBLEM
  495 GOTO 115
C     SORT DELAY SAVINGS/CONSTRUCTION COST RATIOS
  497 M=N
  500 M=M/2
      IF (M.LT.1) GOTO 540
      K=N-M
      JA=1
  510 IA=JA
  520 L=IA+M
      IF (DSV(INDX(IA))/CON(INDX(IA)).GT.DSV(INDX(L))/CON(INDX(L)))
     *GOTO 530
      T=INDX(IA)
      INDX(IA)=INDX(L)
      INDX(L)=T
      IA=IA-M
      IF (IA.GE.1) GOTO 520
  530 JA=JA+1
      IF (JA.GT.K) GOTO 500
```

```
      GOTO 510
C     PRINT OUT SORTED VALUES
  540 WRITE (6,85)
   85 FORMAT ('1',50X,'*** PROBLEM DELAY SAVINGS ***'/49X,
     *'RANKED BY HIGHEST DELAY SAVINGS'/50X,'PER DOLLAR CONSTRUCTION ',
     *'COST'/54X,'(DELAY SAVINGS RATIO)')
      MX=N/50+1
      DO 580 IN=1,MX
      IF (IN.EQ.1) GOTO 560
      WRITE (6,86)
   86 FORMAT ('1')
  560 WRITE (6,87)
   87 FORMAT (//6X,'RANKING',6X,'PROBLEM',14X,'DESCRIPTION',13X,
     *'DISCOUNTED',8X,'CONSTRUCTION',10X,'DELAY',10X,'CUMULATIVE')
      WRITE (6,88)
   88 FORMAT (19X,'NUMBER',38X,'DELAY SAVINGS',10X,'COST',13X,
     *'SAVINGS',8X,'CONSTRUCTION')
      WRITE (6,89)
   89 FORMAT (53X,2(13X,'($000)'),13X,'RATIO',9X,'COST ($000)'/)
C     SET LOWER AND UPPER RANGE OF PROBLEM OUTPUT
      IL=50*IN-49
       IU=50*IN
      IF (IU.GT.N) IU=N
      DO 570 IX=IL,IU
      IP=INDX(IX)
      TCST=TCST+CON(IP)
      TRATIO=DSV(IP)/CON(IP)
      WRITE (6,90) IX,IP,(DSRP(J,IP),J=1,6),DSV(IP),CON(IP),TRATIO,TCST
   90 FORMAT (7X,I4,9X,I4,9X,6(A4),5X,F12.1,8X,F9.1,8X,F10.2,8X,F12.1)
  570 CONTINUE
  580 CONTINUE
  600 STOP
      END
```

*** DELAY SAVINGS MODEL ***

CURRENT YEAR	1983
ASSUMPTIONS	
PERCENTAGE TRUCKS	8.00
VALUE OF TIME, CARS ($/HR)	10.20
VALUE OF TIME, TRUCKS ($/HR)	19.20
DISCOUNT RATE (%)	8.00
PLANNING HORIZON (YEARS)	20

*** PROBLEM INPUT DATA ***

PROBLEM NUMBER 1 IMPROVE FRWY 6/8 LANES

CURRENT ADT 70000.
PROJECTED ADT 176088.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	F	6	2.5	55.	YES	YES	0	MEDIUM
PROPOSED	U	F	8	2.5	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 40000.

PROBLEM NUMBER 2 U4LN UNDIV. TO DIVIDED

CURRENT ADT 15000.
PROJECTED ADT 28145.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	U	4	1.6	55.	YES	NO	0	LOW
PROPOSED	U	D	4	1.6	55.	YES	YES	0	LOW

CONSTRUCTION COST ($000) 2500.

PROBLEM NUMBER 3 BUSWAY FOR 6LN FRWY

CURRENT ADT 80000.
PROJECTED ADT 160000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	F	6	2.1	55.	YES	YES	0	MEDIUM
PROPOSED	U	B	1	2.1	55.	YES	YES	0	MEDIUM

PROPOSED DOES NOT BUILDOVER EXISTING. 10.00 PERCENT PERSONS FROM EXISTING FACILITIY PASSENGER CARS TO USE PROPOSED FACILITY
CONSTRUCTION COST ($000) 20000.

PROBLEM NUMBER 4 SHOULDERS ON RURAL HWY

CURRENT ADT 2000.
PROJECTED ADT 4748.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	R	U	2	5.6	55.	NO	YES	0	HIGH
PROPOSED	R	U	2	5.6	55.	YES	YES	0	HIGH

CONSTRUCTION COST ($000) 1500.

PROBLEM NUMBER 5 4LN DVD TO 8LN FRWY

CURRENT ADT 16000.
PROJECTED ADT 90000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	R	D	4	3.0	55.	YES	YES	0	MEDIUM
PROPOSED	R	F	8	3.0	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 5000.

PROBLEM NUMBER 6 2LN UNDVD TO 4LN DVD

CURRENT ADT 7000.
PROJECTED ADT 45000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	R	U	2	6.0	55.	YES	NO	0	MEDIUM
PROPOSED	R	D	4	6.0	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 10800.

PROBLEM NUMBER 7 2LN DVD TO 4LN DVD

CURRENT ADT 6000.
PROJECTED ADT 15093.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	D	2	3.5	55.	YES	YES	0	MEDIUM
PROPOSED	U	D	4	3.5	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 6000.

PROBLEM NUMBER 8 4LN FRWY TO 10LN FRWY

CURRENT ADT 50000.
PROJECTED ADT 125777.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	F	4	7.5	55.	YES	YES	0	MEDIUM
PROPOSED	U	F	10	7.5	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 79000.

PROBLEM NUMBER 9 4LN UNDIV TO DVD

CURRENT ADT 15000.
PROJECTED ADT 35000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	U	4	2.0	35.	NO	NO	0	MEDIUM
PROPOSED	U	D	4	2.0	40.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 7000.

PROBLEM NUMBER 10 6LN DVD TO 4LN FRWY

CURRENT ADT 20000.
PROJECTED ADT 50311.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	D	6	3.2	55.	YES	YES	0	MEDIUM
PROPOSED	U	F	4	3.2	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 16000.

PROBLEM NUMBER 11 4LN UNDVD TO SHLD/+SPL

CURRENT ADT 3600.
PROJECTED ADT 17200.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	R	U	4	2.1	35.	NO	NO	0	MEDIUM
PROPOSED	R	U	4	2.1	55.	YES	NO	0	MEDIUM

CONSTRUCTION COST ($000) 1500.

PROBLEM NUMBER 12 2LN W/SHLD TO 4LN W/O

CURRENT ADT 2400.
PROJECTED ADT 12000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	R	U	2	2.5	55.	YES	NO	0	MEDIUM
PROPOSED	R	U	4	2.5	55.	NO	NO	0	MEDIUM

CONSTRUCTION COST ($000) 700.

PROBLEM NUMBER 13 ODD LANE FREEWAY

CURRENT ADT 25000.
PROJECTED ADT 175000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	F	6	3.5	55.	YES	YES	0	MEDIUM
PROPOSED	U	F	9	3.5	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 10300.

PROBLEM NUMBER 14 4LN FRWY TO 8LN FRWY

CURRENT ADT 25000.
PROJECTED ADT 120000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	F	4	4.0	55.	YES	YES	0	MEDIUM
PROPOSED	U	F	8	4.0	55.	YES	YES	0	MEDIUM

CONSTRUCTION COST ($000) 20100.

PROBLEM NUMBER 15 4LN FRWY NEW LOCATION

CURRENT ADT 20000.
PROJECTED ADT 50311.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	D	4	3.0	55.	YES	YES	0	MEDIUM
PROPOSED	U	F	4	3.0	55.	YES	YES	0	MEDIUM

PROPOSED DOES NOT BUILDOVER EXISTING. 70.00 PERCENT PERSONS TO USE PROPOSED FACILITY
CONSTRUCTION COST ($000) 50000.

PROBLEM NUMBER 16 BUSWAY FOR 8LN FRWY

CURRENT ADT 137000.
PROJECTED ADT 253000.

FACILITY DESC.	LOC.	HWY TYPE	NO. LANES	LENGTH	SPD LMT	SHOULDERS	L.T. MEDIAN	SIGNALS/MI.	ADT GROWTH
EXISTING	U	F	8	3.1	55.	YES	YES	0	MEDIUM
PROPOSED	U	B	1	3.1	55.	YES	YES	0	MEDIUM

PROPOSED DOES NOT BUILDOVER EXISTING. 10.00 PERCENT PERSONS FROM EXISTING FACILITIY PASSENGER CARS TO USE PROPOSED FACILITY
CONSTRUCTION COST ($000) 23250.

*** PROBLEM DELAY SAVINGS ***
RANKED BY HIGHEST DELAY SAVINGS
PER DOLLAR CONSTRUCTION COST
(DELAY SAVINGS RATIO)

RANKING	PROBLEM NUMBER	DESCRIPTION	DISCOUNTED DELAY SAVINGS ($000)	CONSTRUCTION COST ($000)	DELAY SAVINGS RATIO	CUMULATIVE CONSTRUCTION COST ($000)
1	6	2LN UNDVD TO 4LN DVD	449651.2	10800.0	41.63	10800.0
2	5	4LN DVD TO 8LN FRWY	152926.2	5000.0	30.59	15800.0
3	16	BUSWAY FOR 8LN FRWY	366732.5	23250.0	15.77	39050.0
4	13	ODD LANE FREEWAY	106632.4	10300.0	10.35	49350.0
5	8	4LN FRWY TO 10LN FRWY	523635.7	79000.0	6.63	128350.0
6	14	4LN FRWY TO 8LN FRWY	126032.1	20100.0	6.27	148450.0
7	11	4LN UNDVD TO SHLD/+SPL	7480.3	1500.0	4.99	149950.0
8	1	IMPROVE FRWY 6/8 LANES	156558.1	40000.0	3.91	189950.0
9	9	4LN UNDIV TO DVD	26086.2	7000.0	3.73	196950.0
10	3	BUSWAY FOR 6LN FRWY	47773.9	20000.0	2.39	216950.0
11	15	4LN FRWY NEW LOCATION	66365.4	50000.0	1.33	266950.0
12	12	2LN W/SHLD TO 4LN W/O	814.4	700.0	1.16	267650.0
13	7	2LN DVD TO 4LN DVD	3873.9	6000.0	0.65	273650.0
14	2	U4LN UNDIV. TO DIVIDED	907.6	2500.0	0.36	276150.0
15	4	SHOULDERS ON RURAL HWY	484.7	1500.0	0.32	277650.0
16	10	6LN DVD TO 4LN FRWY	3632.7	16000.0	0.23	293650.0

APPENDIX C

The manual calculation of a delay savings ratio presented in the section titled "Examples of the Models Use" can become dated because of the values of time assumed in the tables and figures. The computer program used to generate Tables 3 - 8 and Figures 1 - 6 has assumed values of time which are used to convert the hours of delay savings into dollars. Of course, those values of time can change over time, especially due to inflation, so this Appendix presents the same tables and figures in terms of hours of delay savings rather than dollars of delay savings. Different values of time can then be used to manually calculate delay savings ratios.

Tables 14 through 20 and Figures 9 through 15 present the discounted hours of delay savings per mile for a variety of highway improvements. Each is presented as thousands of hours, so the delay savings ratio can be calculated with the following formula:

$$DSR = D_H \times 1{,}000 \times VT \times L \div CST$$

where DSR = delay savings ratio

D_H = discounted hours of delay savings (thousands) from Tables 14-20 or Figures 9-15

VT = weighted value of time = $(1-P)(VT_c) + (P)(VT_t)$

P = proportion of trucks (percentage trucks ÷ 100)

VT_c = car value of time (\$/hr)

VT_t = truck value of time (\$/hr)

L = project length in miles

CST = estimated construction cost

The Tables 3-8 and Figures 1-6 in the text assumes the following values:

$P = 0.08$

$VT_c = 10.2$

$VT_t = 19.2$

so, $VT = (1-P)(VT_c) + (P)(VT_t) = (.92)(10.2) + (.08)(19.2) = 10.92$

If the value of time of 10.92 is used, then the Tables and Figures in this Appendix will produce the same delay savings ratios as the ones in the text.

Table 14. Hours of Delay Savings for a 2-Lane Rural Highway, Improved from No Shoulders to Shoulders

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*
1,000	1,412	0.08	1,893	1.34	2,374	1.87
2,000	2,824	3.64	3,786	5.60	4,748	7.93
3,000	4,236	8.51	5,679	13.22	7,122	18.92
4,000	5,648	15.72	7,572	24.70	9,497	41.38
5,000	7,060	25.56	9,465	47.49	11,871	10.22
6,000	8,471	39.16	11,358	187.86	14,245	1,322.67
7,000	9,883	86.66	13,251	930.60	16,619	3,381.66
8,000	11,295	277.24	15,144	2,648.75	18,993	5,506.90

*Discounted Hours of Delay Savings per mile (Thousands)

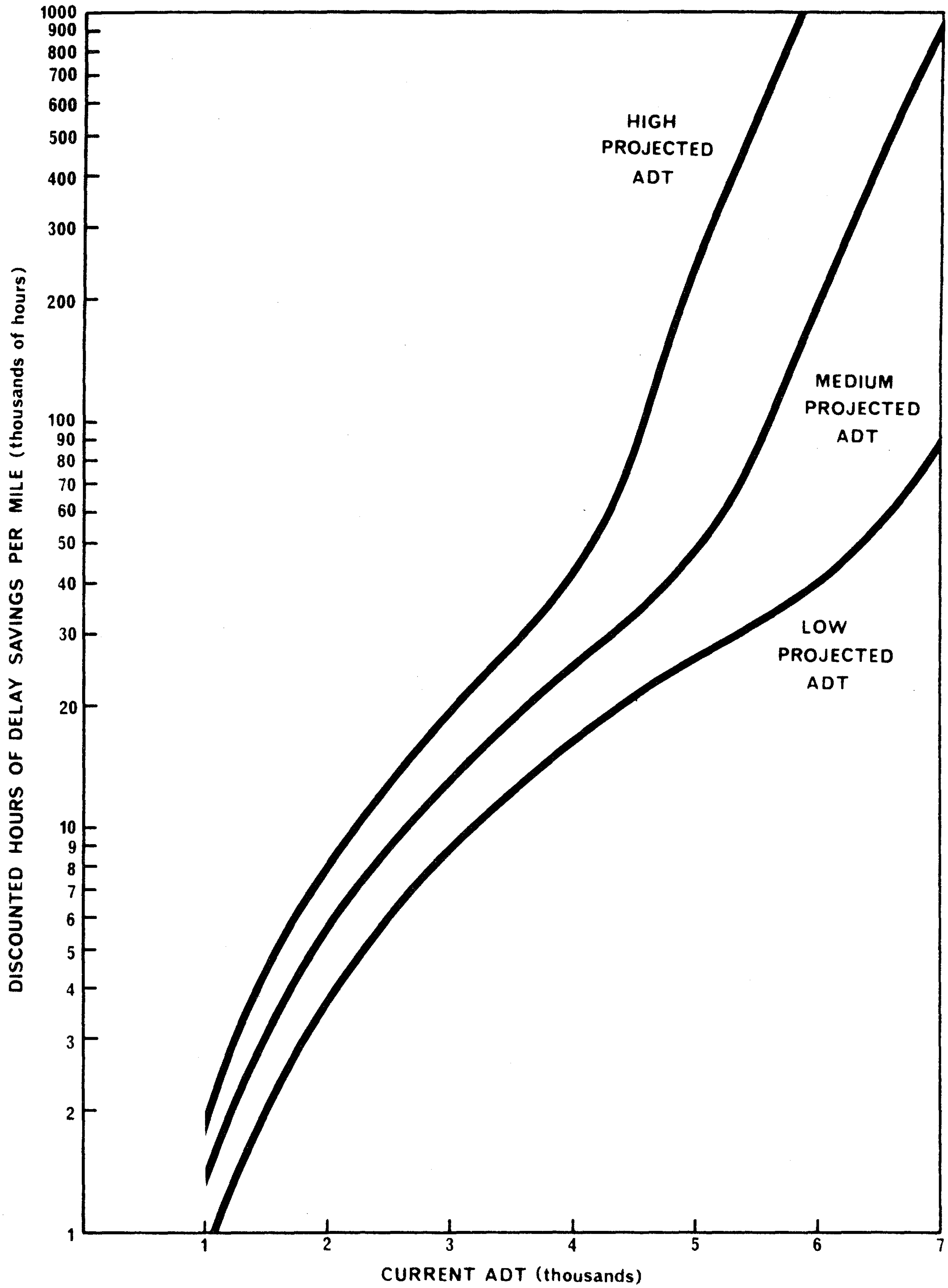

Figure 9. Hours of Delay Savings for a 2-Lane Rural Highway, Improved from No Shoulders to Shoulders

Table 15. Hours of Delay Savings for a 2-Lane Rural Highway with Shoulders, Improved to a 4-Lane Rural Highway without Shoulders

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*
1,000	1,412	0.73	1,839	1.10	2,374	1.53
2,000	2,824	2.94	3,786	4.47	4,748	6.25
3,000	4,236	6.71	5,679	10.23	7,122	14.35
4,000	5,648	12.09	7,572	18.49	9,497	26.04
5,000	7,060	19.15	9,465	29.40	11,871	41.79
6,000	8,471	27.96	11,358	43.09	14,245	83.01
7,000	9,883	38.59	13,251	65.74	16,619	261.29
8,000	11,295	51.12	15,144	153.30	18,993	1,007.82
9,000	12,707	70.08	17,036	438.10	21,367	2,636.81
10,000	14,119	125.26	18,929	1,270.22	23,742	4,939.11
11,000	16,943	277.20	20,822	2,880.81	26,116	7,664.47

*Discounted Hours of Delay Savings per mile (Thousands)

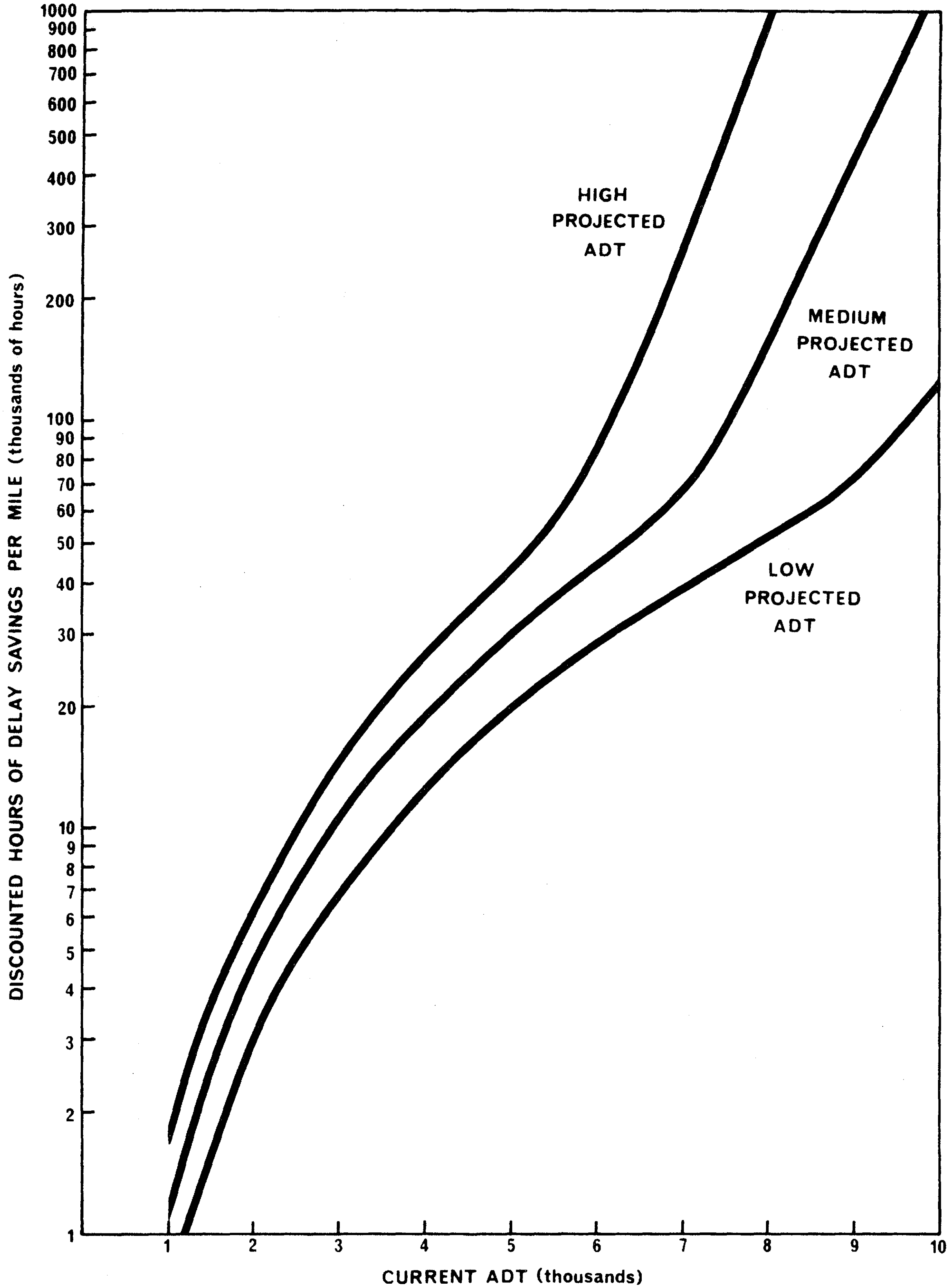

Figure 10. Hours of Delay Savings for a 2-Lane Rural Highway with Shoulders, Improved to a 4-Lane Rural Highway without Shoulders

Table 16. Hours of Delay Savings for a 2-Lane Rural Highway with Shoulders, Improved to a 4-Lane Rural Highway with Shoulders

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*
1,000	1,412	0.74	1,839	1.12	2,374	1.56
2,000	2,824	2.99	3,786	4.54	4,748	6.35
3,000	4,236	6.82	5,679	10.39	7,122	14.57
4,000	5,648	12.28	7,572	18.78	9,497	26.44
5,000	7,060	19.45	9,465	29.85	11,871	42.41
6,000	8,471	28.39	11,358	43.74	14,245	83.92
7,000	9,883	39.17	13,251	66.63	16,619	262.53
8,000	11,295	51.88	15,144	154.46	18,993	1,009.44
9,000	12,707	71.05	17,036	439.57	21,367	2,638.86
10,000	14,119	126.46	18,929	1,272.05	23,742	4,941.66
11,000	16,943	278.65	20,822	2,883.02	26,116	7,667.57

*Discounted Hours of Delay Savings per mile (Thousands)

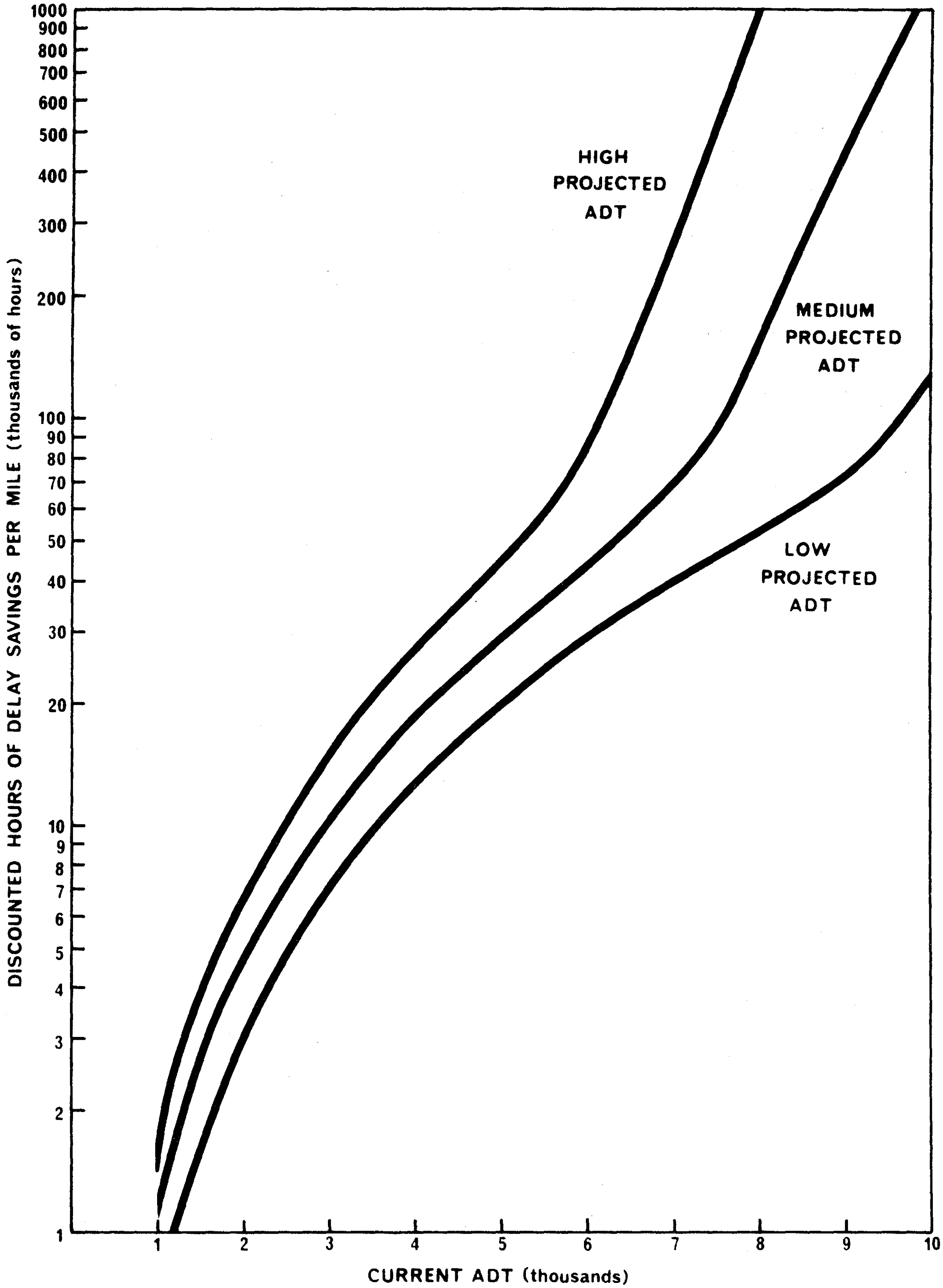

Figure 11. Hours of Delay Savings for a 2-Lane Rural Highway with Shoulders, Improved to a 4-Lane Rural Highway with Shoulders

Table 17. Hours of Delay Savings for a 2-Lane Urban Highway without Shoulders or L.T. Median, Improved to a 4-Lane Urban Highway without Shoulders or L.T. Median

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*
1,000	1,876	2.24	2,516	3.46	3,154	4.91
2,000	3,753	9.31	5,031	14.59	6,308	20.95
3,000	5,629	21.85	7,547	34.68	9,462	51.62
4,000	7,505	40.58	10,062	74.85	12,616	303.68
5,000	9,382	67.57	12,578	354.82	15,770	1,685.74
6,000	11,258	204.63	15,093	1,537.24	18,925	4,338.14
7,000	13,134	684.30	17,609	3,795.34	22,079	7,712.65

*Discounted Hours of Delay Savings per mile (Thousands)

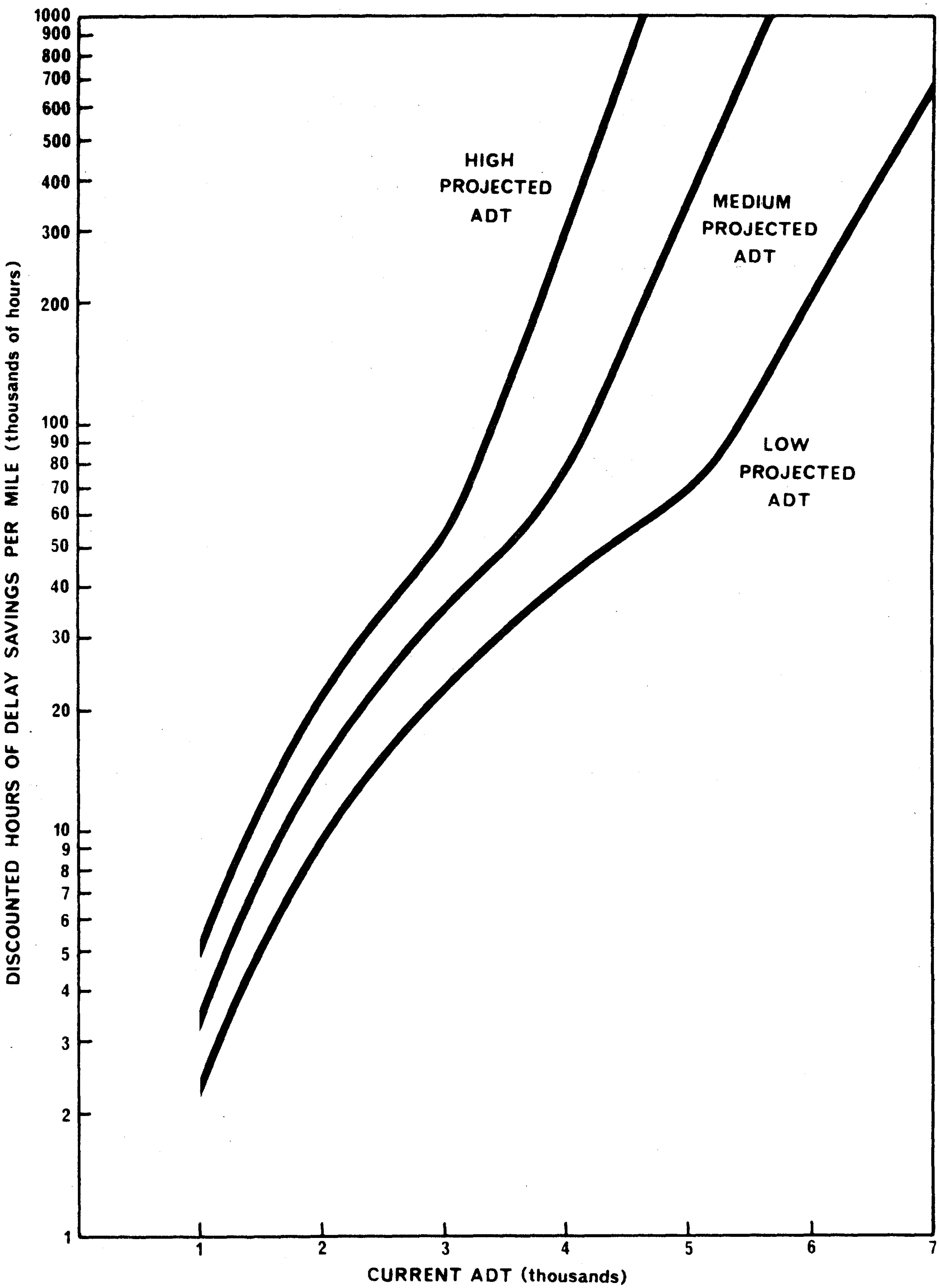

Figure 12. Hours of Delay Savings for a 2-Lane Urban Highway without Shoulders or L.T. Median, Improved to a 4-Lane Urban Highway without Shoulders or L.T. Median

Table 18. Hours of Delay Savings for a 4-Lane Urban Highway without Shoulders or L.T. Median, Improved to a 4-Lane Urban Highway with L.T. Median

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*
3,000	5,629	0.92	7,547	1.43	9,462	2.02
4,000	7,505	1.66	10,062	2.57	12,616	3.65
5,000	9,382	2.62	12,578	4.08	15,770	5.81
6,000	11,258	3.82	15,093	5.96	18,925	8.52
7,000	13,134	5.26	17,609	8.23	22,079	11.81
8,000	15,010	6.95	20,124	10.91	25,233	15.72
9,000	16,887	8.90	22,640	14.02	28,387	33.89
10,000	18,763	11.11	25,155	17.58	31,541	140.41
11,000	20.639	13.60	27,671	29.09	34,695	375.09
12,000	22,516	16.38	30,187	96.45	37,849	849.76
13,000	24,392	19.46	32,702	254.94	41,003	1,797.74
14,000	26,268	23.77	35,218	529.08	44,157	3,203.19
15,000	28,145	43.95	37,733	1,014.26	47,311	4,889.13
16,000	30,021	121.98	40,249	1,868.87	50,465	6,646.15
17,000	31,897	271.68	42,764	3,108.20	53,619	8,223.82

*Discounted Hours of Delay Savings per mile (Thousands)

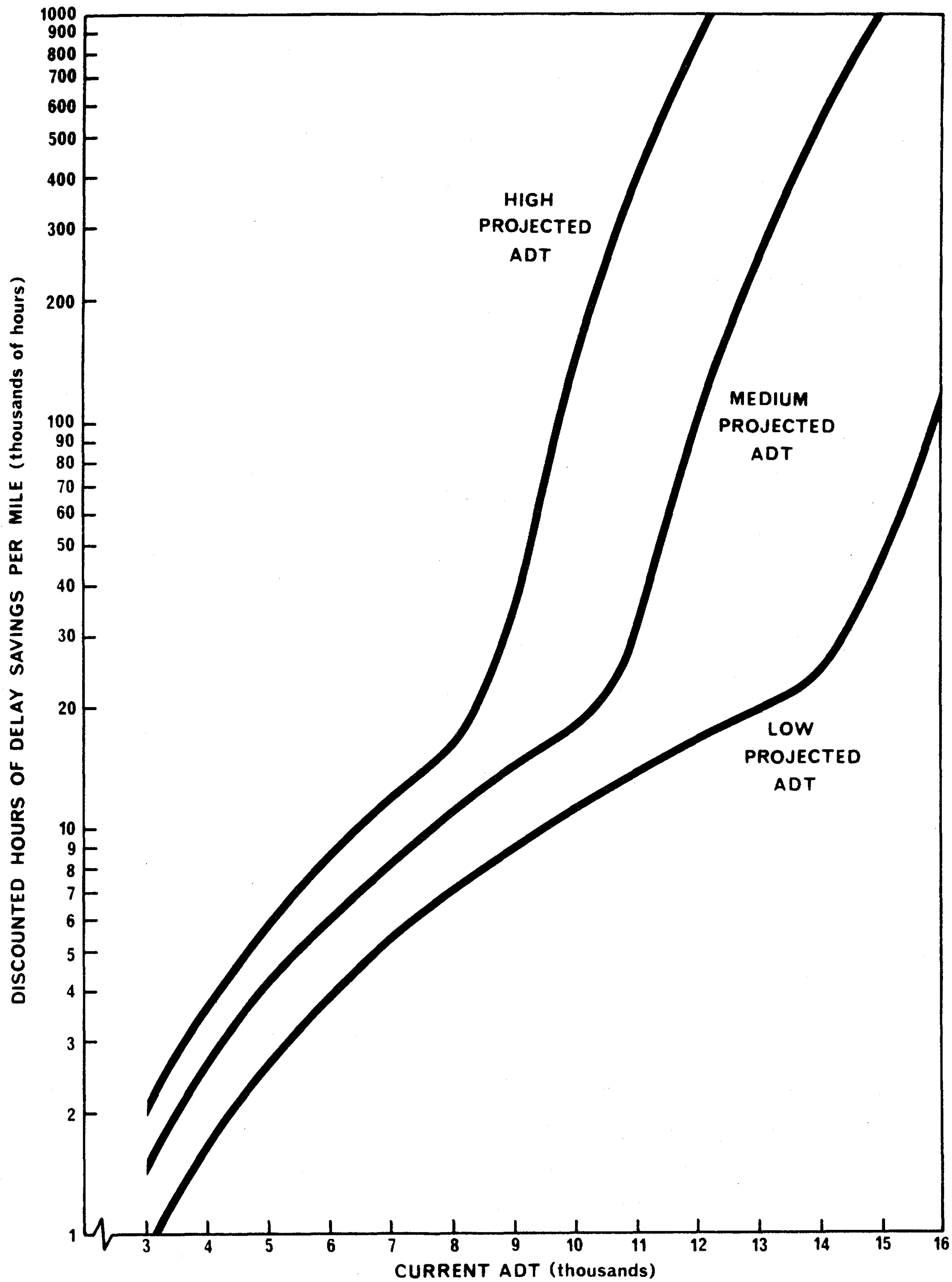

Figure 13. Hours of Delay Savings for a 4-Lane Urban Highway without Shoulders or Median, Improved to a 4-Lane Urban Highway with L.T. Median

Table 19. Hours of Delay Savings for a 4-Lane Urban Highway with L.T. Median, Improved to a 4-Lane Freeway

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*
5,000	9,382	8.51	12,578	13.13	15,770	18.57
7,500	14,072	19.43	18,867	30.11	23,656	42.76
10,000	18,763	35.05	25,155	54.57	31,541	77.84
12,500	23,454	55.60	31,444	86.94	39,426	206.41
15,000	28,145	81.29	37,733	168.42	47,311	935.98
17,500	32,835	112.38	44,022	611.88	55,196	3,629.50
20,000	37,526	198.20	50,311	1,950.67	63,082	8,767.09
22,500	42,417	579.75	56,600	5,356.45	70,967	15,649.14
25,000	46,908	1,453.58	62,889	10,545.51	78,852	23,649.02
27,500	51,598	3,450.49	69,178	16,989.84	86,737	32,466.88
30,000	56,289	7,236.18	75,466	24,234.09	94,623	41,588.97

*Discounted Hours of Delay Savings per mile (Thousands)

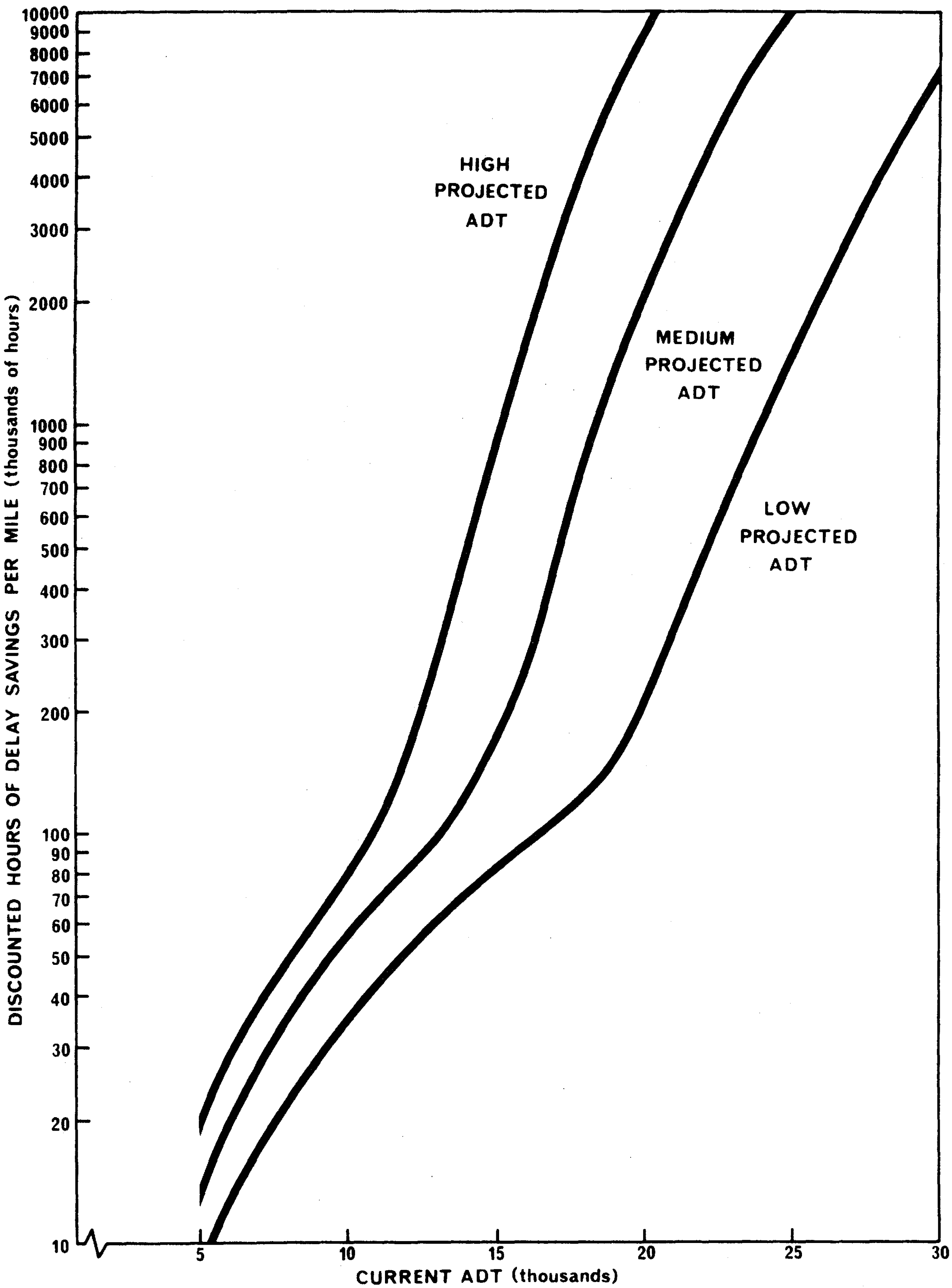

Figure 14. Hours of Delay Savings for a 4-Lane Urban Highway with L.T. Median, Improved to a 4-Lane Freeway

Table 20. Hours of Delay Savings for a 4-Lane Freeway, Improved to a 6-Lane Freeway

Current ADT	Low Projected ADT		Medium Projected ADT		High Projected ADT	
	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*	Projection	Hours of Delay Savings*
20,000	37,526	9.06	50,311	13.98	63,082	19.76
25,000	46,908	14.26	62,889	22.04	78,852	33.11
30,000	56,289	20.67	75,466	32.02	94,623	364.46
35,000	65,671	28.33	88,044	155.93	110,393	1,857.65
40,000	75,052	37.27	100.622	890.65	126,163	6,806.20
45,500	84,434	95.91	113,200	2,884.99	141,934	15,727.35
50,000	93,815	560.80	125,777	8,148.53	157,704	27,141.09
55,000	103,197	1,635.58	138,355	16,485.06	173,475	39,352.03
60,000	112,578	3,883.89	150,933	26,889.12	189,245	50,032.67

*Discounted Hours of Delay Savings per mile (Thousands)

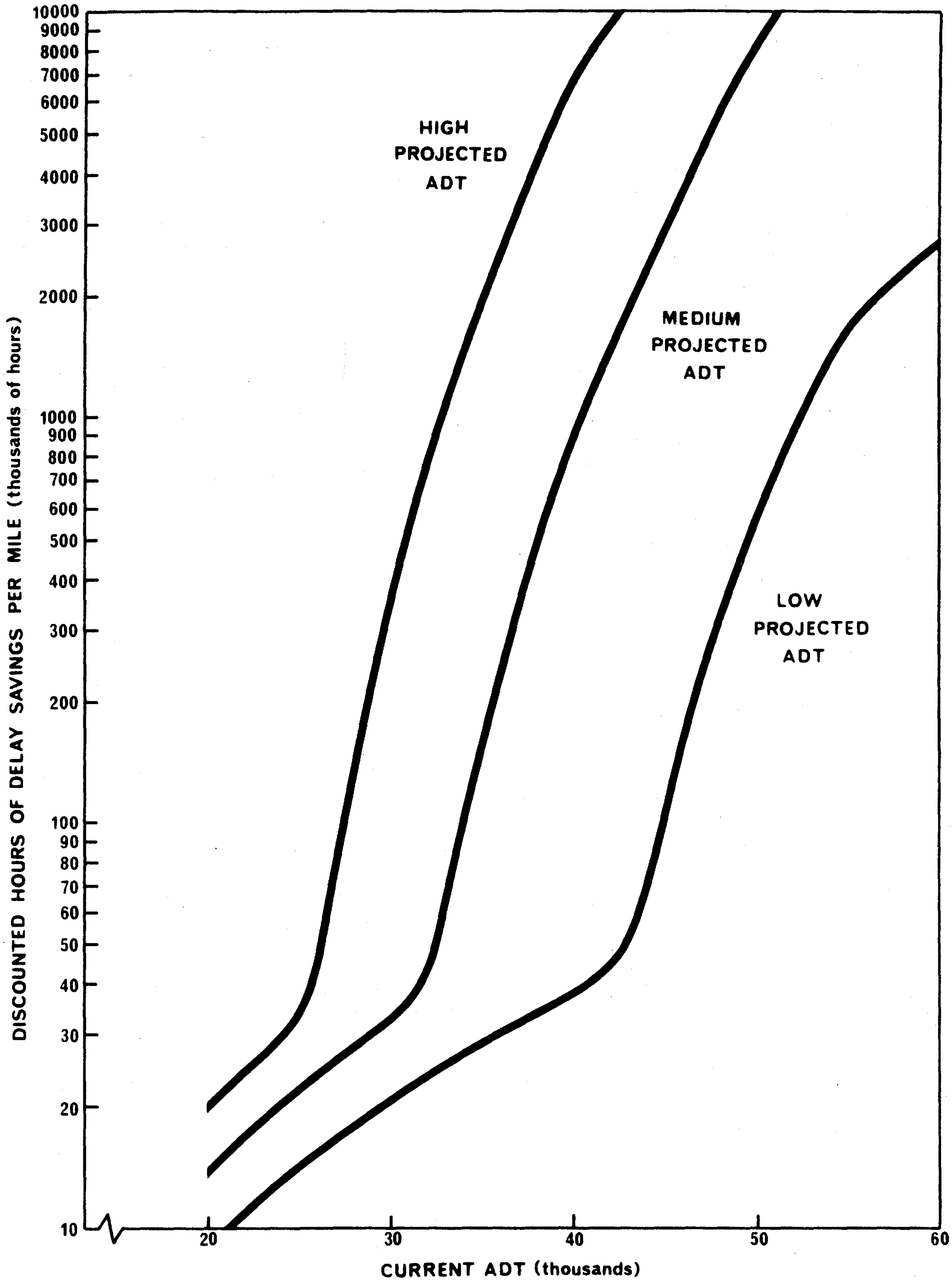

Figure 15. Hours of Delay Savings for a 4-Lane Freeway, Improved to a 6-Lane Freeway