A MODEL TO CALCULATE DELAY SAVINGS FOR HIGHWAY IMPROVEMENT PROJECTS

in cooperation with the
Department of Transportation
Federal Highway Administration

RESEARCH REPORT 327-1
STUDY 2-8-82-327
HIGHWAY PROJECT EVALUATION
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. This 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.
A MODEL TO CALCULATE DELAY SAVINGS FOR HIGHWAY IMPROVEMENT PROJECTS

by

Jeffery L. Memmott
Research Associate

and

Jesse L. Buffington
Research Economist

Research Report 327-1
Research Study Number 2-8-82-327

Sponsored by the State Department of Highways and Public Transportation
in Cooperation with the Federal Highway Administration
U.S. Department of Transportation

October, 1983
Texas Transportation Institute
The Texas A&M University System
College Station, Texas
ACKNOWLEDGEMENTS

The authors wish to thank Harold D. Cooner (D-8, DHT) for the assistance and direction provided during the course of the research documented herein.

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 necessarily 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.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGEMENTS</td>
<td>i</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>ii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>CHARACTERISTICS OF MODEL.</td>
<td>3</td>
</tr>
<tr>
<td>USE OF THE MODEL</td>
<td>7</td>
</tr>
<tr>
<td>EXAMPLES OF THE MODEL'S USE</td>
<td>10</td>
</tr>
<tr>
<td>A Manual Method to Calculate Delay Savings</td>
<td>10</td>
</tr>
<tr>
<td>Comparison of the Delay Savings' Model to HEEM-II</td>
<td>23</td>
</tr>
<tr>
<td>CONCLUSION</td>
<td>30</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>31</td>
</tr>
<tr>
<td>APPENDIX A</td>
<td>32</td>
</tr>
<tr>
<td>DELAY SAVINGS CALCULATIONS.</td>
<td>33</td>
</tr>
<tr>
<td>Calculation of the Projected Traffic Volume.</td>
<td>33</td>
</tr>
<tr>
<td>Calculation of Average Speed</td>
<td>34</td>
</tr>
<tr>
<td>Calculation of Delay Savings</td>
<td>40</td>
</tr>
<tr>
<td>APPENDIX B</td>
<td>42</td>
</tr>
<tr>
<td>PROGRAM DOCUMENTATION</td>
<td>43</td>
</tr>
<tr>
<td>Program Description.</td>
<td>43</td>
</tr>
<tr>
<td>Program Flowchart.</td>
<td>44</td>
</tr>
<tr>
<td>Variable Dictionary.</td>
<td>74</td>
</tr>
<tr>
<td>Program Listing.</td>
<td>79</td>
</tr>
<tr>
<td>Sample Output</td>
<td>87</td>
</tr>
<tr>
<td>APPENDIX C</td>
<td>93</td>
</tr>
</tbody>
</table>
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 is 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
géométrics 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 incor­
porated 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 pro­
jected 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)

<table>
<thead>
<tr>
<th>RANKING</th>
<th>PROBLEM NUMBER</th>
<th>DESCRIPTION</th>
<th>DISCOUNTED DELAY SAVINGS ($000)</th>
<th>CONSTRUCTION COST ($000)</th>
<th>DELAY SAVINGS RATIO</th>
<th>CUMULATIVE CONSTRUCTION COST ($000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>5</td>
<td>2LN UND/TO 4LN DVD</td>
<td>449651.2</td>
<td>10800.0</td>
<td>41.63</td>
<td>10800.0</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>4LN DVD TO 6LN FRWY</td>
<td>152926.2</td>
<td>5000.0</td>
<td>30.59</td>
<td>15800.0</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>BUSWAY FOR 6LN FRWY</td>
<td>366732.5</td>
<td>23250.0</td>
<td>15.77</td>
<td>39050.0</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>ODD LANE FREEWAY</td>
<td>108832.4</td>
<td>10300.0</td>
<td>10.35</td>
<td>49350.0</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>4LN FRWY TO 10LN FRWY</td>
<td>523835.7</td>
<td>79000.0</td>
<td>6.63</td>
<td>128350.0</td>
</tr>
<tr>
<td>6</td>
<td>14</td>
<td>4LN FRWY TO 8LN FRWY</td>
<td>126032.1</td>
<td>20100.0</td>
<td>6.27</td>
<td>148450.0</td>
</tr>
<tr>
<td>7</td>
<td>11</td>
<td>4LN UND/TO SHLD/+SPL</td>
<td>7480.3</td>
<td>1500.0</td>
<td>4.99</td>
<td>149950.0</td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>IMPROVE FRWY 6/8 LANES</td>
<td>156558.1</td>
<td>40000.0</td>
<td>3.91</td>
<td>189950.0</td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>4LN UNDIV TO DVD</td>
<td>26086.2</td>
<td>7000.0</td>
<td>3.73</td>
<td>196950.0</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>BUSWAY FOR 6LN FRWY</td>
<td>47773.9</td>
<td>20000.0</td>
<td>2.39</td>
<td>216950.0</td>
</tr>
<tr>
<td>11</td>
<td>15</td>
<td>4LN FRWY NEW LOCATION</td>
<td>68305.4</td>
<td>50000.0</td>
<td>1.33</td>
<td>266950.0</td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>2LN W/S/SHLD TO 4LN W/D</td>
<td>814.4</td>
<td>700.0</td>
<td>1.16</td>
<td>267650.0</td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>2LN DVD TO 4LN DVD</td>
<td>3873.9</td>
<td>6000.0</td>
<td>0.65</td>
<td>273650.0</td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>U4LN UNDIV TO DIVIDED</td>
<td>907.8</td>
<td>2500.0</td>
<td>0.36</td>
<td>278150.0</td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>SHOULDS ON RURAL HWY</td>
<td>484.7</td>
<td>1500.0</td>
<td>0.22</td>
<td>277650.0</td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>6LN DVD TO 4LN FRWY</td>
<td>3637.7</td>
<td>16000.0</td>
<td>0.23</td>
<td>293650.0</td>
</tr>
</tbody>
</table>
Table 3. Delay Savings Ratios for a 2-Lane Rural Highway, Improved from no Shoulders to Shoulders

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay Projection</td>
<td>Delay Savings Ratio*</td>
<td>Delay Projection</td>
</tr>
<tr>
<td>1,000</td>
<td>1,412</td>
<td>0.10</td>
<td>1,893</td>
</tr>
<tr>
<td>2,000</td>
<td>2,824</td>
<td>0.40</td>
<td>3,786</td>
</tr>
<tr>
<td>3,000</td>
<td>4,236</td>
<td>0.93</td>
<td>5,679</td>
</tr>
<tr>
<td>4,000</td>
<td>5,648</td>
<td>1.72</td>
<td>7,572</td>
</tr>
<tr>
<td>5,000</td>
<td>7,060</td>
<td>2.79</td>
<td>9,465</td>
</tr>
<tr>
<td>6,000</td>
<td>8,471</td>
<td>4.28</td>
<td>11,358</td>
</tr>
<tr>
<td>7,000</td>
<td>9,883</td>
<td>9.46</td>
<td>13,251</td>
</tr>
<tr>
<td>8,000</td>
<td>11,295</td>
<td>30.27</td>
<td>15,144</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay Projection</td>
<td>Delay Savings Ratio*</td>
<td>Delay Projection</td>
</tr>
<tr>
<td>1,000</td>
<td>1,412</td>
<td>0.08</td>
<td>1,893</td>
</tr>
<tr>
<td>2,000</td>
<td>2,824</td>
<td>0.32</td>
<td>3,786</td>
</tr>
<tr>
<td>3,000</td>
<td>4,236</td>
<td>0.73</td>
<td>5,679</td>
</tr>
<tr>
<td>4,000</td>
<td>5,648</td>
<td>1.32</td>
<td>7,572</td>
</tr>
<tr>
<td>5,000</td>
<td>7,060</td>
<td>2.09</td>
<td>9,465</td>
</tr>
<tr>
<td>6,000</td>
<td>8,471</td>
<td>3.05</td>
<td>11,358</td>
</tr>
<tr>
<td>7,000</td>
<td>9,883</td>
<td>4.21</td>
<td>13,251</td>
</tr>
<tr>
<td>8,000</td>
<td>11,295</td>
<td>5.58</td>
<td>15,144</td>
</tr>
<tr>
<td>9,000</td>
<td>12,707</td>
<td>7.65</td>
<td>17,036</td>
</tr>
<tr>
<td>10,000</td>
<td>14,119</td>
<td>13.68</td>
<td>18,929</td>
</tr>
<tr>
<td>11,000</td>
<td>16,943</td>
<td>30.27</td>
<td>20,822</td>
</tr>
</tbody>
</table>

* 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

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

* 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,

\[ DSR = D_N \times \frac{100,000}{CST} \times L \]

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,

\[ DSR = 1.44 \times \frac{100,000}{150,000} \times 2 = 1.92 \]

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,

\[ DS = DSR \times CST = 1.92 \times 150,000 = \$288,000. \]

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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Projection</td>
<td>Delay Savings Ratio*</td>
<td>Projection</td>
</tr>
<tr>
<td>1,000</td>
<td>1,876</td>
<td>0.24</td>
<td>2,516</td>
</tr>
<tr>
<td>2,000</td>
<td>3,753</td>
<td>1.02</td>
<td>15,031</td>
</tr>
<tr>
<td>3,000</td>
<td>5,629</td>
<td>2.39</td>
<td>17,547</td>
</tr>
<tr>
<td>4,000</td>
<td>7,505</td>
<td>4.43</td>
<td>10,062</td>
</tr>
<tr>
<td>5,000</td>
<td>9,382</td>
<td>7.38</td>
<td>12,578</td>
</tr>
<tr>
<td>6,000</td>
<td>11,258</td>
<td>22.35</td>
<td>15,093</td>
</tr>
<tr>
<td>7,000</td>
<td>13,134</td>
<td>74.73</td>
<td>17,609</td>
</tr>
</tbody>
</table>

* 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>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Projection</td>
<td>Delay Savings Ratio*</td>
<td>Projection</td>
</tr>
<tr>
<td>3,000</td>
<td>5,629</td>
<td>0.10</td>
<td>7,547</td>
</tr>
<tr>
<td>4,000</td>
<td>7,505</td>
<td>0.18</td>
<td>10,062</td>
</tr>
<tr>
<td>5,000</td>
<td>9,382</td>
<td>0.29</td>
<td>12,578</td>
</tr>
<tr>
<td>6,000</td>
<td>11,258</td>
<td>0.42</td>
<td>15,093</td>
</tr>
<tr>
<td>7,000</td>
<td>13,134</td>
<td>0.57</td>
<td>17,609</td>
</tr>
<tr>
<td>8,000</td>
<td>15,010</td>
<td>0.76</td>
<td>20,124</td>
</tr>
<tr>
<td>9,000</td>
<td>16,887</td>
<td>0.97</td>
<td>22,640</td>
</tr>
<tr>
<td>10,000</td>
<td>18,763</td>
<td>1.21</td>
<td>25,155</td>
</tr>
<tr>
<td>11,000</td>
<td>20,639</td>
<td>1.49</td>
<td>27,671</td>
</tr>
<tr>
<td>12,000</td>
<td>22,516</td>
<td>1.79</td>
<td>30,187</td>
</tr>
<tr>
<td>13,000</td>
<td>24,392</td>
<td>2.13</td>
<td>32,702</td>
</tr>
<tr>
<td>14,000</td>
<td>26,268</td>
<td>2.60</td>
<td>35,218</td>
</tr>
<tr>
<td>15,000</td>
<td>28,145</td>
<td>4.80</td>
<td>37,733</td>
</tr>
<tr>
<td>16,000</td>
<td>30,021</td>
<td>13.32</td>
<td>40,249</td>
</tr>
<tr>
<td>17,000</td>
<td>31,897</td>
<td>29.67</td>
<td>42,764</td>
</tr>
</tbody>
</table>

* 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,

\[
\text{DSR} = D_F \times 1,000,000 \times L \times \text{CST}
\]

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,

\[
\text{DSR} = 20.29 \times 1,000,000 \times 3 \div 15,000,000 = 4.06
\]

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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Projection</td>
<td>Delay Savings Ratio*</td>
<td>Projection</td>
</tr>
<tr>
<td>5,000</td>
<td>9,382</td>
<td>0.09</td>
<td>12,578</td>
</tr>
<tr>
<td>7,500</td>
<td>14,072</td>
<td>0.21</td>
<td>18,867</td>
</tr>
<tr>
<td>10,000</td>
<td>18,763</td>
<td>0.38</td>
<td>25,155</td>
</tr>
<tr>
<td>12,500</td>
<td>23,454</td>
<td>0.61</td>
<td>31,444</td>
</tr>
<tr>
<td>15,000</td>
<td>28,145</td>
<td>0.89</td>
<td>37,733</td>
</tr>
<tr>
<td>17,500</td>
<td>32,835</td>
<td>1.23</td>
<td>44,022</td>
</tr>
<tr>
<td>20,000</td>
<td>37,526</td>
<td>2.16</td>
<td>50,311</td>
</tr>
<tr>
<td>22,500</td>
<td>42,217</td>
<td>6.33</td>
<td>56,600</td>
</tr>
<tr>
<td>25,000</td>
<td>46,908</td>
<td>15.87</td>
<td>62,889</td>
</tr>
<tr>
<td>27,500</td>
<td>51,598</td>
<td>37.68</td>
<td>69,178</td>
</tr>
<tr>
<td>30,000</td>
<td>56,289</td>
<td>79.02</td>
<td>75,466</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay Projection</td>
<td>Delay Savings Ratio*</td>
<td>Delay Projection</td>
</tr>
<tr>
<td>20,000</td>
<td>37,526</td>
<td>0.10</td>
<td>50,311</td>
</tr>
<tr>
<td>25,000</td>
<td>46,908</td>
<td>0.16</td>
<td>62,889</td>
</tr>
<tr>
<td>30,000</td>
<td>56,289</td>
<td>0.23</td>
<td>75,466</td>
</tr>
<tr>
<td>35,000</td>
<td>65,671</td>
<td>0.31</td>
<td>88,044</td>
</tr>
<tr>
<td>40,000</td>
<td>75,052</td>
<td>0.41</td>
<td>100,622</td>
</tr>
<tr>
<td>45,000</td>
<td>84,434</td>
<td>1.05</td>
<td>113,200</td>
</tr>
<tr>
<td>50,000</td>
<td>93,815</td>
<td>6.12</td>
<td>125,777</td>
</tr>
<tr>
<td>55,000</td>
<td>103,197</td>
<td>17.86</td>
<td>138,355</td>
</tr>
<tr>
<td>60,000</td>
<td>112,578</td>
<td>42.41</td>
<td>150,933</td>
</tr>
</tbody>
</table>

* 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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Delay Savings Model</th>
<th>HEEM-II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Delay Savings Ratio*</td>
<td>Delay Savings Ratio*</td>
</tr>
<tr>
<td></td>
<td>Low Projected ADT</td>
<td>Medium Projected ADT</td>
</tr>
<tr>
<td>20,000</td>
<td>0.10</td>
<td>0.15</td>
</tr>
<tr>
<td>25,000</td>
<td>0.16</td>
<td>0.24</td>
</tr>
<tr>
<td>30,000</td>
<td>0.23</td>
<td>0.35</td>
</tr>
<tr>
<td>35,000</td>
<td>0.31</td>
<td>1.70</td>
</tr>
<tr>
<td>40,000</td>
<td>0.41</td>
<td>9.73</td>
</tr>
<tr>
<td>45,000</td>
<td>1.05</td>
<td>31.50</td>
</tr>
<tr>
<td>50,000</td>
<td>6.12</td>
<td>88.98</td>
</tr>
<tr>
<td></td>
<td>0.16</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>0.25</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>0.36</td>
<td>1.72</td>
</tr>
<tr>
<td></td>
<td>0.36</td>
<td>4.99</td>
</tr>
<tr>
<td></td>
<td>1.54</td>
<td>11.03</td>
</tr>
<tr>
<td></td>
<td>4.03</td>
<td>19.19</td>
</tr>
</tbody>
</table>

* 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.


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.
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...
The projected ADT is calculated using the following equation,

\[ \text{ADT}_P = \text{ADT}_C(T+1)^r \]

where \( \text{ADT}_P \) = projected ADT to year \( T \)
\( \text{ADT}_C \) = 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,

\[ \text{ADT}_t = \text{ADT}_C(t+1)^e \]

where \( \text{ADT}_t \) = estimated ADT for year \( t \)
\( e = (\ln \text{ADT}_P - \ln \text{ADT}_C)/\ln T \)

**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

<table>
<thead>
<tr>
<th>ADT Growth Category</th>
<th>Low</th>
<th>Medium</th>
<th>High</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Areas</td>
<td>.1139</td>
<td>.2096</td>
<td>.2840</td>
</tr>
<tr>
<td>Urban Areas</td>
<td>.2067</td>
<td>.3030</td>
<td>.3773</td>
</tr>
</tbody>
</table>
Table 12. Hourly Traffic Volume as Percent of ADT

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

<sup>1</sup> taken from IH 610, Station 5166
<sup>2</sup> taken from SH 336, Station 5069
Table 11. Coefficients for ADT Projection Equation

<table>
<thead>
<tr>
<th></th>
<th>ADT Growth Category</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Rural Areas</td>
<td>.1139</td>
</tr>
<tr>
<td>Urban Areas</td>
<td>.2067</td>
</tr>
</tbody>
</table>
Table 12. Hourly Traffic Volume as Percent of ADT

<table>
<thead>
<tr>
<th>Hour</th>
<th>Urban Areas¹</th>
<th>Rural Areas²</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.913</td>
<td>0.864</td>
</tr>
<tr>
<td>2</td>
<td>0.500</td>
<td>0.485</td>
</tr>
<tr>
<td>3</td>
<td>0.394</td>
<td>0.485</td>
</tr>
<tr>
<td>4</td>
<td>0.298</td>
<td>0.105</td>
</tr>
<tr>
<td>5</td>
<td>0.391</td>
<td>0.169</td>
</tr>
<tr>
<td>6</td>
<td>1.768</td>
<td>0.485</td>
</tr>
<tr>
<td>7</td>
<td>6.316</td>
<td>1.875</td>
</tr>
<tr>
<td>8</td>
<td>7.683</td>
<td>6.783</td>
</tr>
<tr>
<td>9</td>
<td>6.016</td>
<td>6.994</td>
</tr>
<tr>
<td>10</td>
<td>5.122</td>
<td>5.393</td>
</tr>
<tr>
<td>11</td>
<td>4.915</td>
<td>5.456</td>
</tr>
<tr>
<td>12</td>
<td>5.114</td>
<td>5.941</td>
</tr>
<tr>
<td>13</td>
<td>5.124</td>
<td>6.236</td>
</tr>
<tr>
<td>14</td>
<td>5.275</td>
<td>6.151</td>
</tr>
<tr>
<td>15</td>
<td>5.710</td>
<td>6.214</td>
</tr>
<tr>
<td>16</td>
<td>7.117</td>
<td>6.720</td>
</tr>
<tr>
<td>17</td>
<td>7.870</td>
<td>7.478</td>
</tr>
<tr>
<td>18</td>
<td>7.629</td>
<td>8.784</td>
</tr>
<tr>
<td>19</td>
<td>5.695</td>
<td>6.552</td>
</tr>
<tr>
<td>20</td>
<td>4.417</td>
<td>4.950</td>
</tr>
<tr>
<td>21</td>
<td>3.187</td>
<td>3.623</td>
</tr>
<tr>
<td>22</td>
<td>3.302</td>
<td>3.960</td>
</tr>
<tr>
<td>23</td>
<td>3.373</td>
<td>2.928</td>
</tr>
<tr>
<td>24</td>
<td>1.871</td>
<td>1.559</td>
</tr>
</tbody>
</table>

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,

\[
SP_0 = SPL + 5 \text{ where SPL = speed limit}
\]

\[
SP_1 = SP_0 - SLP(V_1) \text{ where SLP and } V_1 \text{ are from Table 13 and with } SP_1 \geq 28.5
\]

\[
SP_2 = SP_1/2.28 \text{ with } SP_2 \geq 15
\]

\[
V_2 = 1.2(V_1)
\]

\[
SP_3 = SP_1/3.8 \text{ with } SP_3 \geq 10
\]

\[
V_3 = 2.0(V_1)
\]

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

<table>
<thead>
<tr>
<th>Facility</th>
<th>Slope (SLP)</th>
<th>Volume per Lane at LOS D/E(V₁)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-Lane Rural no shoulders</td>
<td>.035</td>
<td>350</td>
</tr>
<tr>
<td>2-Lane Rural with shoulders</td>
<td>.017</td>
<td>500</td>
</tr>
<tr>
<td>2-Lane Urban no shoulders</td>
<td>.040</td>
<td>350</td>
</tr>
<tr>
<td>2-Lane Urban with shoulders</td>
<td>.020</td>
<td>500</td>
</tr>
<tr>
<td>4+ Lane Rural no shoulders</td>
<td>.0035</td>
<td>1000</td>
</tr>
<tr>
<td>4+ Lane Rural with shoulders</td>
<td>.003</td>
<td>1000</td>
</tr>
<tr>
<td>4+ Lane Urban no shoulders, no L. T. median</td>
<td>.015</td>
<td>500</td>
</tr>
<tr>
<td>4+ Lane Urban with shoulders, no L. T. median</td>
<td>.014</td>
<td>500</td>
</tr>
<tr>
<td>4+ Lane Urban no shoulders, with L. T. median</td>
<td>.012</td>
<td>650</td>
</tr>
<tr>
<td>4+ Lane Urban with shoulders, with L. T. median</td>
<td>.010</td>
<td>650</td>
</tr>
<tr>
<td>Freeway</td>
<td>.002</td>
<td>1500</td>
</tr>
</tbody>
</table>
Calculation of Delay Savings

Hourly delay can be calculated using the following equation,

\[ DLY = \frac{L(V)}{SP} \]

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,

\[ DQUE = \frac{QUE}{2} \]

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.

\[ DCST = \frac{(\text{COST})(365)}{(1+R)^T} \]

where \( DCST \) = discounted yearly delay cost
\( \text{COST} \) = 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 built over with the proposed, which would be the case with a new location construction 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.
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.
ENTRY, T=TERMINAL, C=CALL, R=READ, W=WRITE

DELAY SAVINGS MODEL WRITTEN BY JEFFERY L. MEMMOTT

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

DIMENSION LIC(2), LHY(2), LN(2), DT(2), SPL(2), SH(2), LFT(2), ISIG(2), DES(2), ISW(2), IHY(4), IHT(2), TRAF(24,2), SLP(11), CAP(11), TF(2), DCFST(2,2,4,1), DSV(999), CON(9999), INDX(9999), DSRP(6,9999), ADT(41), OCP(2)

DATA ISW/'R','U'/
DATA IHY/'R','D','F','B'/'

DO 98 JU=1,9999

DSV(JJ)=0.
CON(JJ)=0.

98 CONTINUE

C SET END FLAG AND PROBLEM COUNT TO ZERO

IEND=0.
IPR=0.
ICT=0.
N=0.
TCST=0.

C READ IN FIRST CARD

READ (5,5,END=100) YR, PT, V, V, FV, I, PJ

CONTINUE
C NO DATA CARDS

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,14//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 I=1,2

DO 116 IY=1,41

DCST(I,IY)=0.

CONTINUE

C READ IN PROBLEM CARD

IPROB=IPROB+1
READ (5,20,END=120) KPROB,CADT,PADT,(LOC(I),IHWY(I),LN(J),T(I..)
* SPL(I),SH(I),LFT(I),ISIG(I),IDEV(I),I=1,2),IBLD,PBLD,CST,
R *CDES(J),J=1,6)

20 FORMAT (I4,2(F6.0),2(A1),12,F4.0,F2.0,2(I1),12,11,2(A1),12,
*F4.0,F2.0,2(I1),12,2(I1),F3.0,F6.0,6(A4))

GOTO 130

C ALL PROBLEMS READ, GO TO SORTING
C CHECK PROBLEM NUMBER

100 IF (KPROB.GT.0) GOTO 135

25 FORMAT (//2X,'PROBLEM NUMBER MUST BE POSITIVE, ',
'PROBLEM NUMBER ',I4,' SKIPPED'//)

GOTO 115

C CHECK IF VALID LOCATION

135 IPRB=KPROB

DO 140 I=1,2

IF (LOC(I).EQ.ISW(I).OR.LOC(I).EQ.ISW(2)) GOTO 140

IFLAG=1

GOTO 497
IF (IFLAG.NE.1) GOTO 150

C ERROR IN LOCATION

WRITE (6,30) IPROB

30 FORMAT (I2X,'INVALID LOCATION:',I3,' PROBLEM NUMBER',I3,' SKIPPED')

GOTO 115

C SET RURAL-URBAN SWITCH

DO 160 I=1,2

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

160 CONTINUE

C CHECK HIGHWAY TYPE

IHT(I)=0
DO 170 J=1,4
    IF (IHY(I).EQ.IHY(J)) IHT(I)=J
    170 CONTINUE

IF (IHT(I).GT.0) GOTO 180
C INVALID HIGHWAY TYPE
WRITE (6,35) IPROB
FORMAT ('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
FORMAT ('INVALID NUMBER OF LANES')
40 FORMAT (/2X,'INVALID NUMBER OF LANES, MUST BE 1-20,' \n+"PROBLEM NUMBER ',14,' SKIPPED'//)

GOTO 115

OK

190 CONTINUE

C CHECK SPEED LIMIT

200 CONTINUE

C CHECK SHOULDER SWITCH
```fortran
IF (ISH(1).EQ.0.OR.ISH(1).EQ.1) GOTO 210

C INVALID SHOULDER SWITCH
WRITE (6,50) IPROB
50 FORMAT (/2X,'INVALID SHOULDER SWITCH, MUST BE 0 OR I, '
    ,*'PROBLEM NUMBER ',I4, ' SKIPPED'//)
GOTO 115

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 I, '
    ,*'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)
FORMAT (//2X,'INVALID PROJECTED ADT GROWTH CATEGORY',*, 'PROBLEM NUMBER ',I4,' SKIPPED'/)
GOTO 115

230 CONTINUE
C CHECK BUILD OVER SWITCH
IF (IBLD.EQ.0 .OR. IBLD.EQ.1) GOTO 240
C INVALID BUILD OVER SWITCH
WRITE (6, 60)
FORMAT (//2X,'INVALID BUILD OVER 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 BUILOVER SWITCH

IF (IBLD.EQ.0.OR.IBLD.EQ.1) GOTO 240
C INVALID BUILOVER SWITCH
WRITE (6,60) IPROB
60 FORMAT (//2X,'INVALID BUILOVER 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

65 FORMAT (//2X,'WHEN EXISTING ROUTE IS NOT BUILT OVER, 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

66 FORMAT (//2X,'CONSTRUCTION COST MUST BE POSITIVE, '
       '*PROBLEM NUMBER ',I4, ' SKIPPED'//)

GOTO 115
C  CALCULATE PROJECTED ADT IF NECESSARY

250 PYR=1PL+1

IF (PADT.GT.0.) GOTO 290

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

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

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

GOTO 290

OK---------------------------------------------------0

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

GOTO 290

OK---------------------------------------------------0

280 PADT=CADT*(PYR**.2087)

GOTO 290

OK---------------------------------------------------0
IF (IDEV(1)-2) 284, 286, 288
PADT=CADT*(PYR**.2840)
GOTO 290

PADT=CADT*(PYR**.2096)
GOTO 290

PADT=CADT*(PYR**.1133)
C CALCULATE ADT FOR EACH YEAR

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

DO 300 IY=1, IPN
ADT(IY)=CADT*(IY**EXPNT)
300

ADT(IY) = CADT * (IY ** EXPNT)
282 IF (IDEV(I)-2) = 204,206,208
284 PADT=CADT*(PYR**.2840)
GOTO 290

286 PADT=CADT*(PYR**.2096)
GOTO 290

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

0 CALCUKATE 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=ICT+1
WRITE (6,64)
64 FORMAT ('1')
WRITE (6,70) IPROB,(OES(J),J=1,6)
70 FORMAT (/6X,'PROBLEM NUMBER',14,5X,6(A4))
WRITE (6,71) CADT,PADT
71 FORMAT (/6X, 'CURRENT ADT',4X,F7.0/6X,'PROJECTED ADT ',F7.0)
WRITE (6,72) 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
380 CONTINUE
WRITE (6,68) w

FORMAT (8X, 'EXISTING')

GOTO 307

OK

WRITE (6,69) w

FORMAT (8X, 'PROPOSED')

OK

WRITE (6,73) w

FORMAT (+, T76, 'YES')

OK

WRITE (6,75) w

FORMAT (+, T77, 'NO')
320 IF (LFT(I).GT.0) GOTO 330

WRITE (6,76)

76 FORMAT ('+',TB9, 'YES')

GOTO 340

WRITE (6,77)

77 FORMAT ('+',T90, 'NO')

WRITE (6,78) ISIG(1)

78 FORMAT ('+',T103,12)

IF (IDEV(I)-2) 350,360,370

WRITE (6,79)

79 FORMAT ('+',T116, 'HIGH')

GOTO 380
*---------------*
**--------------------*

1 2 3 4 5 6 7 8 9 0

PAGE 15

80 FORMAT ('+',TI15,'MEDIUM')
GOTO 380

81 FORMAT ('+',TI16,'LOW')

380 CONTINUE

IF (IHT(2).EQ.4) GOTO 385

63 FORMAT (6X,'PROPOSED DOES NOT BUILD OVER EXISTING. '+,F5.2,
 '+ PERCENT PERSONS TO USE PROPOSED FACILITY')
GOTO 387

91 FORMAT (IX,')')

IF (IBLD.EQ.0) GOTO 390

WRITE (6,83) W
FORMAT (IX,'PROPOSED DOES NOT BUILD OVER EXISTING. '+,F5.2,
 '+ PERCENT PERSONS TO USE PROPOSED FACILITY')
GOTO 387

WRITE (6,93) W
FORMAT (IX,'PROPOSED DOES NOT BUILD OVER EXISTING. '+,F5.2,
 '+ PERCENT PERSONS TO USE PROPOSED FACILITY')
GOTO 387

390 CONTINUE

IF (IHT(2).EQ.4) GOTO 385

GOTO 387

WRITE (6,63) PBLD
FORMAT (6X,'PROPOSED DOES NOT BUILD OVER EXISTING. '+,F5.2,
 '+ PERCENT PERSONS TO USE PROPOSED FACILITY')
GOTO 387

WRITE (6,93) W
FORMAT (IX,'PROPOSED DOES NOT BUILD OVER EXISTING. '+,F5.2,
 '+ PERCENT PERSONS TO USE PROPOSED FACILITY')
GOTO 387

IF (IHT(2).EQ.4) GOTO 385

GOTO 387

*---------------*
**--------------------*

1 2 3 4 5 6 7 8 9 0
OK----------------------------------------------0

WRITE (6,82) PBLD

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

OK----------------------------------------------0

387 PBLD=PBLD/100.

OK----------------------------------------------0

WRITE (6,83)

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)=1

IF (IHT(I).GE.3) GOTO 397

IF (LN(I).GT.2) GOTO 395

GOTO 397
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

SET OCCUPANCY RATES

IF (IHT(J).EQ.4) GOTO 398

OCP(I)=1..3..3*PT

GOTO 399

OCP(I)=14.

SET UP CALCULATION FOR EXISTING/PROPOSED
C  CALCULATE HOURLY VEHICLE DEMAND AND CAPACITY

TCAP=CAP(I1(I1)+LN(I1))

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

VEH=ADT(IY)*TRAF(KH,ILC(I1))

GOTO 455

OK

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

VEH=ADT(IY)*TRAF(KH,ILC(I1))*(2.-I1+I1-1.3*PBLD)

GOTO 455

OK

447 VEH=ADT(IY)*TRAF(KH,ILC(I1))*(2.-I1+I1-1.3*

GOTO 455

OK

455 IF (VEH.LE.TCAP. AND. QUE.EQ.0.) GOTO 462

CALCULATE VEHICLES IN QUEUE

QUE=QUE

QUE=QUE+VEH-TCAP

PQE+1.
C CALCULATE CAPACITY SPEED

. 467 CSPD=SLP(1(T(I(I)))+CAP(1(T(I(I)))

C CALCULATE QUEUE SPEED

RSPD=CSPD/2.28

IF (RSPD.LT.15.) RSPD=15.

ESPD=CSPD/3.8

IF (ESP.D.LT.10.) ESPD=10.

PCAP=CAP(1(T(I(I)))

RCAP=PCAP+1.2

TVEH=PCAP+QUE/LN(I(II))

IF (TVEH.GT.RCAP) GOTO 468

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

GOTO 469

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

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

CALCULATE CAPACITY SPEED

GOTO 469

DQUE=DI(1(I)+VEH/GSPD

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

GOTO 469

DQUE=DI(1(I)+VEH/GSPD

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V

OK-------------------V
C  CALCULATE DELAY COST

470 IF (IH(I).EQ.4) GOTO 472

471 APT=PT/(1.-PBLD)+(1.-PT)*PT

472 CDLY=(PQE*DQUE+(1.-PQE)*DLY)*(APT*VTT+(1.-APT)*VTC)

473 CDLY=(PQE*DQUE+(1.-PQE)*DLY)*VTC*OCP(I)/1.3

C  ACCUMULATE FOR DAILY COST

475 COST=COST+CDLY
C CALCULATE DISCOUNTED YEARLY DELAY COST
DCST(I,I,IY)=CST*365./(1.+DR)**(IY-1)

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)

DO 480 IY=2,IPN
DSV(IPROB)=DSV(IPROB)/100.

C SAVE CONSTRUCTION COST AND DESCRIPTION
CST(IPROB)=CST
CON(IPROB)=DES

DO 490 J=1,6
DSRV(J,IPROB)=DES(J)
CONTINUE

N=N+1
INDX(N)=IPROB

PRINT WARNING IF QUEUE NOT DISSIPATED AT END OF DAY

IF (LQUE.LT.1) GOTO 495

WRITE (6,84)

FORMAT (2X,'*** WARNING *** EST. QUEUE NOT DISSIPATED AT ',*
*END OF DAY ON PROPOSED ROUTE; BEG. IN ',14,'.',*
* CHECK PROJ. ADT, MAY BE TOO HIGH. ')

PROCESS NEXT PROBLEM

GOTO 115

SORT DELAY SAVINGS/CONSTRUCTION COST RATIOS

M=M/2

IF (M.LT.1) GOTO 540

K=N-M
JA=1
PAGE 25

510 IA=JA

520 L=IA+M

IF (DSV(INDX(IA))/CON(INDX(IA)).GT.DSV(INDX(L))/CON(INDX(L))) *---------------V

GOTO 530

IA=IA-M

INDX(IA)=T

IF (OSV(INDX(IA))/CON(INDX(IA)).GT.DSV(INDX(IA))/CON(INDX(IA))) *---------------V

IAL0

IF (IA.GE.1) GOTO 520

IA=JA+1

IF (JA.GT.K) GOTO 500

GOTO 510

C PRINT OUT SORTED VALUES

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

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

W 540 WRITE (6,85)

AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

C
PAGE 26

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

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=SO*IN-49
IU=50+IN
IF (IU.GT.N) IU=N

WRITE (6,90)

90 FORMAT (100X)
DO 570 IX=IL,1U
    IP=INDX(I)
    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
570 CONTINUE

580 CONTINUE

STOP
END
Variable Dictionary

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

75
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
PAUT  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(1) 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
DELAY SAVINGS MODEL WRITTEN BY JEFFERY L. MEMMOTT

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

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),
* SPL(11), CAP(11), IT(2), DCST(2, 2, 41), DSV(9999), CON(9999),
* INDX(9999), DSRP(6, 9999), ADT(41), OOF(2)

DATA ISW/’R’, ’U’/
DATA IHWY/’U’, ’D’, ’F’, ’B’/
DATA TRAF/.00864, .00485, .00295, .00105, .00485, .01875, .06783,
* .00994, .05393, .05456, .05491, .06236, .08151, .06214, .0672, .07476,
* .06784, .08552, .0495, .03823, .0396, .02928, .01569, .00913, .005, .00394,
* .0293, .00391, .01708, .08316, .07983, .08016, .05122, .04915, .05114,
* .05124, .05275, .051, .07117, .0787, .07629, .05695, .04117, .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.
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, S, END=100) IYR, PT, VTC, VTT, DR, IPL
5 FORMAT (4X, I4, 4(F5.0), 13)
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.
12 IF (VTC.EQ.0.) VTC=10.2
13 IF (VTT.EQ.0.) VTT=19.2
14 IF (DR.EQ.0.) DR=8.
15 IF (IPL.EQ.0.) IPL=20
C PRINT OUT ASSUMPTIONS
20 WRITE (6, 20) IYR, PT, VTC, VTT, DR, IPL
20 FORMAT (’1’, 51X, ’*** DELAY SAVINGS MODEL ***’/4X,
*’ CURRENT YEAR’, 2X, ’/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)’, 2X, ’/13’, ’51X’,
*** PROBLEM INPUT DATA ***’/)
21 PT=PT/100.
22 DR=DR/100.
C ZERO OUT PROBLEM ARRAYS
115  IFLAG=0
116  IBLD=0
117  PBLD=0
118  LOUE=0
119  DCST(I,1,1)=0.
116  CONTINUE
C READ IN PROBLEM CARD
120  IPROB=IPROB+1
121  READ (5,20,END=120) KPROB,CADT, PADT, (LOC(I),IHWY(I),LN(I),DT(I),
122      +SPL(I),ISH(I),LFT(I),ISIG(I),IDEV(I),I=1,2), IBLD,PBLD,CST,
123      *(DES(J),J=I,6)
124  20 FORMAT (I4,2(F6.0),2(A1),12,F4.0,F2.0,2(I1),12,11,2(A1),12,
125      +F4.0,F2.0,2(I1),12,2(I1),F3.0,F6.0,6(A4))
126  GOTO 130
C ALL PROBLEMS READ, GO TO SORTING
127  IEND=1
128  GOTO 497
C CHECK PROBLEM NUMBER
130  IF (KPROB.GT.O) GOTO 135
131  WRITE (6,25) IPROB
132  25 FORMAT (//2X, 'PROBLEM NUMBER MUST BE POSITIVE,
133      '*'PROBLEM NUMBER',I4,' SKIPPED'//)
134  GOTO 115
C CHECK IF VALID LOCATION
135  IPROB=KPROB
136  DO 140 I=1,2
137  IF (LOC(I).EQ.ISW(1).OR.LOC(I).EQ.ISW(2)) GOTO 140
138  IFLAG=I
139  140  CONTINUE
140  CONTINUE
141  IF (IFLAG.NE.1) GOTO 150
C ERROR IN LOCATION
150  WRITE (6,30) IPROB
151  30 FORMAT (//2X,'INVALID LOCATION, ',
152      '*'PROBLEM NUMBER',I4,' SKIPPED'//)
153  GOTO 115
C SET RURAL-URBAN SWITCH
155  DO 160 I=1,2
156  IF (LOC(I).EQ.ISW(I)) ILC(I)=1
157  IF (LOC(I).EQ.ISW(2)) ILC(I)=2
158  160  CONTINUE
C CHECK HIGHWAY TYPE
159  DO 190 I=1,2
160  IF (LN(I).GE.1.0R.LN(I).LE.20) GOTO 190
161  IHT(I)=0
162  170  CONTINUE
163  IF (IHT(I).GT.0) GOTO 180
C INVALID HIGHWAY TYPE
164  WRITE (6,35) IPROB
165  35 FORMAT (//2X,'INVALID HIGHWAY TYPE,
166      '*'PROBLEM NUMBER',I4,' SKIPPED'//)
167  GOTO 115
C CHECK NUMBER OF LANES
168  DO 190 I=1,2
169  IF (LN(I).GE.1.0R.LN(I).LE.20) GOTO 190
170  CONTINUE
C
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 (CLFT(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
!
240 CONTINUE
C CHECK PERCENTAGE PERSONS USING PROPOSED FACILITY
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 BUILDOVER, PERCENTAGE ',
* 'PERSONS USING PROPOSED FACILITY MUST BE 1-99, ',
* 'PROBLEM NUMBER ',I4,' SKIPPED'//)
GOTO 115
C CHECK CONSTRUCTION COST
115 245 IF (CST.GT.0.) GOTO 250
C INVALID CONSTRUCTION COST
116 WRITE (6,65) IPROB
117 66 FORMAT ('/2X, 'CONSTRUCTION COST MUST BE POSITIVE, 
* "PROBLEM NUMBER " ',14, 'SKIPPED/')
118 GOTO 115
C CALCULATE PROJECTED ADT IF NECESSARY
119 250 PYR=IPR+1
120 IF (PADT.GT.0.) GOTO 290
121 IF (ILC(I).EQ.1) GOTO 282
122 IF (IDEV(I)-2) 260,270,280
123 260 PADT=CADT*(PYR**.3773)
124 GOTO 290
125 270 PADT=CADT*(PYR**.3030)
126 GOTO 290
127 280 IF (PADT.GT.0.) GOTO 290
128 IF (IPROB.IEQ.1) GOTO 290
129 282 IF (IDEV(I)-2) 284,286,288
130 284 PADT=CADT*(PYR**.2096)
131 GOTO 290
132 286 PADT=CADT*(PYR**.1133)
133 GOTO 290
134 288 PADT=CADT**(PYR**.1133)
C CALCULATE ADT FOR EACH YEAR
135 290 EXPNT=(ALOG(PADT)-ALOG(CADT))/ALOG(PYR)
136 1PN=IPR+1
137 DO 300 IY=1,IPN
138 ADT(IY)=CADT**IY**EXPNT
139 300 CONTINUE
C PRINT OUT INPUT DATA
140 ICT=1
141 IF (ICT.LT.5) GOTO 302
142 ICT=1
143 WRITE (6,64)
144 64 FORMAT ('i')
145 302 WRITE (6,70) IPROB,(DES(J),J=1,6)
146 70 FORMAT ('/4X, "PROBLEM NUMBER " ',14,5X,6(A4))
147 WRITE (6,71) CADT,PADT
148 71 FORMAT ('/6X, 'CURRENT ADT ',4X,F7.0/6X, 'PROJECTED ADT ',7.0)
149 WRITE (6,72)
150 72 FORMAT ('/6X, 'FACILITY DESC. ',3X,'LOC. ',3X,'HWY TYPE ',3X, 
* NO. LANES ',3X,'LENGTH ',3X,'SPD LMT ',3X,'SHOULDER ',3X, 
* "L. MEDIAN ',3X,'SIGNALS/MI. ',3X,'ADT GROWTH\')
151 DO 380 I=1,2
152 IF (ISH(I).GT.0) GOTO 310
153 WRITE (6,69)
154 69 FORMAT ('/8X, 'EXISTING' )
155 GOTO 307
156 305 WRITE (6,69)
157 69 FORMAT ('/8X, 'PROPOSED')
158 307 WRITE (6,73) LOC(I),IHWY(I),LN(I),DT(I),SPL(I)
159 73 FORMAT ('/4X, 'T25,A1,9X, A1,9X,12,7X,F5.1,6X,F3.0)
160 IF (ISH(I).GT.0) GOTO 310
161 WRITE (6,74)
162 74 FORMAT ('/4X, '176,'YES')
163 GOTO 320
164 310 WRITE (6,75)
165 75 FORMAT ('/4X, '77,'NO')
IF (LFT(I).GT.0) GOTO 330
WRITE (6,78) ISIGCI)
IF (IDEV(I)-2) 350,360,370
350 WRITE (6,79) GOTO 380
360 WRITE (6,80)
370 WRITE (6,81)
380 CONTINUE
WRITE (6,91) PBLD=PBLD/100.
385 WRITE (6,82)
390 WRITE (6,83) CST
392 DD 479 I=1,2
395 IT(I)=1
397 IF (IHT(I).GE.3) GOTO 397
399 IF (LN(I).GT.2) GOTO 395
200 IF (ILC(I).EQ.1.AND.ISH(I).EQ.1) IT(I)=1
201 IF (ILC(I).EQ.1.AND.ISH(I).EQ.0) IT(I)=2
202 IF (ILC(I).EQ.2.AND.ISH(I).EQ.1) IT(I)=3
203 IF (ILC(I).EQ.2.AND.ISH(I).EQ.0) IT(I)=4
GOTO 397
205 395 IT(I)=5
206 IF (ILC(I).EQ.1.AND.ISH(I).EQ.0) IT(I)=6
207 IF (ILC(I).EQ.2.AND.ISH(I).EQ.1.AND.LFT(I).EQ.1) IT(I)=7
208 IF (ILC(I).EQ.2.AND.ISH(I).EQ.0.AND.LFT(I).EQ.1) IT(I)=8
209 IF (ILC(I).EQ.2.AND.ISH(I).EQ.1.AND.LFT(I).EQ.0) IT(I)=9
210 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
399 IF (I.GT.1) GOTO 401
J1=1
J2=1
C SET UP CALCULATION FOR EXISTING/PROPOSED
399 IF (IBLD.EQ.0) GOTO 401
J1=1
J2=1
GOTO 404
401 IF (IBLD.EQ.0) GOTO 403
220 J1=1
221 J2=2
222 GOTO 404
223 403 J1=2
224 J2=2
225 404 DO 478 I1=J1,J2
226 C CALCULATE SPEED AND DELAY FOR EACH HOUR AND YEAR
227 DO 477 IY=2,1,PN
228INUE
229 COST=0.
230 DO 476 KH=1,24
231 PQE=0.
232 DLY=0.
233 DQUE=0.
234 C CALCULATE HOURLY VEHICLE DEMAND AND CAPACITY
235 TCAP=CAP(IT(I1))+LN(I1)
236 IF (I.EQ.2.AND.IBLD.EQ.1) GOTO 445
237 VEH=ADT(IY)+TRAF(KH,ILC(I))
238 GOTO 477
239 445 IF (IHT(I).EQ.4) GOTO 447
240 VEH=ADT(IY)+TRAF(KH,ILC(I1)1)*2.*I1+2.*I1-3.*PBLD
241 GOTO 455
242 447 VEH=ADT(IY)+TRAF(KH,ILC(I1))2.*I1-PBLD*(I-PT)*(2.*I1-1.3
243 *I1-1)/CDP(I1))
244 455 IF (VEH.LE.TCAP.AND.QUE.EQ.0.) GOTO 462
245 C CALCULATE VEHICLES IN QUEUE
246 QUE=QUE
247 PQE=1.
248 IF (QUE.GT.0.) GOTO 460
249 C CALCULATE PROPORTION OF HOUR QUEUE PRESENT
250 PQE=QUE/I(TCAP-VEH)
251 QUE=0.
252 C CALCULATE AVERAGE QUEUE
253 AQUE=(QUEI+QUE)/2.
254 IF (LQUE.EQ.1.OR.QUE.EQ.0..OR.KH.LT.24.OR.I1.EQ.1) GOTO 462
255 LQUE=1
256 460 IF (IYR.EQ.1) GOTO 465
257 IQYR=IYR+IY-1
258 C CALCULATE AVERAGE SPEED
259 SINT=SPL(I1)+5.
260 IF (QUE.EQ.0.) GOTO 467
261 SPD=SINT-SLP(IT(I1))1+VEH/LN(I1)
262 IF (SPD.LT.28.5) SPD=28.5
263 C CALCULATE DELAY
264 DLY=DT(I1)+VEH/SPD
265 IF (PQE.EQ.0.) GOTO 470
266 C CALCULATE CAPACITY SPEED
267 CSPD=SINT-SLP(IT(I1))1+CAP(IT(I1))
268 C CALCULATE QUEUE SPEED
269 RSPD=CSPD/2.28
270 IF (RSPD.LT.15.) RSPD=15.
271 ESPD=CSPD/3.8
272 IF (ESPDLT.10.) ESPD=10.
273 PCAP=CAP(IT(I1))
274 RCAP=PCAP+1.2
275 TVEH=PCAP*AQUE/LN(I1))
276 IF (TVEH.GT.RO.) GOTO 468
277 QSPD=(CSPD-RSPD)X(TVEH-PCAP)/(RCAP-PCAP)
278 GOTO 469
408 QSPD = RSPD + (RSPD - ESPD) + (TVEH - RCAP) / (1 + PCAP - RCAP)
        IF (QSPD LT ESPD) QSPD = ESPD
        C CALCULATE QUEUE DELAY

468 DQUE = DT(TVEH) / (QSPD - VSPD)
        C IF QUEUE NOT DISSIPATED AT END OF DAY, ADD DELAY TO DISSIPATE QUE

470 IF (QSPD LT ESPD) QSPD = ESPD
        C IF QUEUE NOT DISSIPATED

471 APT = PT / ((1 - PBLD) * (1 - PT) * PT)

472 CDLY = (PQE * DQUE + (1 - PQE) * DLY) * (APT * VTT + (1 - APT) * VTC)

473 CDLY = (PQE * DQUE + (1 - PQE) * DLY) * VTC * OCP / 1.3
        C ACCUMULATE FOR DAILY COST

475 COST = COST + CDLY

476 CONTINUE

C CALCULATE DELAY SAVINGS

DO 480 IY = 2, IPN
    DSV(IPROB) = DSV(IPROB) + DCST(I, IY) - DCST(2, IY)

480 CONTINUE

DSV(IPROB) = DSV(IPROB) / 1000.

C PRINT WARNING IF QUEUE NOT DISSIPATED AT END OF DAY

495 GOTO 115

C PROCESS NEXT PROBLEM

C SORT DELAY SAVINGS/CONSTRUCTION COST RATIOS

497 M = N

500 M = M / 2

501 CONTINUE

510 I = JA + 1

520 L = IA + M

530 IF (DSV(INDX(I)) / CON(INDX(I)) GT DSV(INDX(L)) / CON(INDX(L)))
    * GOTO 530

540 T = INDX(I)

550 IA = IA + T

560 IF (IA GE IPN) GOTO 520

570 JA = JA + 1

580 IF (JA GE I) GOTO 500
GOTO 510

PRINT OUT SORTED VALUES

WRITE (6,85)

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)

FORMAT ('1')
WRITE (6,87)
FORMAT (/8X, 'RANKING', 6X, 'PROBLEM', 14X, 'DESCRIPTION', 13X,
* 'DISCOUNTED', 8X, 'CONSTRUCTION', 10X, 'DELAY', 10X, 'CUMULATIVE' )
WRITE (6,88)
FORMAT (I1, I1)

560 CONTINUE

WRITE (6,89)
FORMAT (53X, 2(13X, '($000)'), 13X, 'RATIO', 9X, 'COST ($000)'/)

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,1U
INDEX(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

570 CONTINUE

580 STOP

END
CURRENT YEAR 1983

**ASSUMPTIONS**

<table>
<thead>
<tr>
<th>Assumption</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage Trucks</td>
<td>8.00</td>
</tr>
<tr>
<td>Value of Time, Cars ($/HR)</td>
<td>10.20</td>
</tr>
<tr>
<td>Value of Time, Trucks ($/HR)</td>
<td>19.20</td>
</tr>
<tr>
<td>Discount Rate (%)</td>
<td>8.00</td>
</tr>
<tr>
<td>Planning Horizon (Years)</td>
<td>20</td>
</tr>
</tbody>
</table>
### Problem Input Data

<table>
<thead>
<tr>
<th>Problem Number</th>
<th>Description</th>
<th>CURRENT ADT</th>
<th>PROJECTED ADT</th>
<th>CONSTRUCTION COST ($000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Improve Frwy 6/8 Lanes</td>
<td>70000</td>
<td>176088</td>
<td>40000</td>
</tr>
<tr>
<td>2</td>
<td>U4LN undiv. to divided</td>
<td>15000</td>
<td>28145</td>
<td>2500</td>
</tr>
<tr>
<td>3</td>
<td>Busway for 6LN Frwy</td>
<td>80000</td>
<td>160000</td>
<td>20000</td>
</tr>
<tr>
<td>4</td>
<td>Shoulders on rural Hwy</td>
<td>2000</td>
<td>4748</td>
<td>1500</td>
</tr>
</tbody>
</table>

**Facility Description**

<table>
<thead>
<tr>
<th>Loc.</th>
<th>HWY Type</th>
<th>No. Lanes</th>
<th>Length</th>
<th>Speed Limit</th>
<th>Shoulders</th>
<th>L.T. Median</th>
<th>Signals/MI.</th>
<th>ADT Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ex.</td>
<td>F</td>
<td>6</td>
<td>2.5</td>
<td>55</td>
<td>Yes</td>
<td>Yes</td>
<td>0</td>
<td>Medium</td>
</tr>
<tr>
<td>P.</td>
<td>F</td>
<td>6</td>
<td>2.5</td>
<td>55</td>
<td>Yes</td>
<td>Yes</td>
<td>0</td>
<td>Medium</td>
</tr>
</tbody>
</table>

**Construction Cost ($000)**

- 40000
- 2500
- 20000
- 1500
<table>
<thead>
<tr>
<th>Problem Number</th>
<th>Facility Desc.</th>
<th>Location</th>
<th>Hwy Type</th>
<th>No. Lanes</th>
<th>Length</th>
<th>Spd Lmt</th>
<th>Shoulders</th>
<th>L.T. Median</th>
<th>Signals/MI.</th>
<th>Adt Growth</th>
<th>Construction Cost ($000)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Existing</td>
<td>R D</td>
<td>4</td>
<td>3.0</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
<td>5000.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proposed</td>
<td>R F</td>
<td>8</td>
<td>3.0</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Existing</td>
<td>R D</td>
<td>2</td>
<td>6.0</td>
<td>55.</td>
<td>YES</td>
<td>NO</td>
<td>0</td>
<td>MEDIUM</td>
<td>10800.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proposed</td>
<td>R D</td>
<td>4</td>
<td>6.0</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Existing</td>
<td>U D</td>
<td>2</td>
<td>3.5</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
<td>6000.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proposed</td>
<td>U D</td>
<td>4</td>
<td>3.5</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Existing</td>
<td>U F</td>
<td>4</td>
<td>7.5</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
<td>79000.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Proposed</td>
<td>U F</td>
<td>10</td>
<td>7.5</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem Number</td>
<td>Description</td>
<td>Current ADT</td>
<td>Projected ADT</td>
<td>Facility Desc.</td>
<td>Loc.</td>
<td>HWY Type</td>
<td>No. Lanes</td>
<td>Length</td>
<td>Speed</td>
<td>LMT</td>
<td>Shoulders</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------</td>
<td>-------------</td>
<td>---------------</td>
<td>----------------</td>
<td>------</td>
<td>----------</td>
<td>-----------</td>
<td>--------</td>
<td>-------</td>
<td>-----</td>
<td>-----------</td>
</tr>
<tr>
<td>9</td>
<td>4LN UNDIV TO DVD</td>
<td>15000</td>
<td>35000</td>
<td>Existing</td>
<td>U</td>
<td>U</td>
<td>4</td>
<td>2.0</td>
<td>35.</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>10</td>
<td>6LN DVD TO 4LN FRWY</td>
<td>20000</td>
<td>50311</td>
<td>Existing</td>
<td>U</td>
<td>D</td>
<td>6</td>
<td>3.2</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>11</td>
<td>4LN UNDVD TO SHLD/+SPL</td>
<td>3600</td>
<td>17200</td>
<td>Existing</td>
<td>R</td>
<td>U</td>
<td>4</td>
<td>2.1</td>
<td>35.</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>12</td>
<td>2LN W/SHLD TO 4LN W/O</td>
<td>2400</td>
<td>12000</td>
<td>Existing</td>
<td>R</td>
<td>U</td>
<td>2</td>
<td>2.5</td>
<td>55.</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Problem Number</td>
<td>Facility Description</td>
<td>Location</td>
<td>Hwy Type</td>
<td>No. Lanes</td>
<td>Length</td>
<td>Speed Limit</td>
<td>Shoulders</td>
<td>L.T. Median</td>
<td>Signals/MI.</td>
<td>ADT Growth</td>
<td>Construction Cost ($000)</td>
</tr>
<tr>
<td>----------------</td>
<td>----------------------</td>
<td>----------</td>
<td>-----------</td>
<td>-----------</td>
<td>---------</td>
<td>-------------</td>
<td>-----------</td>
<td>-------------</td>
<td>-------------</td>
<td>------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td>13</td>
<td>ODD LANE FREEWAY</td>
<td>U</td>
<td>F</td>
<td>6</td>
<td>3.5</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>9</td>
<td>3.5</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td>CONSTRUCTION COST ($000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10300.</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>4LN FRWY TO 8LN FRWY</td>
<td>U</td>
<td>F</td>
<td>4</td>
<td>4.0</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>8</td>
<td>4.0</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td>CONSTRUCTION COST ($000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>20100.</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>4LN FRWY NEW LOCATION</td>
<td>U</td>
<td>D</td>
<td>4</td>
<td>3.0</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>D</td>
<td>4</td>
<td>3.0</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td>PROPOSED DOES NOT BUILOVER EXISTING. 70.00 PERCENT PERSONS TO USE PROPOSED FACILITY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CONSTRUCTION COST ($000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>50000.</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>BUSWAY FOR 8LN FRWY</td>
<td>U</td>
<td>F</td>
<td>8</td>
<td>3.1</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F</td>
<td>8</td>
<td>3.1</td>
<td>55.</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>0</td>
<td>MEDIUM</td>
</tr>
<tr>
<td></td>
<td>PROPOSED DOES NOT BUILOVER EXISTING. 10.00 PERCENT PERSONS FROM EXISTING FACILITY PASSENGER CARS TO USE PROPOSED FACILITY</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>CONSTRUCTION COST ($000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>23250.</td>
<td></td>
</tr>
<tr>
<td>RANKING</td>
<td>PROBLEM NUMBER</td>
<td>DESCRIPTION</td>
<td>DISCOUNTED DELAY SAVINGS ($000)</td>
<td>CONSTRUCTION COST ($000)</td>
<td>DELAY SAVINGS RATIO</td>
<td>CUMULATIVE CONSTRUCTION COST ($000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>---------</td>
<td>----------------</td>
<td>-------------</td>
<td>----------------------------------</td>
<td>--------------------------</td>
<td>---------------------</td>
<td>-------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>6</td>
<td>2LN UNDIV TO 4LN DVD</td>
<td>449651.2</td>
<td>10800.0</td>
<td>41.63</td>
<td>10800.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>4LN DVD TO 8LN FRWY</td>
<td>152925.2</td>
<td>5000.0</td>
<td>30.59</td>
<td>15800.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>16</td>
<td>BUSWAY FOR 8LN FRWY</td>
<td>386732.5</td>
<td>23250.0</td>
<td>15.77</td>
<td>39050.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>13</td>
<td>ODD LANE FREEWAY</td>
<td>106632.4</td>
<td>10300.0</td>
<td>10.35</td>
<td>40350.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>4LN FRWY TO 10LN FRWY</td>
<td>523635.7</td>
<td>79000.0</td>
<td>6.63</td>
<td>128350.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>14</td>
<td>4LN FRWY TO 8LN FRWY</td>
<td>126032.1</td>
<td>20100.0</td>
<td>6.27</td>
<td>148450.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>11</td>
<td>4LN UNDIV TO SHLD/SPL</td>
<td>74803.3</td>
<td>1500.0</td>
<td>4.99</td>
<td>149950.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>1</td>
<td>IMPROVE FRWY 6/8 LANES</td>
<td>156558.1</td>
<td>40000.0</td>
<td>3.91</td>
<td>189950.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>9</td>
<td>4LN UNDIV TO DVD</td>
<td>26088.2</td>
<td>7000.0</td>
<td>3.73</td>
<td>196850.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>BUSWAY FOR 6LN FRWY</td>
<td>47773.9</td>
<td>20000.0</td>
<td>2.39</td>
<td>216850.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>15</td>
<td>4LN FRWY NEW LOCATION</td>
<td>68385.4</td>
<td>50000.0</td>
<td>1.33</td>
<td>256950.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>12</td>
<td>2LN W/SHLD TO 4LN W/O</td>
<td>814.4</td>
<td>700.0</td>
<td>1.16</td>
<td>257650.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>2LN DVD TO 4LN DVD</td>
<td>3873.9</td>
<td>6000.0</td>
<td>0.65</td>
<td>273650.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>2</td>
<td>4LN UNDIV. TO DIVIDED</td>
<td>907.6</td>
<td>2500.0</td>
<td>0.36</td>
<td>276150.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>4</td>
<td>SHOULDERS ON RURAL HWY</td>
<td>484.7</td>
<td>1500.0</td>
<td>0.32</td>
<td>277650.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>10</td>
<td>6LN DVD TO 4LN FRWY</td>
<td>3632.7</td>
<td>16000.0</td>
<td>0.23</td>
<td>293650.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
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:

\[
\text{DSR} = D_H \times \frac{1,000}{x} \times VT \times L + CST
\]

where
- \( D_H \) = 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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
</tr>
<tr>
<td>1,000</td>
<td>1,412</td>
<td>1,893</td>
<td>2,374</td>
</tr>
<tr>
<td>2,000</td>
<td>2,824</td>
<td>3,786</td>
<td>4,748</td>
</tr>
<tr>
<td>3,000</td>
<td>4,236</td>
<td>5,679</td>
<td>7,122</td>
</tr>
<tr>
<td>4,000</td>
<td>5,648</td>
<td>7,572</td>
<td>9,497</td>
</tr>
<tr>
<td>5,000</td>
<td>7,060</td>
<td>9,465</td>
<td>11,871</td>
</tr>
<tr>
<td>6,000</td>
<td>8,471</td>
<td>11,358</td>
<td>14,245</td>
</tr>
<tr>
<td>7,000</td>
<td>9,883</td>
<td>13,251</td>
<td>16,619</td>
</tr>
<tr>
<td>8,000</td>
<td>11,295</td>
<td>15,144</td>
<td>18,993</td>
</tr>
</tbody>
</table>

*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

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

*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

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

*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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
</tr>
<tr>
<td>1,000</td>
<td>1,876</td>
<td>2.24</td>
<td>2,516</td>
</tr>
<tr>
<td>2,000</td>
<td>3,753</td>
<td>9.31</td>
<td>5,031</td>
</tr>
<tr>
<td>3,000</td>
<td>5,629</td>
<td>21.85</td>
<td>7,547</td>
</tr>
<tr>
<td>4,000</td>
<td>7,505</td>
<td>40.58</td>
<td>10,062</td>
</tr>
<tr>
<td>5,000</td>
<td>9,382</td>
<td>67.57</td>
<td>12,578</td>
</tr>
<tr>
<td>6,000</td>
<td>11,258</td>
<td>204.63</td>
<td>15,093</td>
</tr>
<tr>
<td>7,000</td>
<td>13,134</td>
<td>684.30</td>
<td>17,609</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
</tr>
<tr>
<td>3,000</td>
<td>5,629</td>
<td>7,547</td>
<td>9,462</td>
</tr>
<tr>
<td></td>
<td>0.92</td>
<td>1.43</td>
<td>2.02</td>
</tr>
<tr>
<td>4,000</td>
<td>7,505</td>
<td>10,062</td>
<td>12,616</td>
</tr>
<tr>
<td></td>
<td>1.66</td>
<td>2.57</td>
<td>3.65</td>
</tr>
<tr>
<td>5,000</td>
<td>9,382</td>
<td>12,578</td>
<td>15,770</td>
</tr>
<tr>
<td></td>
<td>2.62</td>
<td>4.08</td>
<td>5.81</td>
</tr>
<tr>
<td>6,000</td>
<td>11,258</td>
<td>15,093</td>
<td>18,925</td>
</tr>
<tr>
<td></td>
<td>3.82</td>
<td>5.96</td>
<td>8.52</td>
</tr>
<tr>
<td>7,000</td>
<td>13,134</td>
<td>17,609</td>
<td>22,079</td>
</tr>
<tr>
<td></td>
<td>5.26</td>
<td>8.23</td>
<td>11.81</td>
</tr>
<tr>
<td>8,000</td>
<td>15,010</td>
<td>20,124</td>
<td>25,233</td>
</tr>
<tr>
<td></td>
<td>6.95</td>
<td>10.91</td>
<td>15.72</td>
</tr>
<tr>
<td>9,000</td>
<td>16,887</td>
<td>22,640</td>
<td>28,387</td>
</tr>
<tr>
<td></td>
<td>8.90</td>
<td>14.02</td>
<td>33.89</td>
</tr>
<tr>
<td>10,000</td>
<td>18,763</td>
<td>25,155</td>
<td>31,541</td>
</tr>
<tr>
<td></td>
<td>11.11</td>
<td>17.58</td>
<td>140.41</td>
</tr>
<tr>
<td>11,000</td>
<td>20,639</td>
<td>27,671</td>
<td>34,695</td>
</tr>
<tr>
<td></td>
<td>13.60</td>
<td>20.09</td>
<td>375.09</td>
</tr>
<tr>
<td>12,000</td>
<td>22,516</td>
<td>30,187</td>
<td>37,849</td>
</tr>
<tr>
<td></td>
<td>16.38</td>
<td>96.45</td>
<td>849.76</td>
</tr>
<tr>
<td>13,000</td>
<td>24,392</td>
<td>32,702</td>
<td>41,003</td>
</tr>
<tr>
<td></td>
<td>19.46</td>
<td>254.94</td>
<td>1,797.74</td>
</tr>
<tr>
<td>14,000</td>
<td>26,268</td>
<td>35,218</td>
<td>44,157</td>
</tr>
<tr>
<td></td>
<td>23.77</td>
<td>529.08</td>
<td>3,203.19</td>
</tr>
<tr>
<td>15,000</td>
<td>28,145</td>
<td>37,733</td>
<td>47,311</td>
</tr>
<tr>
<td></td>
<td>43.95</td>
<td>1,014.26</td>
<td>4,889.13</td>
</tr>
<tr>
<td>16,000</td>
<td>30,021</td>
<td>40,249</td>
<td>50,465</td>
</tr>
<tr>
<td></td>
<td>121.98</td>
<td>1,868.87</td>
<td>6,646.15</td>
</tr>
<tr>
<td>17,000</td>
<td>31,897</td>
<td>42,764</td>
<td>53,619</td>
</tr>
<tr>
<td></td>
<td>271.68</td>
<td>3,108.20</td>
<td>8,223.82</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
<td>Hours of Delay Savings*</td>
</tr>
<tr>
<td>5,000</td>
<td>9,382</td>
<td>12,578</td>
<td>15,770</td>
</tr>
<tr>
<td>7,500</td>
<td>14,072</td>
<td>18,867</td>
<td>23,656</td>
</tr>
<tr>
<td>10,000</td>
<td>18,763</td>
<td>25,155</td>
<td>31,541</td>
</tr>
<tr>
<td>12,500</td>
<td>23,454</td>
<td>31,444</td>
<td>39,426</td>
</tr>
<tr>
<td>15,000</td>
<td>28,145</td>
<td>37,733</td>
<td>47,311</td>
</tr>
<tr>
<td>17,500</td>
<td>32,835</td>
<td>44,022</td>
<td>55,196</td>
</tr>
<tr>
<td>20,000</td>
<td>37,526</td>
<td>50,311</td>
<td>63,082</td>
</tr>
<tr>
<td>22,500</td>
<td>42,417</td>
<td>56,600</td>
<td>70,967</td>
</tr>
<tr>
<td>25,000</td>
<td>46,908</td>
<td>62,889</td>
<td>78,852</td>
</tr>
<tr>
<td>27,500</td>
<td>51,598</td>
<td>69,178</td>
<td>86,737</td>
</tr>
<tr>
<td>30,000</td>
<td>56,289</td>
<td>75,466</td>
<td>94,623</td>
</tr>
</tbody>
</table>

*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

<table>
<thead>
<tr>
<th>Current ADT</th>
<th>Low Projected ADT</th>
<th>Medium Projected ADT</th>
<th>High Projected ADT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Projection</td>
<td>Hours of Delay Savings*</td>
<td>Projection</td>
</tr>
<tr>
<td>20,000</td>
<td>37,526</td>
<td>9.06</td>
<td>50,311</td>
</tr>
<tr>
<td>25,000</td>
<td>46,908</td>
<td>14.26</td>
<td>62,889</td>
</tr>
<tr>
<td>30,000</td>
<td>56,289</td>
<td>20.67</td>
<td>75,466</td>
</tr>
<tr>
<td>35,000</td>
<td>65,671</td>
<td>28.33</td>
<td>88,044</td>
</tr>
<tr>
<td>40,000</td>
<td>75,052</td>
<td>37.27</td>
<td>100,622</td>
</tr>
<tr>
<td>45,500</td>
<td>84,434</td>
<td>95.91</td>
<td>113,200</td>
</tr>
<tr>
<td>50,000</td>
<td>93,815</td>
<td>560.80</td>
<td>125,777</td>
</tr>
<tr>
<td>55,000</td>
<td>103,197</td>
<td>1,635.58</td>
<td>138,355</td>
</tr>
<tr>
<td>60,000</td>
<td>112,578</td>
<td>3,883.89</td>
<td>150,933</td>
</tr>
</tbody>
</table>

*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