JOINT HIGHWAY RESEARCH PROJECT
JHRP-79-6

METHODOLOGY FOR EVALUATING THE IMPACTS OF ENERGY, NATIONAL ECONOMY, AND PUBLIC POLICIES ON STATE HIGHWAY FINANCING AND PERFORMANCE

F. L. Mannering
Final Report

METHODOLOGY FOR EVALUATING THE IMPACTS OF ENERGY, NATIONAL ECONOMY, AND PUBLIC POLICIES ON STATE HIGHWAY FINANCING AND PERFORMANCE

TO: Harold L. Michael, Director
Joint Highway Research Project

FROM: Kumares C. Sinha, Research Engineer
Joint Highway Research Project

July 11, 1979
File: 3-4-6
Project: C-36-73F

Attached is a Final Report by Mr. Fred L. Mannering, Graduate Instructor in Research on our staff, titled "Methodology for Evaluating the Impacts of Energy, National Economy, and Public Policies on State Highway Financing and Performance". Professor K. C. Sinha directed the research and guided preparation of the Final Report.

The Report describes the development of a computer model that can be utilized to analyze and estimate the complex interactions between the critical factors influencing state highway financing and their impact on highway system performance. The model was extensively tested and applied to the Indiana situation. The options considered in this study revealed that, although a general decline in highway performance can be expected, appropriate highway policy decisions can assure the sustenance of a tolerable level of highway performance well into the future.

The Report is presented as the Final Report on this Study for acceptance as fulfillment of its objectives.

Respectfully submitted,

[Signature]

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Final Report

METHODOLOGY FOR EVALUATING THE IMPACTS OF ENERGY, NATIONAL ECONOMY, AND PUBLIC POLICIES ON STATE HIGHWAY FINANCING AND PERFORMANCE

by

Fred L. Mannering
Graduate Instructor in Research

Joint Highway Research Project

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The author is grateful to the Joint Highway Research Project and to the Indiana State Highway Commission for supplying the financial support without which this research would not have been possible.

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ABSTRACT


Inflationary pressures, stabilizing road-use tax revenues, energy constraints, and recent national automotive policy decisions have created problems which have dramatically affected the highway financing process. The objective of this project was to develop a tool which can be utilized to analyze and estimate the complex interactions between the critical factors influencing state highway financing and their ultimate impact on highway performance, so that the results could enable legislators to make informed decisions regarding this issue. This objective was achieved by the development of a computer simulation model which was extensively tested and applied to the Indiana problem.

The computer model utilized the national energy and economic forecasts developed by Data Resources Inc. along with various assumptions regarding legislative options to project a probable range of Indiana highway performance. The results of the model application indicated that an overall deterioration in highway performance can be expected to continue in Indiana as the funds required to stabilize or improve highway performance are enormous. However, the extent of future highway performance deterioration can be regulated by new
taxing policies, revised highway performance criteria, and governmental promotion of car pooling, mass transit, and other factors that may effectively reduce future highway congestion. The options considered in this study revealed that, although a general decline in highway performance can be expected, appropriate highway policy decisions can assure the sustenance of a tolerable level of highway performance well into the future.
CHAPTER 1
INTRODUCTION

The present state highway financing process is confronted with a number of serious problems that have been aggravated by recent economic conditions and national policy decisions. On one hand the highway construction, operation, and maintenance costs have experienced rampant increases in recent years, as shown in Figure 1, while the amount of road-user tax revenues has remained the same or declined, as shown in Figure 2. At the same time, increasing proportions of the state highway budget are being consumed by non-capital recurring costs such as routine maintenance, highway patrol, safety, planning, research, administration, and debt service (1).

Such problems have led to the deferral of many needed highway improvement projects, and subsequently, the overall highway performance has suffered. Moreover, the long-term impacts that national and regional energy conservation efforts will have on the state highway financing process are not clearly understood.

It is clear that there is a definite need to examine possible legislative actions to substantially change the state revenue generating structure and/or tax rates in order to provide sufficient resources for highway construction, operation, and maintenance. The intent of the present research project is to provide a tool, in the
FIGURE 1. SUMMARY OF NATIONAL HIGHWAY CONSTRUCTION AND HIGHWAY MAINTENANCE & OPERATION COST INDICES

SOURCE: REFERENCE 1.
FIGURE 2: TOTAL HIGHWAY REVENUES BY SOURCE IN INDIANA (1970-1975)

SOURCE: REFERENCE 1.
form of a computer model, to systematically evaluate the impacts that various proposed highway related legislative decisions may have on highway performance in Indiana.

Two recent studies investigated the problem of state highway financing in Indiana (2,3). The first study dealt exclusively with revenue generation (2) while the other study projected estimates of "highway needs" which were determined subjectively only on an aggregated basis (3). Most studies performed in connection with state highway financing, such as the one conducted for Vermont (4), tend to oversimplify many of the underlying factors affecting the highway financing process, and as a result, the forecasting capabilities of such studies are limited.

The most comprehensive study performed in this field has been the 1976 National Highway Inventory and Performance Study (NHIPS) (5). The 1976 NHIPS was the first major study to apply the exacting methods of measuring highway performance that were first introduced in the 1974 National Highway Needs Report (6). The application of such highway performance measurements enabled the detailed projections of highway service, physical conditions, and operating conditions to be made under various highway revenue scenarios. Such projections represented a major departure from previous studies in that the relative effectiveness of various financing policies, in terms of highway performance, could now be readily assessed. However, the 1976 NHIPS and most other studies in this area did not explicitly consider many or all of the interactive economic factors that affect future highway financing and performance forecasts.
In the present study a computer model was developed as a tool to analyze the state highway financing problem, and the broad objectives of this study are mentioned below:

1. Incorporate appropriately the interaction between the economic factors and the highway financing and performance variables.
2. Develop a consistent and detailed technique to measure and project highway performance.
3. Provide sufficient flexibility such that the analysis procedure can account for a variety of state and national legislative options.
4. Minimize the modifications necessary to adapt and transfer the use of the model to geographical areas other than the state of Indiana.

The resulting computer model provides detailed projections of a variety of factors relating to highway financing and highway performance in Indiana. Such information enables the analyst to evaluate many of the dynamic processes simulated by the computer model. An overview of the entire modeling procedure used in the present study is presented in Figure 3.

The national macroeconomic forecasts are provided as input to the modeling procedure. These forecasts directly affect fuel efficiency projections, fuel consumption projections, state highway user revenues, projections of highway performance and projections of highway improvements. Fuel efficiency projections are made on the national level and are a critical component in the determination of
FIGURE 3. OVERVIEW OF THE SIMULATION PROCEDURE
fuel consumption projections which are in turn vital to the estimation of future state highway-user revenues. Additionally, Indiana population projections were made by the cohort survival method and are utilized to estimate the number of registered vehicles and the number of licensed drivers both of which are also important factors in the calculation of state highway-user revenues. Revenues from sources such as federal aid are estimated exogenously, and when combined with the internally projected state highway-user revenues constitute the total funds available for highway improvements.

Finally, the present highway conditions are simulated internally and are used along with projections of highway improvements and other factors to estimate future highway performance which is the ultimate objective of the modeling procedure.

A more detailed explanation of the model simulation procedure is presented in the following chapters. The final two chapters are concerned with the application of the computer model to the Indiana highway financing problem.
CHAPTER 2
ECONOMIC AND ENERGY FORECASTS

In this chapter discussions are presented relating to the macroeconomic forecasts and energy assumptions incorporated in these forecasts. The macroeconomic forecasts including the associated energy assumptions were taken from the study conducted by Data Resources Inc. on a national level (7).

Macroeconomic Forecasts

The three national macroeconomic forecasts developed by Data Resources, Inc. (DRI), TRENDLONG 0978, CYCLELONG 0978, and PESSIMLONG 0978, were used in this analysis to provide a probable range of future economic conditions. These three forecasts are briefly outlined below:

TRENDLONG is essentially a stable long-run simulation of the U.S. economy. In this model the economy achieves a uniform Gross National Product (GNP) growth by the mid-1980's and full-employment is nearly reached after 1985. In addition, the federal budget and the national trade account achieve a near balance by the early 1980's.

CYCLELONG is a cyclical economic simulation model that forecasts the business cycles that have historically characterized the U.S. economy. The cyclical behavior is induced by factors such as financial pressures, inventory variations, foreign demand shifts, and
imperfect policy decisions. The loss of potential output results in a 1990 GNP that is 2.2% less than that projected by the TRENDLONG model.

PESSIMLONG is an economic simulation model that projects essentially the same price, exogenous factors, and final demand behavior that has typified the U.S. economy in the past 10 years. Inflation becomes increasingly troublesome and is fueled by inappropriate policy decisions and increasing food and oil prices. The resultant 1990 GNP is less than that projected by either of the other two models.

A summary of the basic assumptions underlying these macroeconomic forecasts is presented in Table 1. In Figure 4 are illustrated the GNP forecasts generated by these models. The assumptions involving energy supply and demand, as used in the preparing of the three macroeconomic forecasts, are discussed in detail in the next section.

Energy Supply and Demand

In recent years, a number of studies have been undertaken to forecast future energy demands and supplies. The results of such studies have varied considerably as there is much uncertainty relating to future energy reserves, the effectiveness of conservation efforts, and the impacts of technology. However, the general consensus of these studies indicates that the world faces long-term oil and gas shortages which will result from the inability of reserve additions to match energy consumption growth (8,9).
TABLE 1. MAJOR ASSUMPTIONS UNDERLYING DRI MACROECONOMIC FORECASTS.

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<td>FLUCTUATIONS IN POLICY CONTRIBUTE TO THE SEVERITY OF CYCLES.</td>
<td></td>
</tr>
<tr>
<td>CONSUMER BEHAVIOR</td>
<td>LOW INFLATION AND JOB SECURITY INCREASE CONSUMER CONFIDENCE.</td>
<td>CYCLICAL VARIATIONS IN SENTIMENT RESULT IN LARGE FLUCTUATIONS IN DURABLE GOOD EXPENDITURES.</td>
<td></td>
</tr>
<tr>
<td>BUSINESS BEHAVIOR</td>
<td>DECISIONS MADE IN A STABLE ENVIRONMENT.</td>
<td>OUTPUT FLUCTUATIONS AND INFLATION RESULT IN UNCERTAINTY AND INVESTOR CAUTION.</td>
<td></td>
</tr>
<tr>
<td>INFLATION</td>
<td>CAPACITY UTILIZATION AND ENERGY INFLUENCE THE IMMEDIATE FUTURE WITH STEADY IMPROVEMENT BEGINNING IN THE EARLY 1980’S.</td>
<td>CONTINUAL BOOM-BUST PATTERN RAISES THE AVERAGE RATE.</td>
<td>AGGRESSIVE WAGE AND PRICE BEHAVIOR PUSHES RATES UPWARD AND INCREASES THE THE SEVERITY OF ECONOMIC SLOW DOWNS.</td>
</tr>
</tbody>
</table>

SOURCE: REFERENCE 7.
As a result of these projected shortages, the growth in world energy demand must be curtailed such that future supply and demand equilibrium can be attained. The extent of this curtailment can be estimated by analyzing the four major factors influencing future world energy consumption; 1) economic growth, 2) energy prices, 3) inter-fuel substitution, and 4) availability of energy supplies. It must be noted that the above factors are interdependent and the following discussion is made considering this interdependency.

Economic Growth

In the past, a virtually unlimited supply of energy was available for economic growth. With the prospect of future energy shortages, it is necessary to set realistic economic growth goals and to achieve these goals with a more efficient use of limited energy supplies.

At the conclusion of the recent Bonn Summit meeting (July, 1978), seven heads of state released important statements regarding future energy actions. The emphasis of these actions was placed on conservation and increased domestic energy production. To achieve these objectives, aggressive conservation programs as well as the rapid development of domestic energy resources are necessary.

Table 2 summarizes the projected economic and energy growth rates resulting from the summit. These rates were utilized as input to the three macroeconomic models previously described. Barring any major disruptions in the world economic system, the goals set at the summit are quite reasonable and are likely to be achieved.
TABLE 2. ENERGY AND GNP RELATIONS, THE SEVEN SUMMIT COUNTRIES.

<table>
<thead>
<tr>
<th>Country</th>
<th>REAL GNP (1960-73)</th>
<th>REAL GNP (1973-77)</th>
<th>REAL GNP (1977-85)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>REAL ENERGY</td>
<td>REAL ENERGY</td>
<td>REAL ENERGY</td>
</tr>
<tr>
<td>EUROPE</td>
<td>4.9</td>
<td>1.6</td>
<td>3.3</td>
</tr>
<tr>
<td>JAPAN</td>
<td>10.3</td>
<td>3.1</td>
<td>5.1</td>
</tr>
<tr>
<td>CANADA</td>
<td>5.6</td>
<td>3.3</td>
<td>4.4</td>
</tr>
<tr>
<td>U.S.</td>
<td>4.1</td>
<td>2.0</td>
<td>3.8</td>
</tr>
</tbody>
</table>

IMPLIED ENERGY-GNP ELASTICITY

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>EUROPE</td>
<td>1.02</td>
<td>0.25</td>
<td>0.80</td>
</tr>
<tr>
<td>JAPAN</td>
<td>1.09</td>
<td>0.04</td>
<td>0.70</td>
</tr>
<tr>
<td>CANADA</td>
<td>1.02</td>
<td>0.68</td>
<td>0.90</td>
</tr>
<tr>
<td>U.S.</td>
<td>1.00</td>
<td>0.20</td>
<td>0.75</td>
</tr>
</tbody>
</table>

SOURCE: REFERENCE 7.
Energy Prices

Energy prices have been and will continue to be dominated by the price of crude oil. To a large extent, future world crude oil prices will be set by the OPEC cartel which controls an enormous percentage of the total non-communist oil and gas reserves. Most major energy studies have projected OPEC crude oil prices to remain constant in real terms (i.e. price increases equalling the rate of inflation) or increasing only slightly (8,9,10,11,12).

The average annual projected increases in OPEC crude oil prices utilized in the DRI macroeconomic models vary from 7.4% (1.5% above the average U.S. inflation rate) for the TRENDLONG model to 10.7% (2.8% above the average inflation rate) for the PESSIMLONG model. The actual domestic energy prices are influenced additionally by U.S. governmental policies. Current domestic oil prices are well below world levels and recent energy legislation, which proposes to raise domestic oil prices to world levels by 1980, is given virtually no chance of passing. However, increases in nonregulated domestic oil production from the Alaskan slope, enhanced recovery techniques, and stripper wells, will raise the average price of domestic oil over the next few years. As a result, wholesale fuel prices will rise at a more rapid rate than import fuel prices.

The DRI fuel pricing projections are summarized in Table 3.

Interfuel Substitution

The ability of world economies to convert primary oil and gas consumers to consumers of more plentiful energy sources (such as coal
TABLE 3. SUMMARY OF DRI ENERGY-RELATED PROJECTIONS (COMPOUND ANNUAL GROWTH RATES IN PERCENT).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>FUEL IMPORTS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRICE OF FUEL IMPORTS</td>
<td>7.4</td>
<td>9.2</td>
<td>10.7</td>
</tr>
<tr>
<td>REAL FUEL IMPORTS</td>
<td>2.4</td>
<td>2.4</td>
<td>2.4</td>
</tr>
<tr>
<td>DOMESTIC PRICES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WHOLESALE FUEL PRICE</td>
<td>8.9</td>
<td>10.4</td>
<td>11.0</td>
</tr>
<tr>
<td>GASOLINE PRICE DEFlator</td>
<td>6.2</td>
<td>7.3</td>
<td>8.2</td>
</tr>
<tr>
<td>GNP PRICE DEFlator</td>
<td>6.1</td>
<td>6.8</td>
<td>7.9</td>
</tr>
</tbody>
</table>

SOURCE: REFERENCE 7.
and nuclear energy) will be an important factor in determining future energy supply and demand equilibrium. The extent of non-OPEC coal resources is substantial. However, due to the inherent time lag in coal conversions resulting from technological problems and short-term coal production limitations, the importance of coal in the total energy picture will be one of only gradual increase over the time period of this analysis.

It is generally acknowledged that the environmental problems associated with nuclear energy will affect only its short-term growth rates and the continual search for inexpensive energy sources will make nuclear energy an increasingly important energy source throughout the 1980's. Other energy sources, such as solar and geothermal, cannot be expected to make significant contributions to the world energy needs until at least the 1990's.

In conclusion, although interfuel substitution will become a relatively important factor in reducing oil and gas demand pressures (particularly in the late 1980's), it must be realized that oil and gas will remain the dominant energy sources well into the 1990's.

A perspective of U.S. energy supply by type of energy source is presented in Figure 5.

Energy Supplies

Future world energy supplies will be determined by; 1) the energy production of energy importing nations, 2) the OPEC energy production, 3) the energy production of communist nations.
FIGURE 5. A PERSPECTIVE OF U.S. LONG-TERM ENERGY SUPPLY

SOURCE: REFERENCE 12.
Estimates of energy production among energy importing nations, represented here by the Organization for Economic Cooperation and Development (OECD) which includes most major non-communist industrial nations, are provided by the Department of Energy (12) and are summarized in Figure 6. This figure is based on the Department of Energy (DOE) projection series C which used an earlier run of the DRI TRENDLONG model to project future world economic conditions and whose basic energy and economic assumptions are similar to those used in the TRENDLONG model run utilized in this analysis. Table 4 reveals that despite significant increases in OECD energy production, the OECD nations will become even more dependent on non-OECD energy imports in the future.

The projected U.S. petroleum and natural gas supplies, under the same DOE projection scenario C (Figures 7 and 8), reflect the future U.S. dependence on imported energy.

As a result of the energy import needs of OECD nations, the OPEC energy production (specifically oil) is the critical driving force in all energy related projections. Estimations of OPEC oil production capabilities vary considerably. But it is generally realized that sufficient OPEC production capacity exists to meet world needs until at least the 1990's providing that controlled worldwide energy growth rates are achieved.

Much uncertainty shrouds the role that communist nations will play in the world energy balance. It seems most likely that the role of communist nations as net importers or net exporters of energy will be relatively small for some time.
FIGURE 6. OECD ENERGY PRODUCTION 1960–1990 DEPARTMENT OF ENERGY, PROJECTION SERIES C

SOURCE: REFERENCE 12.
<table>
<thead>
<tr>
<th>Country</th>
<th>1975 Actual</th>
<th>1985</th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNITED STATES</td>
<td>16</td>
<td>24</td>
<td>27</td>
</tr>
<tr>
<td>CANADA</td>
<td>24</td>
<td>13</td>
<td>22</td>
</tr>
<tr>
<td>OECD EUROPE</td>
<td>60</td>
<td>52</td>
<td>55</td>
</tr>
<tr>
<td>AUSTRALIA/NEW ZEALAND</td>
<td>27</td>
<td>24</td>
<td>29</td>
</tr>
<tr>
<td>JAPAN</td>
<td>85</td>
<td>79</td>
<td>79</td>
</tr>
<tr>
<td><strong>TOTAL OECD</strong></td>
<td><strong>37</strong></td>
<td><strong>39</strong></td>
<td><strong>43</strong></td>
</tr>
</tbody>
</table>

**Source:** Reference 12.
FIGURE 7, PROJECTED U.S. PETROLEUM LIQUIDS SUPPLY
DEPARTMENT OF ENERGY PROJECTION SERIES C

SOURCE: REFERENCE 12.
FIGURE 8. PROJECTED U.S. NATURAL GAS SUPPLY
DEPARTMENT OF ENERGY PROJECTION SERIES C

SOURCE: REFERENCE 12.
Table 5 presents a comparison of major study forecasts regarding world oil production and consumption in 1985.
### Table 5. Comparison of Alternative World Oil Forecasts for 1985 (Million Barrels per Day).

<table>
<thead>
<tr>
<th></th>
<th>DOE 1/</th>
<th>CIA 2/</th>
<th>CRS 3/</th>
<th>WAES 4/</th>
<th>OECD 5/</th>
</tr>
</thead>
<tbody>
<tr>
<td>World Oil Consumption 6/</td>
<td>66</td>
<td>70</td>
<td>69</td>
<td>61</td>
<td>64</td>
</tr>
<tr>
<td>Non-OPEC Production 6/</td>
<td>24</td>
<td>25</td>
<td>25</td>
<td>23</td>
<td>25</td>
</tr>
<tr>
<td>Net Communist Exports</td>
<td>-2.5</td>
<td>-4</td>
<td>1</td>
<td>NA</td>
<td>1</td>
</tr>
<tr>
<td>OPEC Production</td>
<td>44.5</td>
<td>49</td>
<td>43</td>
<td>38</td>
<td>39</td>
</tr>
</tbody>
</table>

6/ Excludes centrally planned economies.

Source: Reference 12.
CHAPTER 3

FUEL EFFICIENCY PROJECTIONS

In this study, fuel efficiencies are projected for five vehicle types: a) auto, b) motorcycle, c) bus, d) single-unit truck, and e) combination truck. Projections of auto fuel efficiencies were achieved through a modeling procedure, whereas all other vehicle categories were projected using simple linear extrapolation. Details of the assumptions and techniques used for such projections are presented in the following sections.

Auto Fuel Efficiency Model

The estimation of future auto fleet fuel efficiencies is of vital importance to the projection of revenues derived from fuel taxes. Previous efforts in this area have been highly simplified or have ignored the causal economic factors which affect future fleet fuel efficiencies (2,3,13). The approach developed for the present study considered the possible effects of the national economic climate and included a high degree of interaction between the prevailing economic conditions and the model parameters.

The basic approach used in the model is to a) determine the number of autos in use by model year, b) estimate auto fuel efficiencies by model year, and c) establish the relative auto usage by model year. Once these items are estimated, the average auto fleet
fuel efficiency can be readily determined. The entire model simulation procedure is outlined in Figure 9.

As the state level data was not available for Indiana, the auto fleet fuel efficiency values were generated on the national level and then applied to the Indiana auto fleet.

A detailed discussion of the auto model components is presented in the following paragraphs.

**Determination of the Number of Autos in Use by Model Year**

The base year information is provided as input data. A cohort survival technique is then utilized to predict the number of autos in use by model year for the subsequent simulation years. The three major components of this technique are described below.

**New Car Sales** - The obvious impact of new car sales is that it will directly determine the population of the first cohort. However, in addition, new car sales will affect the survival rates of older model years since it is inherently assumed that the same economic conditions that influence new car purchases also influence auto scrappage decisions. Historical data supports this assumption (14).

Alternate projections of new car sales provided by the three macroeconomic model runs prepared by DRI were used for the purpose of this study. These projections are presented in Figure 10. As might be expected, new car sales are influenced considerably by economic conditions as indicated by the variation in sales between the three DRI models.
INPUT TOTAL NUMBER OF AUTOS IN FLEET (1975)

INPUT ANNUAL NEW CAR SALE PROJECTIONS

PROJECT YEARLY SCRAPPAGE RATES BY MODEL YEAR

DETERMINE THE NUMBER OF AUTOS IN USE BY MODEL YEAR

INPUT GOVERNMENT POLICIES REGARDING AUTO FUEL EFFICIENCY

DETERMINE AUTO FUEL EFFICIENCIES BY MODEL YEAR

ESTABLISH RELATIVE AUTO USAGE BY MODEL YEAR

CALCULATE AVERAGE AUTO FLEET FUEL EFFICIENCY BY WEIGHTING THE MODEL YEAR FUEL EFFICIENCIES BY THE NUMBER OF AUTOS IN USE AND THE EXTENT OF THEIR USE BY MODEL YEAR

FIGURE 9. SIMULATION PROCEDURE FOR AUTO FUEL EFFICIENCY MODEL
Figure 10. Summary of DRI New Car Sales Forecasts

Source: Reference 7.
Automobile Ownership - Clearly, total auto ownership will have a direct impact on survival rates and therefore its accurate projection is vital to model accuracy. For the purpose of this study, the national auto ownership forecasts developed by DRI, based on three scenarios of national economic conditions, were used. These projections are presented in Table 6.

Survival Rates - A survival rate is defined as the probability of a vehicle of a particular model year surviving to the next calendar year, and the appropriate base year values were developed on the basis of the data given in the reports provided by R. L. Polk and Company (14), in which the number of autos in use by model year are estimated.

A number of approaches have been used by previous researchers to estimate future auto survival rates. One of the most notable research efforts (15) in this area applied a Weibull distribution to approximate existing survival rates. Although this approach provided reasonably good estimates of existing survival rate distributions, the projection of future survival rates proved to be inaccurate due to the inherent instability of the survival rate distribution over time. To overcome this problem a procedure was developed in the present study that indirectly approximates future survival rate distributions by estimating annual changes in each cohort survival rate.

The primary task of the proposed procedure is to estimate the relative magnitude of change in each cohort survival rate. An analysis of past data revealed that during periods of high overall
<table>
<thead>
<tr>
<th>YEAR</th>
<th>TRENDLONG</th>
<th>CYCLELONG</th>
<th>PESSIMLONG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>98.7</td>
<td>98.7</td>
<td>98.7</td>
</tr>
<tr>
<td>1977</td>
<td>100.8</td>
<td>100.8</td>
<td>100.8</td>
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<tr>
<td>1978</td>
<td>103.0</td>
<td>103.0</td>
<td>103.0</td>
</tr>
<tr>
<td>1979</td>
<td>105.6</td>
<td>105.7</td>
<td>105.9</td>
</tr>
<tr>
<td>1980</td>
<td>108.5</td>
<td>109.4</td>
<td>108.4</td>
</tr>
<tr>
<td>1981</td>
<td>111.0</td>
<td>111.9</td>
<td>110.7</td>
</tr>
<tr>
<td>1982</td>
<td>113.0</td>
<td>112.9</td>
<td>112.7</td>
</tr>
<tr>
<td>1983</td>
<td>115.4</td>
<td>115.1</td>
<td>114.8</td>
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<tr>
<td>1984</td>
<td>118.2</td>
<td>118.7</td>
<td>116.9</td>
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<tr>
<td>1985</td>
<td>120.9</td>
<td>122.0</td>
<td>119.5</td>
</tr>
<tr>
<td>1986</td>
<td>123.5</td>
<td>123.5</td>
<td>122.4</td>
</tr>
<tr>
<td>1987</td>
<td>126.0</td>
<td>126.0</td>
<td>124.6</td>
</tr>
<tr>
<td>1988</td>
<td>128.3</td>
<td>129.6</td>
<td>126.9</td>
</tr>
<tr>
<td>1989</td>
<td>130.5</td>
<td>132.9</td>
<td>129.8</td>
</tr>
<tr>
<td>1990</td>
<td>132.3</td>
<td>134.8</td>
<td>132.4</td>
</tr>
</tbody>
</table>

SOURCE: REFERENCE 7.
survival rate change the survival rates of the older cohorts varied more than those of newer cohorts. This phenomenon is illustrated in Figure 11 and can be attributed to the fact that a larger number of older autos are marginally economic. Therefore, a shift in economic conditions will logically have a larger impact on older auto scrappage decisions and, subsequently, on survival rates.

The above observation led to the development of a random assignment procedure to approximate survival rates. This procedure is based on the assumption that there exists a number of "select" marginally economic autos which can be envisioned as those marginally economic autos that are most likely to be affected by changes in national economic conditions. The number of these autos is computed as the difference between the actual auto ownership and the auto ownership estimated by calculating surviving autos, using the survival rates from the preceding year and adding new car sales. This assumption is based on historical data (14) which reveals a definite relationship between prevailing economic conditions and the magnitude of the difference referred to above. The magnitude of this difference in turn reflects the amount of change in the survival rates, of each cohort, from year to year.

Subsequently, data from years with high survival rate changes was used to determine the historical probabilities of "select" marginally economic autos being retired or retained in each cohort. These historical probabilities were calculated from the following equation:
\[
CP = \frac{ACSA - (SURV_{-1} \times CPOP_{-1})}{\frac{n}{\sum_{i=1}^{n} CPOP_{-1} - \sum_{i=1}^{n} (SURV_{-1} \times CPOP_{-1})}}
\]

(3.1)

where

\( CP \) = the cohort probability of a "select" marginally economic auto being retired or retained in that cohort during a given year.

\( ACSA \) = actual number of surviving autos in the cohort.

\( SURV_{-1} \) = preceding year's survival rate.

\( CPOP_{-1} \) = cohort population of preceding year.

\( CPOP \) = present cohort population.

\( n \) = total number of cohorts.

The results of the application of the above equation were used to create the following regression equation. The t-values are indicated in parentheses.

\[
Y = .02684 + .000127(X)^3
\]

(3.2)

\[
(4.93) \quad (15.69)
\]

\[
F = 246.26 \quad R^2 = .965
\]

where

\( Y \) = the probability of a "select" marginally economic auto being retired or retained in cohort of age \( X \).

\( X \) = the age of the cohort in years.

In this analysis, the age of the cohorts (\( X \) in the above equation) ranged from 1 to 12 years with the 12th year cohort including all autos 12 years old and older. It was decided to include autos of 12 years or older in the final cohort since the survival
rates of autos at this age or older stabilize at approximately the same rate (see Figure 11).

The number of "select" marginally economic autos in any future year is determined from:

\[ \text{SMEA} = \text{AO} - \left[ \sum_{i=1}^{n} (\text{SURV}_{-1} \times \text{CPOP}_{-1}) + \text{NCS} \right] \]  

(3.3)

where

- \( \text{SMEA} \) = the number of "select" marginally economic autos in given year.
- \( \text{AO} \) = projected auto ownership in given year (see Table 6).
- \( \text{SURV}_{-1} \) = cohort survival rate in preceding year.
- \( \text{CPOP}_{-1} \) = cohort population in preceding year.
- \( \text{NCS} \) = new car sales in given year.

These autos (SMEA) are assigned (or detracted, if negative) from specific cohorts using a random number generator and the probabilities estimated in equation 3.2. Each cohort survival rate is then revised (for future use) such that the multiplication of the survival rate by the cohort population of the preceding year is equal to the new cohort population after the random assignment technique described above is implemented. This procedure is illustrated by the following equation:

\[ \text{RCSR} = \frac{\text{SURV}_{-1} \times \text{CPOP}_{-1} + \text{AMA}}{\text{CPOP}_{-1}} \]  

(3.4)

where

- \( \text{RCSR} \) = the revised cohort survival rate.
- \( \text{SURV}_{-1} \) = the cohort survival rate of the previous year.
FIGURE II. CHANGES IN SURVIVAL RATE DISTRIBUTIONS BETWEEN YEARS OF HIGH OVERALL SURVIVAL RATE CHANGES
CPOP\textsubscript{-1} = the cohort population in the preceding year.
AMA = total number of assigned or detracted autos in the cohort during the desired year.

Equations 3.3 and 3.4 are applied annually until the target year is reached. Thus, the number of autos existing in each cohort, during any given year, can be estimated.

This procedure was validated by estimating historical survival rate changes, and it was found that such estimations compared favorably with historical survival rate changes (14).

**Future Auto Fuel Efficiencies by Model Year**

Auto fuel efficiency information is provided as exogenous data to the model. The average model year fuel efficiencies can easily be established since the average efficiency of each existing model year is known from existing data and future fuel efficiencies can be assumed to conform with those mandated by government regulations (see Table 7).

**Relative Auto Usage by Vehicle Age**

Studies have shown that newer autos generally accumulate more annual miles than do older autos (17,18). The most recent study (The Nationwide Personal Transportation Survey 1969-70) was used to develop the following regression equation which estimates the relative auto usage by auto age.

\[
\begin{align*}
Y &= 1.8535 - 0.4813 \ln (X + 1) \\
&= 100.796 \\
R^2 &= 0.92
\end{align*}
\]
TABLE 7. MANDATED FEDERAL FUEL ECONOMY STANDARDS FOR AUTOS.

<table>
<thead>
<tr>
<th>MODEL YEAR</th>
<th>MILES PER GALLON</th>
</tr>
</thead>
<tbody>
<tr>
<td>1978</td>
<td>18.0</td>
</tr>
<tr>
<td>1979</td>
<td>19.0</td>
</tr>
<tr>
<td>1980</td>
<td>20.0</td>
</tr>
<tr>
<td>1981</td>
<td>21.5</td>
</tr>
<tr>
<td>1982</td>
<td>23.0</td>
</tr>
<tr>
<td>1983</td>
<td>24.5</td>
</tr>
<tr>
<td>1984</td>
<td>26.0</td>
</tr>
<tr>
<td>1985 AND BEYOND</td>
<td>27.5</td>
</tr>
</tbody>
</table>

SOURCE: REFERENCE 16.
where

\[ Y = \text{weighted usage by auto age.} \]

\[ X = \text{age of auto in years (e.g. } X=0 \text{ for autos 0-1 years,} \]

\[ X=1 \text{ for autos 1-2 years, etc.)} \]

**Auto Fleet Fuel Efficiency Calculations**

Overall auto fleet fuel efficiency can now be determined simply by multiplying the average fuel efficiencies of each cohort by; a) the number of autos in use in each cohort divided by the total number of autos in use and b) the relative usage factors estimated from the above equation. The summation of these multiplications will be the average auto fleet fuel efficiency in any given year. The above calculation is represented by Equation 3.6.

\[
AFE = \sum_{i=1}^{n} \left( \frac{CPOP}{TPOP} \times RUF \times CFE \right)
\]

(3.6)

where

AFE = auto fleet fuel efficiency in desired year.

CPOP = cohort auto population in desired year.

TPOP = total auto population in desired year.

RUF = relative usage factor calculated in Equation 3.5.

n = total number of cohorts.

CFE = average cohort fleet fuel efficiency.

**Other Vehicle Fuel Efficiency Estimations**

Due to data limitations, fuel efficiency values for other vehicle types cannot be estimated in a detailed manner. Therefore, the fuel efficiency projections of these vehicle types were made by extrapolating
recent efficiency estimates (1) and utilizing the results of previous studies (2,3). Table 8 summarizes the appropriate fuel efficiency projections.

The fleet fuel efficiencies determined in this chapter are used to estimate annual fuel consumption which is then used to project motor fuel tax revenues. The technique utilized to estimate annual fuel consumption is discussed in the next chapter.
<table>
<thead>
<tr>
<th>YEAR</th>
<th>CYCLE MPG</th>
<th>BUS MPG</th>
<th>SINGLE UNITS MPG</th>
<th>TRUCKS COMBINATIONS MPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>50.00</td>
<td>5.29</td>
<td>10.56</td>
<td>5.77</td>
</tr>
<tr>
<td>1977</td>
<td>50.00</td>
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<td>5.80</td>
<td>13.08</td>
<td>7.12</td>
</tr>
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</table>
CHAPTER 4
FUEL CONSUMPTION ESTIMATES

An accurate fuel consumption estimate is vital to the prediction of future fuel tax revenues. The approach most commonly used to project fuel consumption is to annually estimate a) future vehicle-miles of travel and b) future fleet fuel efficiencies. Once the above two elements have been determined, total fuel consumption can be obtained simply by dividing vehicle-miles of travel by fleet fuel efficiencies (in miles per gallon).

An outline of the modeling approach used in this analysis is presented in Figure 12. A detailed discussion of the components of this model procedure is given in the following paragraphs.

Determination of Total Vehicle-Miles of Travel (VMT)
The use of a regression model to predict national VMT is the most widely used technique. The independent variables used in previous national VMT regression equations include (19):

1. Relative price of gas and oil
2. Change in consumer price index
3. Real disposable income
4. Cost per vehicle-mile traveled
5. Unemployment rate
6. Population
PROJECTION OF TOTAL ANNUAL VMT

INPUT MACROECONOMIC DATA

PROJECTION OF THE ANNUAL CHANGE IN COMMERCIAL VEHICLE VMT

SEGREGATION OF TOTAL VMT INTO:
- AUTO VMT
- MOTORCYCLE VMT
- BUS VMT
- SINGLE-UNIT TRUCK VMT
- COMBINATION TRUCK VMT

CALCULATION OF ANNUAL FUEL CONSUMPTION BY DIVIDING THE ABOVE VMT VALUES BY THE APPROPRIATE VEHICLE FUEL EFFICIENCIES DETERMINED IN THE PRECEDING CHAPTER

FIGURE 12. SIMULATION PROCEDURE FOR THE FUEL CONSUMPTION MODEL
7. Number of autos in use

8. Number of households

9. Transit supply

Several forms of regression models were attempted into various combinations of independent variables to develop an acceptable regression equation for predicting the level of annual VMT in Indiana. The most acceptable equation achieved was a multiple time series with real disposable income and the relative gasoline price as independent variables. However, these two variables proved to be highly correlated and therefore the equation could not be used for future VMT estimation.

The problem of multicollinearity in such an analysis is extensive; since any variable that increases regularly with time correlates well with VMT. As a result, it was found that some independent variables accounted for as much as 98% of the VMT variance and that combinations of two or more independent variables seldom accounted for less than 99% of the VMT variance. Therefore, it was virtually impossible to isolate the causal determinants of VMT.

Another factor restricting the application of a regression model is the poor quality of existing VMT data. Traditionally, the most reliable source of VMT data has been the annual estimates provided by the Federal Highway Administration. These estimates are made on the basis of statewide fuel sales and approximations of motor vehicle fleet fuel efficiencies.
The accuracy of the VMT estimates given in *Highway Statistics* (1) is questionable, because a) fleet fuel efficiency estimates tend to be broad estimates, and b) states in general tend to overestimate the VMT values. The Claffey report (20), which was prepared for the FHWA, presented detailed estimates of VMT from fuel consumption reports in eight states; it was observed that the state estimates of VMT averaged 6.5 percent higher than those estimates based on the fuel consumption reports used by Claffey.

Due to the inherent problems of predicting VMT with a regression model, the total VMT estimation for the purpose of this study was made by utilizing the VMT equation developed from the first principles of elasticity by Poister, Larson, and Rao (21). The VMT estimation equation developed by Poister, et.al. is given below:

\[ VMT = VMT_{1977} \times (1+GR)^i \times (1+EP \times \frac{GPI-GPI_{base}}{GPI_{base}}) \] (4.1)

where

- \( VMT \) = total VMT in desired year
- \( VMT_{1977} \) = total VMT in base year (1977)
- \( GR \) = assumed annual growth rate
- \( i \) = number of years beyond base year
- \( EP \) = elasticity of demand for VMT with respect to fuel price
- \( GPI \) = gasoline price index (1977 = 1.00)

The above equation requires the assumption of an annual growth rate and the estimation of the demand elasticity of VMT with respect to fuel price.
The annual growth rate chosen for this analysis is 3.3 percent. A slightly higher value was chosen than the 2.5 percent annual growth rate used in the 1976 National Highway Inventory and Performance Study (5); since the 1976 study accounted for increasing fuel price in the annual growth rate considered, and subsequently, did not consider the elasticity of VMT with fuel price.

The value of -.10 was selected as the gasoline price elasticity of VMT. This value was derived from existing Indiana VMT data and the gasoline price changes along with the relevant literature (13).

Future gasoline price indices were determined by using the gas price deflator forecasts provided by the three DRI macroeconomic models (see Figure 13).

The Estimation of the Rate of Change in Commercial Vehicle-Miles of Travel

The separate estimation of commercial VMT (composed primarily of combination truck VMT) is essential as these vehicles determine, to a large extent, pavement deterioration rates. It was decided, on the basis of available data, that the future commercial vehicle VMT values could be most accurately estimated by modeling the annual rate of change in these values. This modeling procedure is described in the following paragraphs.

The technique developed for this analysis estimates future changes in commercial VMT indirectly, by assuming that the change in total commercial vehicle-miles traveled is proportional to the change in motor truck intercity ton-miles. This assumption is the basis for the following equation:
\[ \frac{\Delta \text{CVMT}}{\text{CVMT}} = \frac{\Delta (\text{TITM}/\text{ALCI})}{(\text{TITM}/\text{ALCI})} \] (4.2)

where

\[ \text{TITM} = \text{the motor truck intercity ton-miles} \]
\[ \text{CVMT} = \text{the total commercial vehicle-miles traveled} \]
\[ \text{ALCI} = \text{the average load carried index (1975 = 1.00) (includes empty and loaded trips)} \]

This equation inherently assumes that the growth rate in intra-city ton-miles will be the same as the growth rate in intercity ton-miles. Fortunately, an overwhelming percentage of total ton-miles are intercity ton-miles, and therefore, should the above assumption prove to be invalid, the overall accuracy of the projections will be affected only slightly.

The use of the above equation to estimate commercial VMT requires the projection of both motor truck intercity ton-miles and the average load carried index.

**Projection of Motor Truck Intercity Ton-Miles**

Several techniques have been developed in recent years to project intercity ton-miles (22). These can be classified into four basic categories: a) the regression analysis, b) econometric models (simultaneous equation systems), c) input-output models and, d) economic base studies. However, almost all of the past studies have been national in scope, and as such, do not address the unique problems encountered when attempting to project intercity ton-miles on a statewide basis. These unique problems include: 1) the non-availability of statewide motor truck intercity ton-mile data,
2) the economic interdependence between states is difficult to quantify, and 3) accurate statewide economic indicators are seldom available.

For the purpose of this study a regression approach was chosen since the lack of necessary statewide data precluded the use of econometric models, input-output models, and economic base studies. The development of a regression model necessitated the accurate approximation of past Indiana motor truck intercity ton-miles. This was achieved by multiplying national motor truck intercity ton-mile estimates by the ratio of the Indiana highway consumption of special fuels to the national highway consumption of special fuels. The highway consumption of special fuels, which constitutes all non-gasoline highway fuel consumption (diesel, LPG, and so on), is documented annually by the Federal Highway Administration. The validity of this proportion technique is based upon the fact that a large percentage of motor truck intercity ton-miles is transported by vehicles which use special fuels. The application of this technique assumes that the national truck characteristics (average load carried, fuel efficiencies, and so on) are approximately equal to the Indiana truck characteristics. This would appear to be a relatively safe assumption on the basis of existing truck characteristic data (23, 24).

The following regression model was constructed using the approximated statewide motor truck intercity ton-miles.

\[
TITM = -51.48 + 8.95 \log BI + 8.72 \log SP \quad (4.3)
\]

\[
R^2 = .97 \quad F = 265.73
\]
where

\[ \text{TITM} = \text{Indiana truck intercity ton-miles} \]

\[ \text{BI} = \text{national business index (1967 = 100.)} \]

\[ \text{SP} = \text{Indiana steel production in millions of tons} \]

The business index, which is a measure of total national industrial production, attempts to account for the economic interdependence between states. In addition, steel production was found to be a strong indicator of Indiana economic conditions and motor truck intercity ton-miles. This is due in part to the fact that steel production correlates highly with coal shipments, production of durable goods (autos, and so on), and other manufacturing activities all of which are determinants of both economic conditions and motor truck intercity shipments. Thus, the inclusion of the business index (BI) and steel production represents the logical assumption that Indiana motor truck intercity ton-mileage is a function of both state and national economic conditions.

Future business index forecasts, as provided by Data Resources Inc. (DRI), are presented in Figure 14. Figure 15 summarizes the DRI forecasts of the national steel production index. It was assumed, on the basis of recent trends and economic projections provided by other sources (12), that the Indiana steel production index would equal the nationally projected steel production index. Therefore, the actual Indiana steel production (in millions of tons) can be calculated from the following equation:

\[
\text{SP} = \text{SP}_b \times \frac{\text{SPI}}{\text{SPI}_b}
\]

(4.4)
where

\[ \begin{align*}
    SP &= \text{steel production in desired year} \\
    SP_b &= \text{steel production in base year} \\
    SPI &= \text{steel production index in desired year} \\
    SPI_b &= \text{steel production index in base year}
\end{align*} \]

Projection of Average Load Carried Index

The average load carried index is a function of a) the efficiency of the trucking industry indicating the extent of the number of empty and partially full trips, and b) the prevailing maximum weight limits.

An accurate determination of the future operating efficiency of the trucking industry is virtually impossible since future efficiencies will depend to a large extent on government policies regarding motor carrier regulations. However, an analysis of recent data has revealed that there has been no appreciable change in the percent of trucks carrying loads or the average load carried by loaded trucks (1). Subsequently, this factor was assumed to have no effect on future average load carried indices (ALCI).

Should Indiana decide to raise the maximum axle weight limits, the ALCI would obviously increase resulting in lower commercial truck VMT values (all other factors remaining constant), since less trucks would be required to move the same amount of tonnage. Estimating the extent of the ALCI change is dependent on a) the magnitude of the increase in maximum axle weight limits and b) the effect that this increase will have on truck weight distributions. An example of the calculation procedure used to estimate the ALCI when maximum axle weight limits are increased is presented in Chapter 8.
Estimation of Future VMT by Vehicle Type

Due to the fact that there is considerable variation in the fuel consumption characteristics of different vehicle types, it was necessary to segregate VMT into a) auto VMT, b) motor cycle VMT, c) bus VMT, d) single unit truck VMT, and e) combination truck VMT. This segregation was achieved by a) estimating the apportionments of total VMT constituted by each vehicle type in the base year and b) projecting future VMT values by vehicle type by applying growth rates to the above apportionments.

The apportionment of total VMT constituted by each vehicle type was determined by assuming that the national estimates of these apportionments would apply to Indiana (1). This assumption is consistent with the efforts of previous researchers (2,3).

Estimates of the future growth rates in the VMT apportionments assigned to single unit trucks, buses, and motorcycles, were made on the basis of recent trends (1) and an analysis of past studies (2,3). The resulting values are: a) a 0.5 percent annual VMT apportionment growth rate for both buses and single unit trucks, and b) a zero growth rate for motorcycle VMT apportionments.

The VMT apportionment by combination trucks was assumed to grow at the same rate as the commercial VMT growth rate (see equation 4.2), since combination trucks are almost exclusively used for commercial purposes.

Auto VMT is determined simply by subtracting the VMT apportionments of other vehicle types from the total VMT.
Calculation of Annual Fuel Consumption

Once the VMT values by vehicle type are known along with the appropriate fuel efficiencies (calculated from the previous chapter), total annual fuel consumption can be determined from the following equation:

\[
AFC = \sum_{i=1}^{5} \frac{VMT_i}{FE_i}
\]

(4.5)

where

\[\begin{align*}
AFC &= \text{annual fuel consumption (in gallons)} \\
i &= \text{vehicle type (auto, bus, and so on)} \\
VMT_i &= \text{annual vehicle-miles traveled by vehicle type } i. \\
FE_i &= \text{average annual fuel efficiency of vehicle type } i.
\end{align*}\]

The annual fuel consumption values, determined from the above equation, are used as a basis to project the state motor fuel tax revenues which constitute the largest single source of Indiana state highway revenue. The procedures used to calculate motor fuel tax revenues and other state road-user revenues are discussed in the next chapter.
CHAPTER 5
REVENUE GENERATION

For this analysis, highway revenues were categorized by 1) state road user tax revenues, 2) federal road user tax revenues, and 3) non-user tax revenues which include appropriations from general funds. Federal road user tax revenues include those revenues collected by federal agencies from federal taxes on fuel, lubricating oil, motor vehicles, tires, vehicle parts and accessories, and motor vehicle usage. Non-user revenues are derived from such sources as property taxes, bond proceeds, appropriations from general funds, and other miscellaneous non-user receipts. An accurate projection of non-user taxes and the portion of federal road user taxes being returned to the state is difficult to obtain, due to the fact that the projection of funds from these sources depends to a large extent upon future legislative decisions which can vary considerably. As a result, revenue estimations from these sources are determined exogenously. A description of the procedure used for such determinations is presented in Chapter 8.

The revenues derived from state user taxes can be readily calculated once estimates of future tax and fee rates and projections of revenue sources are made. A set of possible future tax and fee rates was considered which were then used in various model runs. Revenue
sources were projected by classifying state user-tax revenues into four basic sources: 1) revenues derived from motor vehicle registrations, 2) revenues derived from license fees, 3) revenues derived from state taxes on motor fuel and, 4) revenues derived from miscellaneous user sources.

**Projected Motor Vehicle Registrations**

Registration projections were made under the following assumptions:

1. Motorcycle registrations, bus registrations, and single-unit truck registrations (which are comprised mainly of privately owned pickups and vans) will be proportional to future auto registrations.

2. Combination truck registrations will be independent of auto registrations and influenced by prevailing economic conditions.

**Auto Registration Projections**

Although the DRI macroeconomic forecasts provided nationwide auto ownership projections, the Indiana auto ownership estimates could not be made as a proportion to national auto ownership, because of differential growth rates observed in historical data (1). As a result, a separate procedure was developed to predict automobile registrations in Indiana.

In an attempt to develop an appropriate regression equation the problem of multi-collinearity among independent variables made the task of isolating causal determinants impossible. Previous researchers (25) have developed regression equations to predict auto
ownership using real disposable income as the independent variable. Although pre-1974 data would appear to substantiate these equations; the data of recent years renders the validity of such an approach questionable as the observed decrease in real disposable income has had virtually no effect on auto ownership trends (1). It is therefore reasonable to suggest that auto ownership is determined by a far more complex behavioral choice process than the simple income model.

Due to the absence of data necessary to simulate the actual behavioral choice process that determines auto ownership, an alternative technique was adopted. This technique, utilized in a number of previous studies (2,15,26) assumes that an automobile saturation will be reached at which time the number of vehicles per capita will stabilize. This assumption seems reasonable since the current rate of increase in per capita ownership cannot be expected to continue indefinitely. However, establishing the point at which per capita ownership will stabilize was somewhat subjective as there was little evidence of such stabilization trends in existing data. The saturation value of .6 autos (in use) per capita to be achieved in the year 2000 was used in the present analysis. This value is comparable to the values selected by other researchers (2,26).

Once the saturation value was established, a power curve was fitted to the original data so that annual estimates of per capita auto ownership could be made. The equation used assumes the following form:

\[ Y = S + K(100 - X)^P \]  
(5.1)
where

\[ Y = \text{projected persons per auto in a given year.} \]

\[ S = \text{projected saturation point for the year 2000.} \]

\[ K = \text{constant determined through curve fitting.} \]

\[ X = \text{last two digits of a given year.} \]

\[ P = \text{exponent determined through curve fitting.} \]

Once the number of persons per auto is established from the above equation, estimates of future Indiana auto registrations can be readily calculated providing statewide population projections are made.

**Statewide Population Projections**

In this study, the cohort survival method was used to project statewide population. This method accounts for births, deaths, and adjusts for migration. The projection was achieved by dividing the total population into 16 male and female age groups considered in five year increments. The initial number in each of the five year cohorts was obtained from data presented in the 1970 U.S. Census.

The future survival rates, which are defined as the probability of a cohort member surviving to the succeeding cohort, were taken directly from the estimates presented by the Bureau of the Census (27). The bureau also provides low, intermediate and high estimates of future cohort fertility rates. The future fertility rates used in this study (see Table 9) were assumed to be between the low and intermediate estimates so as to be consistent with recent fertility rate trends.

Indiana has experienced a relatively high net outward migration in recent years. Since the exodus of industry and population to the
sunbelt states is expected to continue well into the future, net outward migration can be assumed to persist over the time period of this analysis. However, the magnitude of this outward migration was projected to decrease over time, due to the fact that economic conditions in Indiana are expected to compare favorably to those of other industrial states. The estimated migration rates are presented in Table 10.

Population projections using five year cohorts can be made only at five year intervals, therefore, linear extrapolation was used to obtain intermediate annual estimates. Table 11 presents the results of the cohort method using the survival, fertility, and migration rates described above. These results tend to be lower than those estimated by other studies (2,3,28). This is due largely to the fact that previous studies have under-estimated the actual net outward migration in Indiana from 1970-1975.

The number of registered autos in any given year can be estimated simply by dividing the appropriate annual state population by the corresponding persons per auto determined from Equation 5.1. The results obtained for the state using the saturation procedure used in this study were observed to be consistent with the DRI national auto ownership projections.

Truck, Bus, and Motorcycle Registrations

Projections of single-unit truck registrations and bus registrations were made by multiplying auto registrations by an appropriate factor which was derived from recent registration data. Growth rates
### TABLE 9. ESTIMATED ANNUAL FERTILITY RATES PER 1000 WOMEN OF CHILD-BEARING AGE (15-49) IN INDIANA.

<table>
<thead>
<tr>
<th>YEARS</th>
<th>FERTILITY RATE</th>
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</thead>
<tbody>
<tr>
<td>1970-1975</td>
<td>71.5</td>
</tr>
<tr>
<td>1975-1980</td>
<td>70.0</td>
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<tr>
<td>1980-1985</td>
<td>69.1</td>
</tr>
<tr>
<td>1985-1990</td>
<td>67.1</td>
</tr>
</tbody>
</table>

### TABLE 10. ESTIMATED NET MIGRATION FOR INDIANA (IN PERCENT OF POPULATION).

<table>
<thead>
<tr>
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<th>MALE</th>
<th>FEMALE</th>
</tr>
</thead>
<tbody>
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<td>-1.90</td>
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<tr>
<td>1975-1980</td>
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<td>-2.00</td>
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<td>1980-1985</td>
<td>-0.95</td>
<td>-0.86</td>
</tr>
<tr>
<td>1985-1990</td>
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<td>-0.48</td>
</tr>
<tr>
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<td>FEMALE</td>
<td>MALE</td>
</tr>
<tr>
<td>------</td>
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<td>-----------</td>
</tr>
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</table>
for these factors were applied to single-unit truck registrations (.5 percent per annum) and bus registrations (.05 percent per annum). These growth rates were determined from observed trends in state registration data (1). The projection equation assumed the following form:

\[ X_{\text{REG}} = \text{PRP}_{\text{base}} \times (1 + \text{GRP})^i \times \text{AREG} \quad (5.2) \]

where

- \( X_{\text{REG}} \) = the registration estimate by vehicle type in the desired year.
- \( \text{PRP}_{\text{base}} \) = the ratio of registration by vehicle type to auto registration in the base year.
- \( \text{GRP} \) = the assumed growth rate in the ratio described above.
- \( \text{AREG} \) = total auto registration in the desired year.

Motorcycle registrations were assumed to remain at the same proportion to auto registration (i.e., \( \text{GRP} = 0 \)) over the time period of this analysis. Table 12 summarizes the registration projections achieved using the above techniques.

The number of combination trucks being registered in any given year is dependent, to some extent, upon economic conditions, since combination trucks are used almost exclusively for commercial purposes. Problems of multicollinearity among independent variables precluded the use of a regression analysis involving a detailed evaluation of the causal variables. Future combination truck registrations were estimated by assuming a growth rate and an elasticity of demand for registrations with respect to the business
TABLE 12. SUMMARY OF INDIANA MOTOR VEHICLE REGISTRATION PROJECTIONS.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AUTO REGISTRATIONS</th>
<th>SINGLE UNIT TRUCK REGISTRATIONS</th>
<th>BUS REGISTRATIONS</th>
<th>MOTORCYCLE REGISTRATIONS</th>
</tr>
</thead>
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<td>1990</td>
<td>3143945</td>
<td>910249</td>
<td>17738</td>
<td>172917</td>
</tr>
</tbody>
</table>
index (which is a measure of industrial production and a strong indicator of economic conditions). The following equation was used to project combination truck registrations:

\[ CTR = CTR_{base}(1+GR)^i \times (1+EP \times \frac{(BI-BI_{base})}{BI_{base}}) \] (5.3)

where

CTR = combination truck registrations in the desired year.
GR = assumed growth rate in combination truck registrations.
i = number of years beyond the base year.
EP = elasticity of demand for registrations with respect to the business index.
BI = business index (1967 = 100).

The elasticity of the demand for registrations with respect to the business index was determined to be +.24. This value was derived from a number of multiple time series regressions, which were run using data from the past 15 years (1). A growth rate of 1.5 percent per annum was chosen for the time period of this analysis. This growth rate was determined by discounting the observed Indiana combination truck registration growth rate trends, which have averaged 2.5 percent annually over the past 15 years.

**Review of the Current Indiana Motor Vehicle Registration Fee Structure**

The current registration fees in Indiana are $12 for passenger cars, $16 for school and church buses, and $6 for motorcycles. Truck registration fees are assessed on the basis of gross vehicle weight.
It was assumed in the present study that the Indiana gross vehicle weight distributions of trucks would remain constant over the time period of this analysis and would equal the observed 1975 Indiana weight distributions of trucks. The only exception to this assumption occurs when an increase in permissible truck weight limits is considered; the effects of this consideration will be described in Chapter 8. The 1975 Indiana truck weight distributions, obtained from the 1975 *Highway Statistics* (1) are summarized in Table 13.

The current fee structure for trucks and private buses is outlined in Table 14.

**Projected Number of Licensed Drivers**

Projections of the number of licensed drivers were performed by estimating the ratio of licensed drivers per 1,000 driving age population (15 years and over). The driving age population was obtained from the cohort population projection described earlier.

The Indiana ratio of licensed drivers per 1,000 driving age population has increased steadily until the late 1960's from which time fluctuations have been evidenced with a general upward trend. It can be expected that the growth in this ratio would be small over the time period of this analysis. This decreased growth can be attributed to 1) the anticipated increase in auto costs, 2) the decreased growth rate in per capita auto ownership, and 3) the anticipated increase in transit usage.

Table 15 presents past and projected ratios of licensed drivers per 1,000 driving age population.
TABLE 13. INDIANA PERCENTAGE OF TOTAL TRUCKS BY TRUCK TYPE AND WEIGHT CATEGORY.

<table>
<thead>
<tr>
<th>GROSS WEIGHT NOT EXCEEDING (LBS)</th>
<th>SINGLE UNIT TRUCKS</th>
<th>TRACTOR TRUCKS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7000</td>
<td>78.0</td>
<td>0.0</td>
</tr>
<tr>
<td>9000</td>
<td>3.1</td>
<td>0.0</td>
</tr>
<tr>
<td>11000</td>
<td>5.2</td>
<td>0.0</td>
</tr>
<tr>
<td>16000</td>
<td>4.1</td>
<td>0.0</td>
</tr>
<tr>
<td>20000</td>
<td>2.6</td>
<td>1.5</td>
</tr>
<tr>
<td>25000</td>
<td>5.0</td>
<td>0.8</td>
</tr>
<tr>
<td>30000</td>
<td>1.1</td>
<td>1.3</td>
</tr>
<tr>
<td>36000</td>
<td>0.3</td>
<td>1.9</td>
</tr>
<tr>
<td>42000</td>
<td>0.5</td>
<td>3.9</td>
</tr>
<tr>
<td>48000</td>
<td>0.5</td>
<td>3.0</td>
</tr>
<tr>
<td>54000</td>
<td>0.2</td>
<td>5.6</td>
</tr>
<tr>
<td>60000</td>
<td>0.0</td>
<td>12.8</td>
</tr>
<tr>
<td>66000</td>
<td>0.1</td>
<td>2.1</td>
</tr>
<tr>
<td>72000 AND OVER</td>
<td>1/ 0.3</td>
<td>11.4</td>
</tr>
</tbody>
</table>

1/ INCLUDES ALL VEHICLES WITH WEIGHTS OF 66,001 POUNDS AND OVER

SOURCE: REFERENCE 1.
### TABLE 14. INDIANA MOTOR TRUCK REGISTRATION FEES (IN DOLLARS)

<table>
<thead>
<tr>
<th>GROSS WEIGHT NOT EXCEEDING (LBS)</th>
<th>SINGLE UNIT TRUCKS AND BUSES</th>
<th>TRACTOR TRUCKS W/ SEMITRAILERS</th>
</tr>
</thead>
<tbody>
<tr>
<td>7000</td>
<td>16</td>
<td>-</td>
</tr>
<tr>
<td>9000</td>
<td>24</td>
<td>-</td>
</tr>
<tr>
<td>11000</td>
<td>40</td>
<td>-</td>
</tr>
<tr>
<td>16000</td>
<td>65</td>
<td>-</td>
</tr>
<tr>
<td>20000</td>
<td>100</td>
<td>110</td>
</tr>
<tr>
<td>25000</td>
<td>120</td>
<td>190</td>
</tr>
<tr>
<td>30000</td>
<td>175</td>
<td>235</td>
</tr>
<tr>
<td>36000</td>
<td>225</td>
<td>285</td>
</tr>
<tr>
<td>42000</td>
<td>275</td>
<td>310</td>
</tr>
<tr>
<td>48000</td>
<td>325</td>
<td>360</td>
</tr>
<tr>
<td>54000</td>
<td>375</td>
<td>385</td>
</tr>
<tr>
<td>60000</td>
<td>400</td>
<td>410</td>
</tr>
<tr>
<td>66000</td>
<td>425</td>
<td>435</td>
</tr>
<tr>
<td>72000</td>
<td>$450$</td>
<td>485</td>
</tr>
<tr>
<td>72000 AND OVER</td>
<td>-</td>
<td>500</td>
</tr>
</tbody>
</table>

1/ INCLUDES ALL VEHICLES WITH WEIGHTS OF 66,001 POUNDS AND OVER

SOURCE: REFERENCE 3.
TABLE 15. SUMMARY OF RATIOS OF LICENSED DRIVERS PER 1000 DRIVING AGE POPULATION.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>LICENSED DRIVERS PER 1000 DRIVING AGE POPULATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950</td>
<td>583</td>
</tr>
<tr>
<td>1955</td>
<td>699</td>
</tr>
<tr>
<td>1960</td>
<td>720</td>
</tr>
<tr>
<td>1965</td>
<td>807</td>
</tr>
<tr>
<td>1970</td>
<td>735</td>
</tr>
<tr>
<td>1975</td>
<td>851</td>
</tr>
<tr>
<td>1980</td>
<td>860</td>
</tr>
<tr>
<td>1985</td>
<td>868</td>
</tr>
<tr>
<td>1990</td>
<td>877</td>
</tr>
</tbody>
</table>
Projected Net Tax Revenues From Motor Fuel Consumption

The motor fuel consumption model, discussed earlier, provides estimates of annual motor fuel consumption from which gross fuel tax revenues can be calculated simply by multiplying the total gallonage of fuel consumed by a given fuel tax rate. The net fuel tax revenues can then be computed by subtracting motor fuel refunds (originating from such sources as evaporation, spillage, and non-highway use tax compensation) from the gross fuel tax revenues. These refunds have historically averaged 3 percent of the gross fuel tax revenues and, for projection purposes, it was assumed that this value would apply over the time period of this analysis. The following equation was then used to calculate net fuel tax revenues.

\[ NFR = 0.97 \times MFC \times TR \]

where

- **NFR** = net fuel tax revenues
- **MFC** = total motor fuel consumption
- **TR** = given tax rate.

Projections of Revenue from Miscellaneous Sources

Miscellaneous sources include such items as chauffeur licenses, distributor licenses, and a variety of other motor fuel and vehicle sources. The individual projection of such sources would be a difficult and tedious task. Fortunately, the amount of revenue derived from miscellaneous sources has remained almost constant, in recent years, at 8 percent of the total state user tax revenues.
Therefore, for projection purposes, revenues from miscellaneous sources were accounted for by adding 8 percent to the sum of the revenues derived from motor fuel taxes, vehicle registrations, and driver licenses. The same approach was used by McCarthy in an earlier study (2).
CHAPTER 6
HIGHWAY PERFORMANCE

In this study, the relative performance of highway sections was considered by functional classification (e.g. interstate, arterial, collector, and so on) and it was measured in terms of a "condition index". The condition indices were scaled from 0 to 100 and they are derived by appropriately weighting relevant highway characteristics. The characteristics used to determine such an index are components of the following elements:

1. Condition - this element reflects the structural status of the roadway and is determined by such factors as the type of pavement and the pavement condition.

2. Service - the service element is a measure of traffic congestion during peak periods and is an indicator of the level of service provided by the roadway under such conditions. Highway characteristics such as peak-hour volume/capacity ratios and peak-hour operating speeds are used to evaluate this element.

3. Safety - this element is an assessment of the accident potential of the roadway. An estimate of this index is made on the basis of features such as lane widths and right shoulder widths.
The initial values of the condition indices were approximated indirectly using statewide data provided in the 1976 National Highway Inventory and Performance Study (NHIPS) (5). Tables 16 through 18 summarize the Indiana data available from this source. It should be noted that the 1976 NHIPS data is categorized by rural, urban, and small urban highway functional classifications due to the inherent variability in design standards and travel characteristics between such systems.

Descriptions of the functional systems, as defined by the FHWA publication, "Highway Functional Classification, concepts, criteria, and Procedures" (29) are as follows:

1) **Principal Arterial System** -- In rural areas, a network of routes that primarily serves travel of statewide or interstate significance; serves virtually all urban areas over 50,000 population; provides high overall travel speed with minimum interference to through activity; serves the highest traffic volume corridors and the longest trip lengths; and carries a high proportion of urban area travel.

The principal arterial system is substratified as follows:
1) interstate; 2) other freeways and expressways (in urban areas only); and 3) other principal arterials.

2) **Minor Arterial System** -- In rural areas, a network of routes which provides access to principal arterial routes, and in conjunction with principal arterials, forms a network which links cities and larger towns to facilitate interstate and intercounty service.

In urban areas, this system provides service to trips of moderate length at a somewhat lower level of travel mobility. Such routes interconnect with and augment the principal arterial system. They may carry local bus routes and provide intra community connectivity.

3) **Collector Systems** -- In rural areas, a network of routes which generally serves travel of a more localized nature rather than statewide importance and on which predominant travel distances are shorter than on arterial routes. The collector system is stratified as follows: 1) major collectors - serving county seats and other traffic generators not directly served by arterial routes; and 2) minor collectors - linking locally important traffic generators with smaller communities.
TABLE 16. 1975 RURAL HIGHWAY SUMMARY BY FUNCTIONAL CLASSIFICATION.
(IN PERCENTS):

<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>Other PRIN Art Miles</th>
<th>Other PRIN Art Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Major Collector Miles</th>
<th>Major Collector Travel</th>
<th>Minor Collector Miles</th>
<th>Minor Collector Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>48</td>
<td>70</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Intermediate</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>42</td>
<td>25</td>
<td>74</td>
<td>72</td>
</tr>
<tr>
<td>Low</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>5</td>
<td>19</td>
<td>13</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pavement Condition: 1/</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>6</td>
<td>7</td>
<td>5</td>
</tr>
<tr>
<td>Fair</td>
<td>20</td>
<td>18</td>
<td>29</td>
<td>31</td>
<td>38</td>
<td>43</td>
<td>47</td>
<td>45</td>
<td>66</td>
<td>59</td>
</tr>
<tr>
<td>Good</td>
<td>80</td>
<td>82</td>
<td>69</td>
<td>67</td>
<td>61</td>
<td>57</td>
<td>49</td>
<td>49</td>
<td>27</td>
<td>37</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vol/Cap Ratios: 2/</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; .31</td>
<td>55</td>
<td>37</td>
<td>71</td>
<td>73</td>
<td>75</td>
<td>58</td>
<td>98</td>
<td>92</td>
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<td>97</td>
</tr>
<tr>
<td>.31 - .80</td>
<td>45</td>
<td>63</td>
<td>28</td>
<td>23</td>
<td>25</td>
<td>41</td>
<td>2</td>
<td>8</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>&gt; .80</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane Width (FT):</th>
<th></th>
<th></th>
<th></th>
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<th></th>
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<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>30</td>
<td>20</td>
<td>64</td>
<td>56</td>
</tr>
<tr>
<td>10 - 11</td>
<td>0</td>
<td>0</td>
<td>17</td>
<td>17</td>
<td>36</td>
<td>32</td>
<td>58</td>
<td>59</td>
<td>34</td>
<td>38</td>
</tr>
<tr>
<td>&gt; 11</td>
<td>100</td>
<td>100</td>
<td>83</td>
<td>83</td>
<td>64</td>
<td>68</td>
<td>12</td>
<td>21</td>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

1/ Poor - PSR <2.0 (<2.5 PRINCIPAL ARTERIAL); Fair - PSR 2.0 to 3.4; Good - PSR >3.4.
2/ Travel is for peak hour. One direction only.

Source: Reference 5.
**TABLE 17. 1975 URBAN HIGHWAY SUMMARY BY FUNCTIONAL CLASSIFICATION.**

*(IN PERCENTS)*

<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>OTH FWY &amp; EXPY Miles</th>
<th>OTH FWY &amp; EXPY Travel</th>
<th>Other Prin Art Miles</th>
<th>Other Prin Art Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Collector Miles</th>
<th>Collector Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>86</td>
<td>85</td>
<td>38</td>
<td>51</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Intern</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>15</td>
<td>62</td>
<td>49</td>
<td>81</td>
<td>85</td>
</tr>
<tr>
<td>Low</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**Pavement Condition:1/**

<table>
<thead>
<tr>
<th></th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>90</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>5</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>6</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>9</td>
<td>91</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>50</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>49</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>42</td>
<td>50</td>
</tr>
<tr>
<td>Poor</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>FAIR</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>GOOD</td>
<td>0</td>
<td>0</td>
<td>0</td>
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</table>

**Vol/Cap Ratios:2/**

<table>
<thead>
<tr>
<th></th>
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<th>.31 – .90</th>
<th>&gt; .90</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>21</td>
<td>69</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>71</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>73</td>
<td>24</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>59</td>
<td>41</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>27</td>
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<td>21</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>37</td>
<td>8</td>
</tr>
</tbody>
</table>

**Lane Width (ft):**

<table>
<thead>
<tr>
<th></th>
<th>&lt; 10</th>
<th>10 – 11</th>
<th>&gt; 11</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>20</td>
<td>24</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>29</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td>34</td>
<td>13</td>
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</tr>
<tr>
<td></td>
<td>44</td>
<td>8</td>
<td>0</td>
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<tr>
<td></td>
<td>44</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>62</td>
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<td>0</td>
</tr>
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<td></td>
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<td>0</td>
</tr>
<tr>
<td></td>
<td>23</td>
<td>62</td>
<td>0</td>
</tr>
</tbody>
</table>

1/ Poor - PSR < 2.0 (<2.5 principal arterial); Fair - PSR 2.0 to 3.4; Good - PSR > 3.4.

2/ Travel is for peak hour. One direction only.

---

**Source:** Reference 5.
Table 18. 1975 Small Urban Highway Summary by Functional Classification.

(IN PERCENTS)

<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Oth Fwy &amp; Expwy Miles</th>
<th>Other Prin Art Miles</th>
<th>Minor Arterial Miles</th>
<th>Collector Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>96</td>
<td>42</td>
</tr>
<tr>
<td>Interim</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Low</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pavement Condition:1/</th>
<th>Interstate</th>
<th>Oth Fwy &amp; Expwy</th>
<th>Other Prin Art</th>
<th>Minor Arterial</th>
<th>Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Fair</td>
<td>0</td>
<td>0</td>
<td>8</td>
<td>10</td>
<td>54</td>
</tr>
<tr>
<td>Good</td>
<td>100</td>
<td>100</td>
<td>92</td>
<td>90</td>
<td>46</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vol/Cap Ratios:2/</th>
<th>Interstate</th>
<th>Oth Fwy &amp; Expwy</th>
<th>Other Prin Art</th>
<th>Minor Arterial</th>
<th>Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; .31</td>
<td>17</td>
<td>9</td>
<td>78</td>
<td>77</td>
<td>29</td>
</tr>
<tr>
<td>.31 - .90</td>
<td>83</td>
<td>91</td>
<td>22</td>
<td>23</td>
<td>63</td>
</tr>
<tr>
<td>&gt; .90</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane Width (ft):</th>
<th>Interstate</th>
<th>Oth Fwy &amp; Expwy</th>
<th>Other Prin Art</th>
<th>Minor Arterial</th>
<th>Collector</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
</tr>
<tr>
<td>10 - 11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>22</td>
</tr>
<tr>
<td>&gt; 11</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>67</td>
</tr>
</tbody>
</table>

1/ Poor - PSR <2.0 (<2.5 PRINCIPAL ARTERIAL); Fair - PSR 2.0 to 3.4; Good - PSR >3.4. 
2/ Travel is for peak hour, one direction only.

Source: Reference 5.
In urban areas, such routes distribute trips to and from the arterials to their ultimate destinations. Such routes provide for local traffic movement within residential neighborhoods, commercial areas, and industrial areas.

The highway functional classifications described above have been standardized since the early 1970's and they provide a practical level of aggregation for the purpose of system analysis.

The highway characteristics used in the present study to evaluate the condition, service, and safety elements are: 1) pavement type, 2) pavement condition, 3) peak-hour volume/capacity ratio and, 4) lane width. The impact that the above characteristics have on the condition index vary according to rural and urban systems and functional classifications. The weights assigned to the three elements and their components were derived from the 1976 NHIPS and are shown in Table 19.

The variation in the condition index weights reflects the difference between service oriented high volume facilities and condition oriented high speed facilities. In most cases the safety element, represented by lane widths, is given equal importance, and subsequently, was assigned the same weighting regardless of the type of facility.

Regretably, the highway characteristic data provided by the 1976 NHIPS (Tables 16-18) is not nearly detailed enough to be used as a basis for projecting highway condition indices, and therefore, it was necessary to devise a procedure that would provide the level of aggregation necessary for such projections.

Procedure to Estimate Present Highway Performance

A Monte Carlo sampling technique was used to create a sample of roadway sections which were categorized by highway functional classification.
TABLE 19. URBAN AND RURAL CONDITION INDEX WEIGHTS BY FUNCTIONAL CLASSIFICATION.

<table>
<thead>
<tr>
<th></th>
<th>URBAN WEIGHTS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRINCIPAL</td>
<td>MINOR</td>
<td>COLLECTORS</td>
</tr>
<tr>
<td></td>
<td>ARTERIALS</td>
<td>ARTERIALS</td>
<td></td>
</tr>
<tr>
<td>CONDITION:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAVEMENT TYPE</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>PAVEMENT COND.</td>
<td>30</td>
<td>35</td>
<td>40</td>
</tr>
<tr>
<td>SERVICE:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOL/CAP RATIO</td>
<td>40</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>SAFETY:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANE WIDTH</td>
<td>20</td>
<td>25</td>
<td>30</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>RURAL WEIGHTS</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PRINCIPAL</td>
<td>MINOR</td>
<td>COLLECTORS</td>
</tr>
<tr>
<td></td>
<td>ARTERIALS</td>
<td>ARTERIALS</td>
<td></td>
</tr>
<tr>
<td>CONDITION:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PAVEMENT TYPE</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>PAVEMENT COND.</td>
<td>30</td>
<td>40</td>
<td>50</td>
</tr>
<tr>
<td>SERVICE:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOL/CAP RATIO</td>
<td>40</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>SAFETY:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANE WIDTH</td>
<td>20</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>
Each of the roadway sections was assigned a set of attributes which were then used to project the four basic determinants of the condition index: pavement type, pavement condition, volume/capacity ratio, and lane width. The section attributes were: 1) section length, 2) traffic volume, 3) number of lanes, 4) pavement thickness, 5) pavement condition, 6) peak-hour volume/capacity ratio and 7) lane width. An explanation as to how these attributes were assigned is given below.

**Section Lengths** - Highway section lengths are used to determine future maintenance and construction costs which are estimated on a per mile basis. The number of section lengths assigned are governed, in most cases, by computer memory limitations which restrict the number of sections to 100 for each functional classification. The minimum section length was chosen to be 2 miles, since it was felt that smaller lengths would provide an unrealistic variation in highway attributes among functional classifications with small mileages. Therefore, in most instances, the section length is determined by dividing the functional classification system mileage by 100. However, in those cases when the resultant value is less than 2 miles, the section length is set at 2 miles and the number of sections representing that functional classification is reduced accordingly.

Table 20 summarizes the 1975 Indiana system mileage and daily vehicle miles traveled by functional classification.

**Traffic Volumes** - Traffic volumes are used to project peak-hour volume/capacity ratios and pavement conditions. Section traffic volumes were determined by assuming that the average daily traffic (ADT) volumes can be approximated by a normal distribution within each
### TABLE 20. 1975 INDIANA HIGHWAY SYSTEM MILEAGE AND DAILY UMT.

<table>
<thead>
<tr>
<th></th>
<th>MILEAGE</th>
<th>DAILY-UMT (THOUSANDS)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RURAL:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>827</td>
<td>11330</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>1048</td>
<td>4972</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>3032</td>
<td>13131</td>
</tr>
<tr>
<td>MAJOR COLLECTORS</td>
<td>8724</td>
<td>8829</td>
</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>11332</td>
<td>2572</td>
</tr>
<tr>
<td><strong>URBAN:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>210</td>
<td>7718</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPWY</td>
<td>67</td>
<td>946</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>761</td>
<td>11182</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>1526</td>
<td>9500</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>1183</td>
<td>2794</td>
</tr>
<tr>
<td><strong>SMALL URBAN:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>27</td>
<td>608</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPWY</td>
<td>52</td>
<td>173</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>512</td>
<td>4284</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>733</td>
<td>3291</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>614</td>
<td>959</td>
</tr>
</tbody>
</table>

**SOURCE:** REFERENCE 5.
functional classification. The average ADT's and their corresponding standard deviations were estimated from the 1975 traffic map of Indiana which was prepared by the Division of Planning of the Indiana State Highway Commission. Table 21 summarizes the average 1975 ADT's and their standard deviations for each functional classification.

Once the average ADT's and their attendant standard deviations have been established, the traffic volume on each randomly sampled roadway section was assigned by generating a series of normally distributed random numbers with the specified mean and standard deviation. Minimum volumes were set to prevent the possibility of negative or unrealistically low values.

**Number of Lanes** - This attribute will influence future pavement conditions and peak-hour volume/capacity ratios. The number of lanes assigned to each roadway section was determined by first, assuming an appropriate peak-hour factor (as shown in Table 24) which when multiplied by the average daily traffic volume provides an approximation of one direction peak-hour volumes, and second, estimating the maximum per lane hourly capacity (30). Once the above estimations are made, the number of lanes in each direction is simply equal to the resultant of the one direction peak-hour volume divided by the lane capacity. This value is appropriately rounded off to provide an integer value.

**Pavement Thickness** - Pavement thickness is used directly to represent the pavement structure quality, which is a significant component of the condition index. In this analysis, pavements were classified as high type (all rigid pavements or flexible pavements
<table>
<thead>
<tr>
<th></th>
<th>AVERAGE ADT</th>
<th>STANDARD DEVIATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>16400</td>
<td>6650</td>
</tr>
<tr>
<td>OTHER PRIM ART</td>
<td>5700</td>
<td>3500</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>5200</td>
<td>3300</td>
</tr>
<tr>
<td>MAJOR COLLECTORS</td>
<td>1200</td>
<td>600</td>
</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>600</td>
<td>230</td>
</tr>
<tr>
<td>URBAN:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>44000</td>
<td>16000</td>
</tr>
<tr>
<td>OTH FWY &amp; EXFWY</td>
<td>16300</td>
<td>7200</td>
</tr>
<tr>
<td>OTHER PRIM ART</td>
<td>17200</td>
<td>7500</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>7460</td>
<td>3100</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>2830</td>
<td>1700</td>
</tr>
<tr>
<td>SMALL URBAN:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>27020</td>
<td>10800</td>
</tr>
<tr>
<td>OTH FWY &amp; EXFWY</td>
<td>4000</td>
<td>1800</td>
</tr>
<tr>
<td>OTHER PRIM ART</td>
<td>10000</td>
<td>5100</td>
</tr>
<tr>
<td>MINOR ARTERIALS'</td>
<td>5400</td>
<td>3000</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>1870</td>
<td>1000</td>
</tr>
</tbody>
</table>
with a thickness index greater than 3.1 inches), intermediate type (flexible pavements with a thickness index greater than 2.6 inches and less than 3.1 inches), and low type (flexible pavements with a thickness index less than 2.6 inches or unpaved facilities). This classification was done only to simplify the computer model output, and the actual thickness indices or slab thicknesses (in the case of rigid pavements) were used in the condition index computations.

The thickness index for flexible pavements was defined by the following equation.

\[ TI = 0.44D_1 + 0.14D_2 + 0.11D_3 \]  \hspace{1cm} (6.1)

where

\( TI \) = thickness index  
\( D_1 \) = surfacing thickness, inches  
\( D_2 \) = base thickness, inches  
\( D_3 \) = subbase thickness, inches

For rigid pavements, the slab thickness alone was used and these values were estimated by utilizing the summary of Indiana rigid pavement depths presented in reference 31.

The values for flexible pavement thickness indices were determined using daily truck volumes as a criterion. The truck volumes on each roadway section were calculated using data available from the 1975 national truck characteristics report (24) in which ratios of the truck volume to total vehicle volume are presented and categorized by highway functional classification. Once the truck volumes on each roadway section were established, an appropriate thickness index was
selected using a procedure similar to the group-index method, which is widely used in flexible pavement design (31).

**Pavement Condition** - The present pavement conditions will directly affect future pavement conditions since the present conditions along with the pavement thickness determine the number of additional axial loads the pavement can sustain. Pavement conditions are measured by using the present serviceability rating (PSR). The PSR values range from 5.0 for new pavements to 0.0 for completely deteriorated pavements. The 1976 NHIPS data categorizes pavement conditions into good (PSR=3.4 to 5.0), fair (PSR=2.5 to 3.4 for principal arterials and PSR=2.0 to 3.4 for other classifications), and poor (PSR<2.5 for principal arterials and PSR<2.0 for other classifications). It was assumed that such values are uniformly distributed within each of the three categories of pavement condition. The assignment of PSR values then was made by generating a series of uniformly distributed random numbers which in turn was used to; 1) select good, fair, or poor categories with the probability of selection equal to the proportion of mileage in each category and, 2) select a specific PSR value with equal probability within each category.

**Peak-Hour Volume/Capacity Ratios** - The peak-hour volume/capacity ratios (V/C) are used exclusively to measure the service element, and subsequently, play an important role in the determination of the condition index. The 1976 NHIPS data provides three broad categories of peak-hour V/C ratios. The assignment of V/C ratios to individual roadway sections is done assuming that the V/C ratios are uniformly distributed within each category. However in this case, there exists
the fact that high volume sections are more likely to have high V/C ratios than low volume sections and, therefore, the probability of selecting a V/C category was assumed to be a function of the ratio, percent mileage/percent volume, for each category. The selection of specific V/C ratios within each category was done with uniform probability as was the case with pavement conditions.

Lane Widths - The lane widths are used to represent the safety element of the roadway. The 1976 NHIPS data categorizes lane widths into; 1) less than 10 feet, 2) 10 to 11 feet, and 3) greater than 11 feet. It was assumed that lane widths would be uniformly distributed within each of the above categories. A minimum lane width of 9 feet and a maximum lane width of 12 feet were applied to the first and third categories respectively. Individual lane widths were then determined using the same random sampling approach as that used for the assignment of pavement conditions. The interstate systems were excluded from the approach described above as all of these facilities exclusively have 12 feet lane widths and were so assigned.

Estimation of Future Highway Performance

Future highway performance was estimated simply by projecting the seven attributes assigned to each roadway section. Attributes such as the number of lanes, pavement thickness, and lane widths will remain constant unless appropriate construction is performed on the roadway section. If no reconstruction is performed on a given section, the attributes that will change in the future are: 1) section length, 2) traffic volume, 3) peak-hour volume/capacity ratio, and 4) pavement condition.
Projection of Section Lengths - From year to year there are changes in the system mileages of each functional classification. These changes are induced by urban growth which results in the transfer of mileage from rural to urban systems, the upgrading of facilities to higher classifications, and the growth in total highway mileage. The estimation of the extent of annual fluctuations in functional classification system mileage is achieved by approximating 1990 system mileages and assuming a uniform annual growth rate between 1975 and 1990. The 1990 system mileages were derived using a number of sources (3, 32, 33), and are presented along with the annual growth rates in Table 22. Once the growth rates are known, the annual system mileages are calculated and the section lengths of each functional classification are increased or decreased such that the summation of the section lengths is equal to the calculated classification mileages.

Projections of Traffic Volumes - Future traffic volumes were estimated under the assumption that the growth in traffic volume would be proportional to the growth in the vehicle-miles of travel (VMT) per mile of highway. This assumption is illustrated by the following equation:

\[ \text{PGRV} = \frac{\frac{\text{FVMT}}{\text{FSM}} - \frac{\text{FVMT}_{-1}}{\text{FSM}_{-1}}}{\frac{\text{FVMT}_{-1}}{\text{FSM}_{-1}}} \times 100 \]  

(6.2)

where

\text{PGRV} = \text{percent growth in functional system volumes.}

\text{FVMT} = \text{functional system VMT in desired year.}

\text{FVMT}_{-1} = \text{functional system VMT in preceding year.}
### TABLE 22. 1990 INDIANA HIGHWAY SYSTEM MILEAGE AND TOTAL 1975 TO 1990 MILEAGE GROWTH RATES

<table>
<thead>
<tr>
<th></th>
<th>MILEAGE</th>
<th>MILEAGE GROWTH RATE (PERCENT)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RURAL:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>869</td>
<td>5.0</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>1170</td>
<td>11.6</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>3100</td>
<td>2.2</td>
</tr>
<tr>
<td>MAJOR COLLECTORS</td>
<td>8700</td>
<td>-0.3</td>
</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>11250</td>
<td>-0.7</td>
</tr>
<tr>
<td><strong>URBAN:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>225</td>
<td>7.1</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPHWY</td>
<td>119</td>
<td>77.6</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>897</td>
<td>14.9</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>1635</td>
<td>7.1</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>1225</td>
<td>3.6</td>
</tr>
<tr>
<td><strong>SMALL URBAN:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>35</td>
<td>29.7</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPHWY</td>
<td>77</td>
<td>48.1</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>609</td>
<td>18.9</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>839</td>
<td>14.5</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>656</td>
<td>6.8</td>
</tr>
</tbody>
</table>
\[ \text{FSM} = \text{functional system mileage in desired year.} \]

\[ \text{FSM}_{-1} = \text{functional system mileage in preceding year.} \]

The functional system mileages are known during each year from the uniform annual growth rate assumption made earlier (see Table 22). However, it was necessary to develop a technique to determine VMT values by functional classification (FVMT in Equation 6.2).

Since the growth in the total highway system VMT can be obtained from the VMT equation used in the fuel consumption model, a logical solution to the problem of determining functional system VMT values is to apply a proportion of individual functional system VMT growth to total system VMT growth. These proportions were developed by using the 1976 NHIPS estimates of 1990 VMT by functional classification to calculate annual VMT growth rates from 1975 to 1990 (assuming uniform growth) on each functional classification. The division of these growth rates by the average annual growth rate of the entire system mileage resulted in the desired growth rate proportions. These values are presented in Table 23.

Once these proportions are known, the VMT of each functional classification can be determined by applying the following equation:

\[
\text{FVMT} = \text{FVMT}_{-1} \times (\text{PR} \times \frac{\Delta \text{VMT}}{\text{TVMT}_{-1}} + 1) \quad (6.3)
\]

where

\[
\begin{align*}
\text{FVMT} & = \text{functional system VMT in desired year.} \\
\text{FVMT}_{-1} & = \text{functional system VMT in preceding year.} \\
\text{PR} & = \text{proportion of functional system VMT growth to total VMT growth.}
\end{align*}
\]
<table>
<thead>
<tr>
<th>FUNCTIONAL CLASSIFICATION</th>
<th>GROWTH RATE PROPORTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL:</td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>0.80</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>1.00</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>0.72</td>
</tr>
<tr>
<td>MAJOR COLLECTORS</td>
<td>0.64</td>
</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>0.64</td>
</tr>
<tr>
<td>URBAN:</td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>1.32</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPWY</td>
<td>2.16</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>1.12</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>1.12</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>1.02</td>
</tr>
<tr>
<td>SMALL URBAN:</td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>1.00</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPWY</td>
<td>1.24</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>1.00</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>1.02</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>1.02</td>
</tr>
</tbody>
</table>
ΔTVMT = change in total system VMT.

TVMT\(_{-1}\) = total system VMT in preceding year.

Should there be a case where the system VMT values decline, the reciprocals of the growth rate proportions shown in Table 23 would be used as PR in Equation 6.3. This assures that high growth systems will have lower loss rates should such a situation arise.

The traffic volume growth rates on each functional classification are now known from Equation 6.2. The only remaining task is to determine the volume growth rates on individual highway sections within each functional classification. This was done by generating a series of normally distributed random numbers with a mean of 0.0 and a standard deviation of 1.5 percent and adding these numbers to the volume growth rates of each functional classification. This procedure provides a distribution of growth rates that is compatible with historical growth rate distributions (30). The standard deviation value of 1.5 percent was chosen to be consistent with the 3.3 percent growth rate used in the VMT equation discussed earlier.

**Projection of Peak-Hour Volume/Capacity Ratios** - Although the peak-hour volume/capacity ratios (V/C) can be assigned to roadway sections using the technique previously described, an estimation of peak-hour volumes and hourly capacities are necessary for the projection of V/C ratios.

Peak-hour volumes were approximated using the percentage of average daily volumes occurring in the peak-hour as a basis. The initial values of this percentage are shown in Table 24 (30). It must be realized that the values shown in Table 24 are generalized
<table>
<thead>
<tr>
<th>TYPE OF FACILITY</th>
<th>PERCENTAGE IN PEAK HOUR (ONE DIRECTION)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL:</td>
<td></td>
</tr>
<tr>
<td>FREeway</td>
<td>23.6</td>
</tr>
<tr>
<td>EXPRESSway</td>
<td>21.5</td>
</tr>
<tr>
<td>HIGHWAY WITH MORE THAN 2 LANES</td>
<td>21.2</td>
</tr>
<tr>
<td>2 LANE TWO WAY HIGHWAY</td>
<td>23.0</td>
</tr>
<tr>
<td>URBAN:</td>
<td></td>
</tr>
<tr>
<td>FREeway</td>
<td>15.0</td>
</tr>
<tr>
<td>EXPRESSway</td>
<td>14.6</td>
</tr>
<tr>
<td>STREET WITH MORE THAN 2 LANES</td>
<td>13.8</td>
</tr>
<tr>
<td>2 LANE TWO WAY STREET</td>
<td>14.8</td>
</tr>
</tbody>
</table>
and the actual values will naturally vary between roadway sections within the same functional classification. Consequently, an adjustment was necessary to account for this variation, and it is discussed later in this section.

The hourly capacity estimates were made on a volume per lane basis. The per lane hourly capacities were initially assumed to be: 2000 vehicles per hour (VPH) for interstates; 1600 VPH for freeways, expressways, and other principal rural arterials; 1400 VPH for other principal urban arterials and minor rural arterials; and 1000 VPH for all other classifications. These capacities also will vary between sections of the same functional classification. This variation is caused by such factors as lane widths, signal timings, and turning movements.

The problem of accounting for the variations in peak-hour percentages and per lane capacities between roadway sections was resolved by utilizing an adjusting factor. This factor was calculated from the following equation:

\[
K = \frac{IVC}{PH*IADT} \times \frac{100*NL*CAP}{100*NL*CAP}
\]

(6.4)

where:

\(K\) = adjusting factor.

\(IVC\) = initial section V/C ratio.

\(PH\) = peak-hour percentages (Table 24).

\(IADT\) = initial section average daily volume.

\(NL\) = number of lanes (one direction) in the section.

\(CAP\) = estimated hourly capacity per lane.
The initial V/C ratios, number of lanes, and initial average daily volumes are known from the simulation procedure described earlier. Hence the adjusting factor can be readily calculated.

This adjusting factor is merely a ratio of peak-hour percentage correction to the hourly capacity correction. Once the adjusting factor is known, future volume/capacity ratios can be determined from Equation 6.5.

\[
VC = K * \frac{PH \times AV}{100 \times NL \times CAP} \tag{6.5}
\]

where

- VC = volume/capacity ratio in the desired year.
- AV = daily volume in the desired year.
- All other variables are same as in Equation 6.4.

Items such as the addition of lanes, increased lane width, and assumptions regarding peaking characteristics will affect future V/C ratios and the adjustment factors. The impacts that such items will have on V/C ratio projections are discussed in the next chapter.

**Projection of Pavement Conditions** - The AASHO Road Test performance equations were used as a basis to estimate future pavement conditions since the results provided by these equations are consistent with pavement life experience in Indiana (3). The AASHO Road performance equations assume the following forms:

\[
P = C_0 - (C_0 - C_1) \left( \frac{V}{\rho} \right)^\beta \tag{6.6}
\]
where

\[ P = \text{the present serviceability rating (PSR)} \]
\[ C_0 = \text{the initial serviceability rating} \]
\[ C_1 = \text{the serviceability rating below which the pavement is considered to be out of service} \]
\[ W = \text{the accumulated axle load applications at the time when } P \text{ is to be determined.} \]

\[ \beta \text{ and } \rho \text{ are functions of design and load and are determined from the following equations:} \]

\[ \beta = 0.4 + \frac{0.81 (L_1 + L_2)^{3.23}}{(D_1 + 1)^{5.19} L_2^{3.23}} \quad (6.7) \]

\[ \rho = \frac{10^{5.93} (D_1 + 1)^{9.35} L_2^{4.33}}{(L_1 + L_2)^{4.79}} \quad (6.8) \]

For rigid pavements:

\[ \beta = 1.0 + \frac{3.63 (L_1 + L_2)^{5.2}}{(D_2 + 1)^{8.46} L_2^{3.52}} \quad (6.9) \]

\[ \rho = \frac{10^{5.85} (D_2 + 1)^{7.35} L_2^{3.28}}{(L_1 + L_2)^{4.62}} \quad (6.10) \]

where

\[ \rho \text{ and } \beta \text{ = design and load functions.} \]
\[ L_1 = \text{nominal axle weight in kips.} \]
\[ L_2 = 1 \text{ for single axle vehicles} \]
\[ 2 \text{ for tandem axle vehicles} \]
\[ D_1 = \text{thickness index (described earlier)} \]
\[ D_2 = \text{slab thickness, inches} \]

The initial serviceability rating \((C_0 \text{ in Equation 6.6)}\) is known from the assignments of pavement conditions. The serviceability ratings below which the pavement can be considered to be out of service \((C_1 \text{ in Equation 6.6)}\) were determined to be 2.0 for principal arterials and 1.5 for minor arterials and collectors using the values presented in the National Highway Functional Classification and Needs Study Manual (34) as a basis.

In Equations 6.7-6.10, the thickness indices and slab thicknesses are already known from the pavement type assigned to a particular section as discussed earlier. Therefore, to calculate \(\rho\) and \(\beta\), it is necessary only to determine the nominal axle weights \((L_1)\) and establish whether these weights are from single or tandem axles \((L_2)\).

The basic approach used to determine \(L_1\) and \(L_2\) was to simulate a representative sample of vehicles and their associated axle weights, and then to translate these axle weights into 18 kip single axle weight equivalents.

**Vehicle Axle Weight Sampling** - Three categories of vehicles are considered in the axle weight analysis; automobiles, single unit trucks and combination trucks. The axle weight analysis was achieved by simulating a random sample of 1000 vehicles in each of the three categories mentioned above. Details of this sampling procedure are presented in the following paragraphs.

When considering the relative impact on pavement deterioration, the axle weights of automobiles are insignificant when compared with
truck axle weights, however, for the sake of completeness, automobile axle weights were also considered.

The estimation of auto axle weights was made by assuming that auto weights are normally distributed. A mean value of 3,300 pounds and a standard deviation of 800 pounds was chosen on the basis of findings in literature (35). It was assumed that the front axle would carry 60 percent of the total vehicle weight and the rear axle would carry the balance. A minimum value of 1,200 pounds was applied since it was not considered likely that an auto would weigh less than this amount.

Three sub-categories of single unit trucks were considered due to the high variation in loading characteristics. These sub-categories are: 1) 2-axle vehicles with 4 tires, 2) 2-axle vehicles with 6 tires, and 3) vehicles with 3 axles or more. It was assumed that the weights of loaded and empty vehicles in each sub-category would be normally distributed. This assumption was made on the basis of the truck weight distribution summaries presented in the 1975 National Truck Characteristic Report (NTCR) (24). The percentages of loaded and empty vehicles were also determined from this report and the values used were 50.6% and 49.4%, respectively.

Similarly, combination trucks were divided into 3 sub-categories; 3 axle vehicles, 4 axle vehicles, and vehicles with 5 axles or more. Once again the loaded and empty weight distributions within each sub-category were assumed to be normal. The percentages of loaded and empty vehicles were estimated to be 69.8 and 31.2 respectively.
The percent of vehicles in each sub-category, the means, standard deviations, and the fractions of load on each axle, for each sub-category of single unit and combination trucks, are presented in Table 25. This table was derived from the data provided in the 1975 NTCR (24).

The procedure implemented to establish the weight of each truck sample vehicle within each category (single unit or combination) consisted of the following steps: 1) selecting the sub-category by generating uniformly distributed random numbers and using the percent of trucks by truck type as the probability of selection; 2) determining whether the vehicle was loaded or empty by generating uniformly distributed random numbers using the percent of loaded and empty trucks as the probability; 3) estimating the vehicle weight by generating normally distributed random numbers using the appropriate mean and standard deviation. Once the weight of each sample truck is known, the weight is distributed to the axles using the fractions of weights by axle shown in Table 25.

These resultant axle loads (both automobile and trucks) are translated into 18 kip single axle equivalent loads (SAEL) by using Equations 6.11, 6.12 and 6.13 which were derived from the AASHO Road Tests (36).

For single axles:

\[
18 \text{ SAEL} = 6.213 \times 10^{-6} \times AL^{4.16}
\]

(6.11)

For tandem axles, flexible pavements:

\[
18 \text{ SAEL} = 4.711 \times 10^{-7} \times AL^{4.16}
\]

(6.12)
## Table 25. Truck Weight Means, Standard Deviations, and Percentage of Weights by Axle.

<table>
<thead>
<tr>
<th>Vehicle Type 1/</th>
<th>Percent of Trucks by Type</th>
<th>Mean Weight (in kips)</th>
<th>Standard Deviation (in kips)</th>
<th>Weights by Axle 2/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Single Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Ax 4 Tire</td>
<td>77.0</td>
<td>5.5</td>
<td>2.0</td>
<td>.42</td>
</tr>
<tr>
<td>2 Ax 6 Tire</td>
<td>19.0</td>
<td>10.5</td>
<td>4.0</td>
<td>.44</td>
</tr>
<tr>
<td>3 Ax or More</td>
<td>4.0</td>
<td>17.0</td>
<td>7.0</td>
<td>.38</td>
</tr>
<tr>
<td>Combination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Axle</td>
<td>5.0</td>
<td>22.0</td>
<td>7.0</td>
<td>.31</td>
</tr>
<tr>
<td>4 Axle</td>
<td>15.0</td>
<td>25.0</td>
<td>8.0</td>
<td>.25</td>
</tr>
<tr>
<td>5 Axle or More</td>
<td>80.0</td>
<td>30.0</td>
<td>4.0</td>
<td>.26</td>
</tr>
<tr>
<td>Loaded</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Unit</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 Ax 4 Tire</td>
<td>77.0</td>
<td>6.2</td>
<td>2.6</td>
<td>.31</td>
</tr>
<tr>
<td>2 Ax 6 Tire</td>
<td>19.0</td>
<td>14.7</td>
<td>6.0</td>
<td>.37</td>
</tr>
<tr>
<td>3 Ax or More</td>
<td>4.0</td>
<td>34.0</td>
<td>14.0</td>
<td>.28</td>
</tr>
<tr>
<td>Combination</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 Axle</td>
<td>5.0</td>
<td>30.0</td>
<td>5.0</td>
<td>.27</td>
</tr>
<tr>
<td>4 Axle</td>
<td>15.0</td>
<td>33.0</td>
<td>12.0</td>
<td>.18</td>
</tr>
<tr>
<td>5 Axle or More</td>
<td>80.0</td>
<td>60.0</td>
<td>14.0</td>
<td>.15</td>
</tr>
</tbody>
</table>

T = Tandem Axles
1/ Tandem Axles counted as two axles
2/ Tandem Axles counted as one axle
For tandem axles, rigid pavements:

\[ 18 \text{ SAEL} = 9.07 \times 10^{-7} \times AL^{4.12} \quad (6.13) \]

where

18 SAEL = 18 kip single axle equivalent load.

AL = nominal axle load in kips.

The summation of all of the 18 kip SAEL's within each of the three categories (auto, single unit, and combination trucks) provides the equivalent axle loads per 1000 vehicles by vehicle category. For projective purposes and ultimately estimating accumulated axle load applications (W in Equation 6.6), it is desirable to transform the above results into 18 kip SAEL's per 1000 vehicles, irrespective of vehicle category. This was accomplished by approximating the percentage of vehicle categories operating on each functional classification. These percentages were derived from the 1975 NTCR and are summarized in Table 26. Hence, the number of 18 kip SAEL's per 1000 vehicles operating on each functional classification can be determined simply by multiplying the percentages in Table 26 by the corresponding summation of 18 kip SAEL's derived from each of the three 1000 vehicle samples.

Referring back to Equations 6.7-6.10, \( \rho \) and \( \beta \) can be readily calculated for all vehicles, now that \( L_1 \) is known to be 18 kips and \( L_2 \) is one (since all tandem loads are now single axle equivalents).

The only remaining requirement, to project the pavement condition, is the estimation of the number of axle load applications during a specified time period (W in Equation 6.6). In the present analysis,
### TABLE 26. 1975 VEHICLE TYPES AS A PERCENT OF ALL VEHICLES (BY FUNCTIONAL CLASSIFICATION).

<table>
<thead>
<tr>
<th></th>
<th>Autos</th>
<th>Single Unit Trucks</th>
<th>Combination Trucks</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RURAL:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>70.0</td>
<td>14.7</td>
<td>15.3</td>
</tr>
<tr>
<td>Other Prin Art</td>
<td>70.0</td>
<td>20.3</td>
<td>9.7</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>72.0</td>
<td>20.3</td>
<td>7.7</td>
</tr>
<tr>
<td>Major Collectors</td>
<td>72.0</td>
<td>23.5</td>
<td>4.5</td>
</tr>
<tr>
<td>Minor Collectors</td>
<td>72.0</td>
<td>23.5</td>
<td>4.5</td>
</tr>
<tr>
<td><strong>ALL URBAN:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>80.0</td>
<td>11.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Oth Fwy &amp; Expwy</td>
<td>80.0</td>
<td>14.0</td>
<td>6.0</td>
</tr>
<tr>
<td>Other Prin Art</td>
<td>80.0</td>
<td>16.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>75.0</td>
<td>23.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Collectors</td>
<td>75.0</td>
<td>23.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>
pavement conditions are calculated annually; the number of annual load applications on a given roadway section is determined by the following equation:

\[
LA = \frac{ADT}{1000} \times 365 \times ELPTV
\]  

(6.14)

where

- \( LA \) = the number of annual load applications.
- \( ADT \) = daily traffic volume on the section.
- \( ELPTV \) = number of 18 kip SAEL's per 1000 vehicles operating on the system.

As the above equation indicates, the number of load applications in any given year will be a function of the daily volume (the projection of which was described earlier) and the 18 kip equivalent loads per 1000 vehicles. The future values of \( ELPTV \) will be influenced by: 1) shifts in the percent of vehicle type using each functional classification, 2) changes in the weight distributions of trucks and autos, and 3) fluctuations in the percentage of loaded trucks. The sampling technique devised for the present analysis allows an evaluation of the impacts of changing weight distributions and variations in the percentage of loaded trucks. However, it can be assumed, on the basis of recent trends, that the above two factors will be essentially constant over the time period of this analysis provided that the maximum axle weight laws are not revised.

Shifts in the percent of vehicle types using each functional classification were determined by asserting that the increase in the 18 kip \( ELPTV \)'s would be proportional to the increase in commercial
truck VMT relative to the increase in total VMT. This technique is valid since an overwhelming percentage of the total 18 kip ELPTV is determined by commercial vehicles. Therefore, future 18 kip ELPTV's are estimated on each functional classification by applying the following equation:

\[
ELPTV = \frac{1 + \frac{PICV}{100}}{1 + \frac{PITV}{100}} \times ELPTV_{-1}
\]  

where

\begin{align*}
ELPTV &= 18 \text{ kip equivalent axle loads per 1000 vehicles in desired year.} \\
PICV &= \text{percent increase in commercial VMT from the preceding year.} \\
PITV &= \text{percent increase in total VMT from the preceding year.} \\
ELPTV_{-1} &= \text{ELPTV in preceding year.}
\end{align*}

Once the ELPTV is known, the number of annual load applications may be calculated using Equation 6.14 and the summation of these annual load applications is used in Equation 6.6 (as \( W \)) from which the pavement condition can be determined annually.

The only remaining factor affecting future pavement conditions is the possible repair or resurfacing of a roadway section, and this item is discussed in the next chapter.

**Computation of Condition Index Values**

Once the pavement type, pavement condition, peak-hour volume/capacity (V/C) ratios, and lane width of each section are known; the appropriate condition indices can be readily calculated. This calculation is performed by using the following set of equations:
For pavement type;

\[ CI_1 = \frac{(D - 1.6) \times CW_1}{8.4} \]  

(6.16)

where

- \( CI_1 \) = the portion of the condition index determined by pavement type.
- \( D \) = the slab thickness for rigid pavements or the thickness index for flexible pavements.
- \( CW_1 \) = the condition index weight for pavement type (Table 19).

Pavements with a "D" of 10 inches or more are given total points (i.e. \( CI_1 = CW_1 \)) and those pavements with a "D" of 1.6 inches or less are given no points (\( CI_1 = 0 \)).

For pavement condition;

\[ CI_2 = \frac{(PC - 1.) \times CW_2}{4} \]  

(6.17)

where

- \( CI_2 \) = the portion of the condition index determined by pavement condition.
- \( PC \) = the present serviceability rating (PSR) of the pavement (0 to 5).
- \( CW_2 \) = the condition index weight for pavement condition (see Table 19).

Sections with a PSR of one or less are given no points (\( CI_2 = 0 \)).

For peak-hour V/C ratios;

\[ CI_3 = \frac{(1. - PVC) \times CW_3}{.6} \]  

(6.18)
where

\[ CI_3 = \text{the portion of the condition index determined by the peak-hour V/C ratios.} \]

\[ PVC = \text{the peak-hour V/C ratio of the section.} \]

\[ CW_3 = \text{the condition index weight for V/C ratios (see Table 19).} \]

Volume/capacity ratios of 0.4 or less are given total points

\[ (CI_3 = CW_3). \]

For lane widths,

\[ CI_4 = \frac{((LW - 9.) \cdot CW_4)}{3} \tag{6.19} \]

where

\[ CI_4 = \text{the portion of the condition index determined by the lane widths.} \]

\[ LW = \text{the lane widths of the section in feet.} \]

\[ CW_4 = \text{the condition index weight for lane widths (Table 19).} \]

Sections with a lane width of 12 feet or more are given total points

\[ (CI_4 = CW_4) \]

and those with lane width of 9 feet or less are given no points \((CI_4 = 0)\).

The condition index of any roadway section can then be determined simply by adding the results of Equations 6.16 to 6.19.

In the present study, the condition index of any given functional classification is equal to the average of the classification's individual section condition indices weighted by the corresponding section traffic volumes. This is illustrated by the following equation:
\[
SCI = \frac{\sum_{i=1}^{n} (CI_i \times V_i)}{\sum_{i=1}^{n} V_i}
\]

(6.20)

where

- \( SCI \) = total functional classification system condition index.
- \( CI_i \) = the condition index of section \( i \).
- \( V_i \) = the traffic volume of section \( i \).
- \( n \) = the total number of sections comprising the specified functional classification.

The condition indices determined in this chapter are used as 1) a measurement of highway performance and 2) a basis to distribute the funds available for highway repair among the roadway sections comprising each functional classification. The details of the technique utilized to distribute funds to roadway sections are discussed in the next chapter.
CHAPTER 7
ALLOCATION OF CAPITAL FUNDS

The allocation of capital funds was performed in two steps. First, capital funds were distributed to individual highway functional classifications, and second, the capital funds distributed to such functional classifications were allocated to specific roadway sections within each functional classification. The former step will be discussed in the next chapter and the present chapter is concerned only with the allocation of funds to roadway sections.

Allocation of Capital Funds to Roadway Sections

Since it is highly improbable that sufficient capital improvement funds will be available to repair all deficiencies on every roadway section; it is necessary to apply a priority setting technique whereby the available funds can be allocated to those sections with the most critical deficiencies. The method used in the present study establishes funding priority on the basis of two equally weighted factors. The first factor gives priority to the roadway sections with low condition indices. The second factor gives priority to roadway sections with the most cost-effective improvement. Thus the procedure is to allocate half of the funds on the basis of condition indices and the remainder on the basis of cost-effectiveness factors.
The determination of the first factor is simple, since the condition indices of each roadway section are known from the procedures discussed in the previous chapter. The cost-effectiveness of an improvement, which is used as a basis for the application of the second priority factor, is defined by the following equation:

\[ CE_i = \frac{(CI_N - CI_I) \times V}{Cost_i} \] (7.1)

where

- \( CE_i \) = the cost-effectiveness of improvement type \( i \) in a specified year for a given section
- \( CI_N \) = the condition index after the implementation of improvement type \( i \).
- \( CI_I \) = the initial condition index of the roadway section in the specified year
- \( V \) = the traffic volume on the roadway section in the specified year
- \( Cost_i \) = the cost of implementing improvement type \( i \) in the specified year on the given section.

The traffic volume \( (V) \) and the Initial Condition Index \( (CI_I) \) are known in any given year from the procedures discussed in the preceding chapter. It is therefore necessary to establish: 1) the types of needed improvements, 2) the effects that such improvements will have on section condition indices and 3) the costs of such improvements in any given year.
Improvement Types

In this analysis, as is the case with most major studies in this subject area (3,5,6,32), capital improvements are categorized into eight major improvement types. These categories, along with their definitions are as follows:

1. New location - complete construction of the roadway on a new alignment.
2. Reconstruction - reconstruction of the roadway on essentially the same alignment.
3. Isolated reconstruction - reconstruction of some portion of the roadway to correct a particular deficiency such as a dangerous curve.
4. Major widening - addition of lanes to the roadway section.
5. Minor widening - provides for additional lane width.
6. Resurfacing - overlaying of the existing pavement.
7. Resurfacing and shoulder improvements - in addition to the overlaying of existing pavements, provisions for the widening of shoulders are made.
8. Structures - the rehabilitation or replacement of deficient structures.

Data limitations necessitated the allocation of a constant percentage of capital funds to structure improvements, and hence, such improvements are excluded from further discussion in this chapter.

The type of improvement needed on a specific roadway section was determined by applying data available in the 1972 National Highway Needs Report (32) in which national estimates of needed capital
improvements (presented in Tables IV-5, IV-15, and IV-16) from 1970 to 1990 by improvement type and functional classification are provided. These estimates were applied to Indiana and used to establish the relative probability of a specific capital improvement type being assigned to any given roadway section within each functional classification.

Effects of Improvements on the Condition Index

After the assignment of the improvement type to each roadway section is made through a random sampling technique the condition index of the section resulting from the improvement \( (CI_N) \) in Equation 7.1) can be determined. This determination is made by evaluating the effects that each improvement type will have on the four basic components of the condition index. These effects are outlined below.

1. Pavement Type - All improvement types may potentially change this component. The pavement type is appropriately re-determined on the basis of the current truck volume (and its estimated growth rate) using the technique for pavement thickness estimation described in the preceding chapter.

2. Pavement Condition - Once again, all improvement types will affect this component. The present serviceability rating (PSR) is assigned maximum value, which was estimated to be 4.8 for principal arterials and 4.4 for all other classifications, and the accumulated axle loads are re-initialized.
3. Peak-Hour Volume/Capacity Ratios - Only lane widths and lane additions were considered to affect V/C ratios. Therefore the major widening, minor widening, new location, and reconstruction improvements were considered to affect this component. The V/C ratios are recalculated by estimating the increased capacity resulting from the addition of lanes and/or increases in lane widths. The 1965 Highway Capacity Manual (30) was used as a basis for such calculations.

4. Lane Widths - Major widening, minor widening, new location and reconstruction will affect this component. It is assumed that the lane widths will be raised to the current design standard of 12 feet when any of the above improvement types are implemented.

After the values of the condition index components are determined, after the implementation of a specified improvement type, the $C_{IN}$ value in Equation 7.1 can be readily calculated.

Improvement Costs

The costs associated with each capital improvement type ($Cost_i$ in Equation 7.1) were estimated by developing an average cost per mile using the national data provided in the 1972 National Highway Needs Report and applying these values to Indiana. The resultant costs (1969 prices) are presented in Table 27. To evaluate the impact that economic conditions will have on these costs, annual projections were made by; 1) transforming the 1969 unit costs to 1975 unit costs using the cost indices provided in the 1975 Highway Statistics (1) and 2) using the deflators for capital improvement presented in Figure 16.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>363</td>
<td>1722</td>
<td>126</td>
<td>631</td>
<td>326</td>
<td>173</td>
<td>98</td>
</tr>
<tr>
<td>Other Prin Art</td>
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<td>153</td>
<td>581</td>
<td>177</td>
<td>128</td>
<td>67</td>
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<tr>
<td>Minor Arterial</td>
<td>664</td>
<td>358</td>
<td>91</td>
<td>565</td>
<td>145</td>
<td>86</td>
<td>41</td>
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<tr>
<td>Major Collector</td>
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<td>584</td>
<td>120</td>
<td>51</td>
<td>22</td>
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<tr>
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<td>161</td>
<td>145</td>
<td>35</td>
<td>185</td>
<td>89</td>
<td>40</td>
<td>18</td>
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<tr>
<td>URBAN:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>8244</td>
<td>3929</td>
<td>5311</td>
<td>2021</td>
<td>1233</td>
<td>658</td>
<td>223</td>
</tr>
<tr>
<td>Oth Fwy &amp; Expwy</td>
<td>5385</td>
<td>3864</td>
<td>756</td>
<td>2826</td>
<td>1305</td>
<td>574</td>
<td>207</td>
</tr>
<tr>
<td>Other Prin Art</td>
<td>2387</td>
<td>1452</td>
<td>414</td>
<td>1481</td>
<td>740</td>
<td>225</td>
<td>139</td>
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<tr>
<td>Minor Arterial</td>
<td>1095</td>
<td>942</td>
<td>231</td>
<td>1004</td>
<td>502</td>
<td>128</td>
<td>116</td>
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<td>Collectors</td>
<td>632</td>
<td>587</td>
<td>123</td>
<td>705</td>
<td>350</td>
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<td>68</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>764</td>
<td>800</td>
<td>273</td>
<td>155</td>
</tr>
<tr>
<td>Oth Fwy &amp; Expwy</td>
<td>2442</td>
<td>2016</td>
<td>1087</td>
<td>921</td>
<td>877</td>
<td>403</td>
<td>172</td>
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<tr>
<td>Other Prin Art</td>
<td>1575</td>
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<td>249</td>
<td>905</td>
<td>605</td>
<td>149</td>
<td>96</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>795</td>
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<td>156</td>
<td>619</td>
<td>419</td>
<td>138</td>
<td>66</td>
</tr>
<tr>
<td>Collectors</td>
<td>582</td>
<td>472</td>
<td>721</td>
<td>506</td>
<td>306</td>
<td>107</td>
<td>49</td>
</tr>
</tbody>
</table>
FIGURE 16. SUMMARY OF DRI DEFALATORS FOR HIGHWAY CAPITAL IMPROVEMENTS

SOURCE: REFERENCE 7.
Equation 7.1 can now be applied to determine the cost effectiveness of a capital expenditure on each roadway section. Subsequently, the priority of expenditures can now be established.

Improvement Assignment

The approach described thus far is similar to that used by the 1976 National Highway Inventory and Performance Study, however unlike the 1976 NHIPS, which utilized a deterministic approach in priority setting, the present study's approach is probabilistic. Two major arguments can be raised against the application of a purely deterministic approach to set priorities for capital expenditures. First, since the condition index requires a considerable amount of subjective input, it is ill-advised to use it as an absolute basis. The second argument relates to the impact of political decisions which tend to make the programming process highly probabilistic.

As a result of the deficiencies inherent in the deterministic approach in priority programming, a dual threshold analysis technique (which is probabilistic by nature) was developed for use in this study. This technique assumes that all roadway sections with a condition index below a specified threshold or a cost effectiveness value above a specified threshold have an equal probability of selection. The thresholds used in this study are simply the average condition index and the average cost-effectiveness factor of the roadway sections which comprise each functional classification. Therefore, the priority setting of capital improvements was achieved by the application of the following steps:
1. Roadway sections are selected randomly and compared to the average condition index of the functional classification.

2. When a roadway section is found to have a condition index less than the average, the section is assigned the appropriate improvement and both the condition index and cost effectiveness factor are revised to reflect the impact of that improvement. The cost of the improvement is calculated by multiplying the section lengths with the costs per mile derived from the values presented in Table 27.

3. Roadway sections are selected randomly and compared to the average cost effectiveness factor of the roadway sections comprising a particular functional classification.

4. When a roadway section is found to have a cost effectiveness factor above the average, the same procedure described in step 2 is implemented.

5. Steps 1 through 4 are repeated until the total capital improvement funds allocated to the specific functional classification during a particular year are exhausted.

This dual threshold analysis technique provides projections of condition indices by functional classification which are only slightly affected by the order in which individual roadway sections are selected for threshold comparisons. It is felt that the consistency of condition index projections as well as the theoretical basis of this approach makes the dual threshold analysis technique an appropriate procedure instead of the deterministic approaches used in the past.
Stopgap Repairs

In addition to capital improvements, provisions were made for stopgap repairs. Stopgap repairs are defined as those repairs necessary to keep a roadway section in usable condition. These repairs, which include such activities as isolated resurfacing, were made only when insufficient funding is available to perform the needed capital improvement.

In this study, stopgap repairs were considered only on roadway sections with severely deteriorated pavements. The cost of such repairs is assumed to be 15% of the resurfacing costs (3). These repairs were assumed to add, in general, three to five years of service life to the roadway section.
CHAPTER 8
MODEL RESULTS

A listing of the computer model that eventually evolved is presented in Appendix A. Before the model could be applied it was necessary to establish the validity of the model results. The 1975 highway performance data, which was used as the basis for the estimation of highway performance in this study, was the only complete performance data available, and therefore, it was not possible to validate the model by comparing model results with more recent data. Subsequently, the model was validated by 1) carefully monitoring the values of model variables at various stages of the computational process in terms of their consistency, and 2) comparing the model results for 1990 with those obtained by the 1976 National Highway Inventory and Performance Study which is the only other study to provide detailed projections of future highway performance. The results of the present study were found to be compatible with those obtained in the 1976 NHIPS, although a direct comparison was not possible since the 1976 study provides highway performance on a national basis, while the present study projects highway performance for the state of Indiana.
Model Application

A number of scenarios was considered to analyze the effects that legislative policy options, changes in future travel characteristics and a relaxation of present improvement standards may have on the performance of the Indiana highway system. In discussing the results in this chapter, the scenarios tested are identified by a letter and number coding system. The letter denotes the macroeconomic model used to provide economic data for the scenario run. For example, T indicates that the TRENDLONG data was used, C the CYCLELONG data, and P the PESSIMLONG data. The number which follows the letter in the scenario coding system refers to a specific option of possible legislative alternatives along with other attendant assumptions.

It was assumed, in all scenarios tested, that legislative policy options would have no effect on the macroeconomic data used as input. The only exception to the assumption was the gasoline price deflator which would be influenced by changes in fuel taxing rates. This assumption is reasonable since a recent study observed that a probable range of highway funding options have negligible impacts on economic conditions (5).

Revenue Assumptions

Revenues from federal agencies, state general fund appropriations, and other non-state road-user tax sources, were estimated by assuming that such revenues would be proportional to the revenues collected from state road-user taxes. This assumption was based on 1) an analysis of past data, which revealed that revenues from non-state
road-user sources have historically constituted a relatively constant share of total highway revenues (see Figure 17) and 2) consideration of the taxing effort, which is a measure of a state's taxing policies relative to other states, and is an important factor in determining the amount of federal aid allocated to states, and therefore, revenues from federal sources can be expected to be proportional to changes in state road-user tax revenues (37).

Disbursement Assumptions

In this study, highway disbursements are categorized into four broad classifications: 1) local capital outlays which include all expenditures for capital improvements on the local road functional classification, 2) non-local capital outlays which include all expenditures for capital improvements on non-local functional classifications (e.g. interstates, arterials, and collectors), 3) structure costs which include funds allocated for the rehabilitation of roadway structures, and 4) routine maintenance, administration, and all others. It was assumed that the last group of expenditures would increase at an annual rate that is proportional to the annual increase in the price deflator for capital outlays. Hence the disbursements for this group were determined from the following equation:

\[ DMA = DMA_{-1} \times (1 + DCO \times PR) \]  

(8.1)

where

DMA = the annual disbursement for maintenance, administration, and all others.
FIGURE 17. PERCENT OF TOTAL HIGHWAY RECEIPTS FROM SOURCES OTHER THAN STATE ROAD-USER TAXES FOR INDIANA

SOURCE: REFERENCE 1.
DMA<sub>-1</sub> = the disbursement for maintenance, and so on in the preceding year,

DCO = the price deflator for capital outlays,

PR = the assumed proportion of DMA increase relative to DCO increase.

The above equation is based on an analysis of recent trends which revealed an approximate equality between maintenance and operation cost increases and increases in capital outlay costs (1). The proportion (PR in Equation 8.1) was introduced to reflect the ability of the highway agencies to reduce low priority routine maintenance and administration programs, thereby permitting more funds to be directed to needed capital improvement projects. A value of .25 was used in all scenarios for this proportion. This value reflects a considerable effort by the agencies to limit such disbursements, and this value is consistent with recent Indiana highway disbursement trends (1).

Once the disbursements for maintenance, administration, and others have been calculated, a fixed percentage of the remaining funds is allocated to structures, local and non-local capital outlays. It was assumed for all scenarios that 33 percent of the funds would be allocated to local road capital improvement projects, 3 percent of the funds would be allocated to structures, and the remaining 64 percent to non-local capital improvements. These values were estimated using historical data and the values estimated by previous studies (3,5,32).
Distribution of Non-Local Capital Funds
Among Functional Classifications

Two alternate funding distributions were developed using, as a basis, the funding distributions presented in the 1976 National Highway Inventory and Performance Study (5) and the estimation of future Indiana capital improvement needs made for the 1972 National Highway Needs Study (32). The first funding distribution (series I) was used for all scenarios which assume that the highway performance standards and the travel characteristics would remain unchanged over the time period of the present study. The series I distribution allocates a relatively large percentage of capital improvement funds to high volume facilities (see Table 28). This distribution reflects state preference for maintaining the condition of high volume facilities as opposed to low volume facilities which are given a lower priority particularly when funding levels are not sufficient to meet highway needs.

The second funding distribution (series II) was used for scenarios that assumed changes in highway performance standards or in travel characteristics. These assumed changes result in a considerable reduction in the need for capital improvements on high volume facilities. Subsequently, the series II distribution (see Table 29) allocates more funding to low volume facilities than does the series I distribution.

Discussion of Options
Table 30 summarizes the assumptions made for the seven options used in this analysis. Appendix B presents a sample computer output
<table>
<thead>
<tr>
<th>System</th>
<th>Distribution of Funds (Percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural:</td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>8.0</td>
</tr>
<tr>
<td>Other Prin Art</td>
<td>9.5</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>16.5</td>
</tr>
<tr>
<td>Major Collectors</td>
<td>6.0</td>
</tr>
<tr>
<td>Minor Collectors</td>
<td>6.0</td>
</tr>
<tr>
<td>Urban:</td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>18.0</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPWY</td>
<td>7.0</td>
</tr>
<tr>
<td>Other Prin Art</td>
<td>12.0</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>5.5</td>
</tr>
<tr>
<td>Collectors</td>
<td>3.0</td>
</tr>
<tr>
<td>Small Urban:</td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>0.5</td>
</tr>
<tr>
<td>OTH FWY &amp; EXPWY</td>
<td>1.0</td>
</tr>
<tr>
<td>Other Prin Art</td>
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</tr>
<tr>
<td>Minor Arterials</td>
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</tr>
<tr>
<td>Collectors</td>
<td>2.0</td>
</tr>
<tr>
<td>SYSTEM</td>
<td>DISTRIBUTION OF FUNDS (PERCENT)</td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>RURAL:</td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>5.5</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
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</tr>
<tr>
<td>MINOR ARTERIALS</td>
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</tr>
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<td>MAJOR COLLECTORS</td>
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</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>10.5</td>
</tr>
<tr>
<td>URBAN:</td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>12.5</td>
</tr>
<tr>
<td>OTHER PRIN ART</td>
<td>8.0</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>11.0</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>8.5</td>
</tr>
<tr>
<td>SMALL URBAN:</td>
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<td>INTERSTATE</td>
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<tr>
<td>OTHER PRIN ART</td>
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## Table 30. Summary of Option Assumptions.

<table>
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<tr>
<th>Option</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td><strong>State Road-User</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Tax Rates</td>
<td>Same as 1979</td>
<td>$.11 Gas Tax</td>
<td>$.11 Gas Tax</td>
<td>20 Percent Ad Valorem</td>
<td>Same as 1979</td>
<td>$.11 Gas Tax</td>
<td>$.11 Gas Tax</td>
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<td><strong>Fraction of Total Revenues Obtained From Non-State Road-User Tax Sources</strong></td>
<td>.45</td>
<td>.45</td>
<td>.55</td>
<td>.45</td>
<td>.45</td>
<td>.45</td>
<td>.45</td>
</tr>
<tr>
<td><strong>Distribution of Capital Funds to Functional Classifications</strong></td>
<td>Series 1</td>
<td>Series 1</td>
<td>Series 1</td>
<td>Series 1</td>
<td>Series 1</td>
<td>Series 2</td>
<td>Series 2</td>
</tr>
<tr>
<td><strong>Other Assumptions</strong></td>
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<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

- Increase in permissible axle loads.
- Relaxed improvement standards.
- Reduce peaking by 20 percent.
of a typical option model run. The results of all seven options tested are discussed in the following paragraphs.

Option 1

This option was designed to analyze the effects that a continuation of present Indiana highway taxing policies will have on future Indiana highway performance. It was examined in terms of all three macroeconomic forecasts so that the full impacts of varying national economic conditions could be assessed. Table 31 summarizes the 1990 values of select model parameters using the TRENDLONG, CYCLELONG, and PESSIMLONG macroeconomic forecasts. As might be expected, when comparing the three model run parameters presented in this table, the high inflation rates and lower industrial productions of the CYCLELONG and PESSIMLONG model runs result in lower VMT values, lower fleet fuel efficiencies, higher gasoline prices, and lower highway revenues which have less buying power per dollar.

The effects that economic conditions have on highway performance are shown in Table 32. This table summarizes the percent change in the condition indices of each functional classification between 1976 and 1990 under Option 1. It is apparent that if current highway taxing policies are continued, a considerable deterioration is expected in Indiana highway performance, particularly on lower volume facilities. This loss in highway performance arises from an overall decline in system pavement conditions and increased congestion.

As for the impacts of economic conditions, in this option the more pessimistic economic assumptions result in less highway performance
<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>T-1</th>
<th>C-1</th>
<th>P-1</th>
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<tbody>
<tr>
<td>TOTAL UMT (MILLIONS)</td>
<td>53399</td>
<td>51594</td>
<td>49920</td>
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<tr>
<td>COMBINATION UMT (MILLIONS)</td>
<td>3115</td>
<td>2873</td>
<td>2917</td>
</tr>
<tr>
<td>TOTAL FLEET EFFICIENCY (MPG)</td>
<td>18.56</td>
<td>18.51</td>
<td>18.45</td>
</tr>
<tr>
<td>RETAIL GAS PRICE (DOLLARS)</td>
<td>1.31</td>
<td>1.48</td>
<td>1.65</td>
</tr>
<tr>
<td>TOTAL REVENUES (THOUSANDS OF DOLLARS)</td>
<td>586272</td>
<td>570112</td>
<td>560827</td>
</tr>
<tr>
<td>NON-LOCAL CAPITAL OUTLAYS (THOUSANDS OF DOLLARS)</td>
<td>182056</td>
<td>167843</td>
<td>153113</td>
</tr>
<tr>
<td>PRICE DEFlator FOR CAPITAL OUTLAYS (1975=1.00)</td>
<td>2.75</td>
<td>2.92</td>
<td>3.38</td>
</tr>
<tr>
<td>OTHER NON-CAPITAL DISBURSEMENTS (THOUSANDS OF DOLLARS)</td>
<td>314546</td>
<td>319599</td>
<td>332299</td>
</tr>
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</table>
TABLE 32. SUMMARY OF THE PERCENT CHANGE IN CONDITION INDICES (1976-1990) UNDER SCENARIOS T-1, C-1, AND P-1.

<table>
<thead>
<tr>
<th>FUNCTIONAL CLASSIFICATION</th>
<th>T-1</th>
<th>C-1</th>
<th>P-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>-11.2</td>
<td>-9.8</td>
<td>-8.9</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-5.8</td>
<td>-4.1</td>
<td>-3.6</td>
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<td>-9.6</td>
<td>-7.6</td>
<td>-7.4</td>
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<td>-19.3</td>
<td>-18.7</td>
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<td>-29.6</td>
<td>-25.6</td>
<td>-25.4</td>
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<td>URBAN:</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>-13.5</td>
<td>-12.5</td>
<td>-12.1</td>
</tr>
<tr>
<td>OTHER FREEWAYS AND EXPRESSWAYS</td>
<td>-14.4</td>
<td>-13.2</td>
<td>-10.9</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-10.4</td>
<td>-10.3</td>
<td>-9.6</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>-19.3</td>
<td>-19.1</td>
<td>-17.9</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>-18.5</td>
<td>-18.5</td>
<td>-16.4</td>
</tr>
</tbody>
</table>
loss. This is due to the fact that pessimistic economic assumptions result in 1) less congestion as total VMT growth rates are restrained, and 2) less axle load accumulations as the growth in intercity ton-milage takes place only on a moderate level. For this option, the above two factors offset the effects of decreasing highway revenues and reductions in per dollar buying power. The result is that a less reduction in highway performance is observed.

It must be pointed out, however, that in no way can it be concluded that more pessimistic economic assumptions will necessarily result in less deterioration in highway performance. In some cases, as will be shown later, revised highway performance standards and travel characteristics result, on certain functional classifications, in less reduction in highway performance, even under more optimistic economic scenarios. This is due to the fact that highway performance is the result of the interaction of economic conditions, the performance criteria used, the travel characteristics assumed, and the physical attributes of each functional classification.

Option 2

Option 2 has essentially the same assumptions as Option 1, however this option implements an 11 cents per gallon gasoline tax in 1980 which is a 3 cent increase over current gasoline tax rates. The increase in gasoline tax, which is also accompanied by increases in funds from other non-state road-user revenue sources, results in a 27 percent increase in total highway revenues in calendar year 1980 (see Table 34) using the TRENDLONG macroeconomic data. The impact
that the additional revenue has on the Indiana highway performance is summarized in Table 33. When comparing scenarios T-1 and T-2 it is evident that the increased revenue results in only moderate improvement in highway performance after a certain threshold level. This is due to the fact that the capital investment/performance curve for each functional classification is asymptotic (see Figure 18), and therefore, a large increase in capital investment may result in only modest increases in the condition index.

Option 3

Option 3 assumes a 3 cents per gallon increase in the gas tax in 1980 accompanied by an increase in the proportion of federal aid, general fund appropriations, and other revenue shares such that these revenue sources constitute 55 percent of the total highway budget as opposed to the 45 percent used in previous options. The above assumptions result in total 1980 highway revenues which are 22 percent and 36 percent greater than the Option 2 and Option 1 1980 revenues respectively, using the TRENDLONG macroeconomic data (see Table 34). Table 33 summarizes the changes in highway performance under scenarios T-1, T-2, and T-3. Once again, the additional revenue results in only moderate reductions in highway performance loss.

Option 4

Option 4 assumes that a 20 percent per gallon ad valorem gasoline tax is implemented in 1980 in an attempt to keep pace with the inflationary pressures which push capital improvement costs up by 275 percent, between 1975 and 1990, under the TRENDLONG macroeconomic
FIGURE 18. GENERALIZED SHAPE OF THE HIGHWAY INVESTMENT / PERFORMANCE CURVE (ONE FOR EACH FUNCTIONAL CLASSIFICATION)

SOURCE: REFERENCE 5.
<table>
<thead>
<tr>
<th>FUNCTIONAL CLASSIFICATION</th>
<th>T-1</th>
<th>T-2</th>
<th>T-3</th>
</tr>
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<tbody>
<tr>
<td><strong>RURAL:</strong></td>
<td></td>
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</tr>
<tr>
<td>INTERSTATE</td>
<td>-11.2</td>
<td>-10.0</td>
<td>-7.7</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-5.8</td>
<td>-3.1</td>
<td>-0.8</td>
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<td>MINOR ARTERIALS</td>
<td>-9.6</td>
<td>-5.8</td>
<td>-4.4</td>
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<tr>
<td>MAJOR COLLECTORS</td>
<td>-22.5</td>
<td>-18.6</td>
<td>-12.6</td>
</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>-29.6</td>
<td>-27.0</td>
<td>-23.8</td>
</tr>
<tr>
<td><strong>URBAN:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>-13.5</td>
<td>-10.7</td>
<td>-7.3</td>
</tr>
<tr>
<td>OTHER FREEWAYS AND EXPRESSWAYS</td>
<td>-14.4</td>
<td>-12.5</td>
<td>-10.1</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-10.4</td>
<td>-9.7</td>
<td>-7.5</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>-19.3</td>
<td>-18.8</td>
<td>-16.5</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>-18.5</td>
<td>-15.6</td>
<td>-13.7</td>
</tr>
</tbody>
</table>
assumptions. Table 34 summarizes total highway revenues generated by the four options discussed thus far. The ad valorem tax obviously generates the most revenue. This is particularly evident in the mid-1980's when decreasing fuel consumption actually reduces the total revenues collected from the other three options.

Although the highway performance in scenario T-4 is noticeably improved over scenario T-1 (see Table 36), it is evident that, despite a considerable increase in revenues, the highway performance still declines on most functional classifications. This indicates that the generated revenue is still not sufficient to perform the capital improvements necessary to maintain 1975 highway performance. There are essentially two reasons for this. First, the asymptotic shape of the investment/performance curve provides less improvement than would be expected if a linear relationship existed. Second, the ad valorem tax is indexed to the price of fuel, which in the TRENDLONG macro-economic forecast, increases at a rate which is less than the rate of increase in the cost for capital improvements, and therefore, inflation continues to erode highway dollars but to a lesser extent than previous options.

Option 5

Option 5 was designed to evaluate the impacts that an increase in the permissible axle loads would have on Indiana highway performance. Currently Indiana weight limits are 18 kips for single axles, 32 kips for tandem axles, and 73.28 kips for total gross weight. There has been considerable pressure on the Indiana state legislature to raise
### TABLE 34. SUMMARY OF TOTAL HIGHWAY REVENUES GENERATED BY SCENARIOS T-1, T-2, T-3, AND T-4 (IN THOUSANDS OF DOLLARS).

<table>
<thead>
<tr>
<th>YEAR</th>
<th>T-1</th>
<th>T-2</th>
<th>T-3</th>
<th>T-4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1976</td>
<td>587716</td>
<td>587716</td>
<td>587716</td>
<td>587716</td>
</tr>
<tr>
<td>1977</td>
<td>593720</td>
<td>593720</td>
<td>593720</td>
<td>593720</td>
</tr>
<tr>
<td>1978</td>
<td>597849</td>
<td>597849</td>
<td>597849</td>
<td>597849</td>
</tr>
<tr>
<td>1979</td>
<td>598809</td>
<td>598809</td>
<td>598809</td>
<td>598809</td>
</tr>
<tr>
<td>1980</td>
<td>598065</td>
<td>761765</td>
<td>930108</td>
<td>884334</td>
</tr>
<tr>
<td>1981</td>
<td>596759</td>
<td>758872</td>
<td>925507</td>
<td>921084</td>
</tr>
<tr>
<td>1982</td>
<td>593267</td>
<td>753158</td>
<td>919515</td>
<td>957142</td>
</tr>
<tr>
<td>1983</td>
<td>590975</td>
<td>748962</td>
<td>914378</td>
<td>991797</td>
</tr>
<tr>
<td>1984</td>
<td>587528</td>
<td>743186</td>
<td>907310</td>
<td>1037210</td>
</tr>
<tr>
<td>1985</td>
<td>583165</td>
<td>736284</td>
<td>898908</td>
<td>1082107</td>
</tr>
<tr>
<td>1986</td>
<td>580312</td>
<td>731508</td>
<td>893022</td>
<td>1128559</td>
</tr>
<tr>
<td>1987</td>
<td>579679</td>
<td>729455</td>
<td>890520</td>
<td>1181415</td>
</tr>
<tr>
<td>1988</td>
<td>580814</td>
<td>730018</td>
<td>891190</td>
<td>1242025</td>
</tr>
<tr>
<td>1989</td>
<td>583106</td>
<td>732149</td>
<td>893790</td>
<td>1309155</td>
</tr>
<tr>
<td>1990</td>
<td>586272</td>
<td>735529</td>
<td>897942</td>
<td>1380767</td>
</tr>
</tbody>
</table>
these limits to conform with the weight limits of most other states which are; 20 kips, 32 kips, and 80 kips for single axle, tandem axle, and gross weight respectively. This option implements these higher weight limits at the beginning of 1980. The other assumptions are the same as in Option 1.

The increase in permissible weight limits will have the following impacts on Indiana truck characteristics:

1. The average weight of a loaded truck will increase.

2. The average weight of an empty truck will increase as additional structural support will be required to carry the increase in loads.

3. The commercial VMT will decrease as less truck trips are required to transport the same amount of tonnage.

Estimations of the increases in the mean weights of empty and loaded trucks (see Table 35) were developed from the 1975 National Truck Characteristic Report and other appropriate studies (24,38,39). The standard deviations, weight distributions by axle, and percent of trucks by type, were assumed to be unchanged as the data available to estimate these changes was inconclusive; however, since the increase in the permissible weight limits is relatively small, such an assumption will not cause any significant errors.

The measurement of the decrease in commercial VMT is achieved by estimating the average load carried index (ALCI) described earlier in Chapter 4. The factor was estimated by applying the following equation:
TABLE 35. REVISED TRUCK WEIGHT MEANS, STANDARD DEVIATIONS, AND PERCENTAGE OF WEIGHTS BY AXLE.

<table>
<thead>
<tr>
<th>VEHICLE TYPE 1/</th>
<th>PERCENT OF TRUCKS BY TYPE</th>
<th>MEAN WEIGHT (IN KIPS)</th>
<th>STANDARD DEVIATION (IN KIPS)</th>
<th>WEIGHTS BY AXLE 2/</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>SINGLE UNIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 AX 4 TIRE</td>
<td>77.0</td>
<td>5.5</td>
<td>2.0</td>
<td>.42</td>
</tr>
<tr>
<td>2 AX 6 TIRE</td>
<td>19.0</td>
<td>10.9</td>
<td>4.0</td>
<td>.44</td>
</tr>
<tr>
<td>3 AX OR MORE</td>
<td>4.0</td>
<td>17.5</td>
<td>7.0</td>
<td>.38</td>
</tr>
<tr>
<td>COMBINATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AXLE</td>
<td>5.0</td>
<td>23.0</td>
<td>7.0</td>
<td>.31</td>
</tr>
<tr>
<td>4 AXLE</td>
<td>15.0</td>
<td>27.0</td>
<td>8.0</td>
<td>.25</td>
</tr>
<tr>
<td>5 AXLE OR MORE</td>
<td>80.0</td>
<td>31.2</td>
<td>4.0</td>
<td>.26</td>
</tr>
<tr>
<td>SINGLE UNIT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2 AX 4 TIRE</td>
<td>77.0</td>
<td>7.0</td>
<td>2.6</td>
<td>.31</td>
</tr>
<tr>
<td>2 AX 6 TIRE</td>
<td>19.0</td>
<td>16.4</td>
<td>6.0</td>
<td>.37</td>
</tr>
<tr>
<td>3 AX OR MORE</td>
<td>4.0</td>
<td>36.5</td>
<td>14.0</td>
<td>.28</td>
</tr>
<tr>
<td>COMBINATION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 AXLE</td>
<td>5.0</td>
<td>34.5</td>
<td>5.0</td>
<td>.27</td>
</tr>
<tr>
<td>4 AXLE</td>
<td>15.0</td>
<td>43.0</td>
<td>12.0</td>
<td>.18</td>
</tr>
<tr>
<td>5 AXLE OR MORE</td>
<td>80.0</td>
<td>63.0</td>
<td>14.0</td>
<td>.15</td>
</tr>
</tbody>
</table>

T = TANDEM AXLES
1/ TANDEM AXLES COUNTED AS TWO AXLES
2/ TANDEM AXLES COUNTED AS ONE AXLE
\[
ALCI = \frac{\sum_{i=1}^{6} PT_i \cdot (NMLW_i - NMEW_i)}{\sum_{i=1}^{6} PT_i \cdot (IMLW_i - IMEW_i)}
\]  \hspace{1cm} (8.2)

where

\(ALCI\) = the average load carried index.

\(i\) = the truck type (single unit 2 axle 4 tire, and so on).

\(PT_i\) = truck type \(i\) as a percent of all truck types.

\(NMLW_i\) = new mean loaded weight of truck type \(i\).

\(NMEW_i\) = new mean empty weight of truck type \(i\).

\(IMLW_i\) = 1975 mean loaded weight of truck type \(i\).

\(IMEW_i\) = 1975 mean empty weight of truck type \(i\).

A value of 1.09 was calculated from the above equation indicating a 9 percent average increase in load carried per vehicle. This value was then used in equation 4.2 to calculate the change in commercial VMT.

The resulting changes in highway performance are summarized in Table 36. In comparing scenarios T-1 and T-5 it is evident that the increasing of the axle weight limits has only a small adverse effect on the performance of the principal arterial systems, however, the increase has a significant adverse impact on the lower volume facilities. This is due to the fact that lower volume facilities generally have lighter pavement designs which are more sensitive to increases in axle loads (36), and subsequently, the collector systems will tend to suffer the most from increasing weight limits.
<table>
<thead>
<tr>
<th>FUNCTIONAL CLASSIFICATION</th>
<th>T-1</th>
<th>T-4</th>
<th>T-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>-11.2</td>
<td>-4.2</td>
<td>-11.1</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-5.8</td>
<td>+1.8</td>
<td>-5.9</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>-9.6</td>
<td>-1.1</td>
<td>-10.3</td>
</tr>
<tr>
<td>MAJOR COLLECTORS</td>
<td>-22.5</td>
<td>-8.4</td>
<td>-27.7</td>
</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>-29.6</td>
<td>-17.7</td>
<td>-33.4</td>
</tr>
<tr>
<td>URBAN:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>-13.5</td>
<td>-4.4</td>
<td>-15.0</td>
</tr>
<tr>
<td>OTHER FREEWAYS AND EXPRESSWAYS</td>
<td>-14.4</td>
<td>-9.5</td>
<td>-15.3</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-10.4</td>
<td>-6.7</td>
<td>-11.3</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>-19.3</td>
<td>-15.6</td>
<td>-22.4</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>-18.5</td>
<td>-10.3</td>
<td>-22.9</td>
</tr>
</tbody>
</table>
Option 6

The purpose of this option was to evaluate the effects that a relaxation of present highway performance standards will have on future Indiana highway performance. This relaxation was achieved by attaching more importance to pavement conditions and less importance to volume/capacity ratios and lane widths. Table 37 presents a summary of the weighting values resulting from relaxed performance standards. Such a relaxation in standards would permit the state to concentrate more of its capital funds on pavement rehabilitation and less funds on costly widening improvements.

This option also included the assumption of the 1980 implementation of an 11 cent per gallon gas tax. It was further assumed that non-local capital funds would be distributed among functional classifications by the series II distribution which allocates a greater share of capital funds to lower volume facilities. The resulting impacts on Indiana highway performance are summarized in Table 38. In comparing scenarios T-2 and T-6 it is apparent that there is a general improvement in the performance deterioration of the latter. The relaxation of standards enables the performance losses of the T-6 high volume facilities to be comparable to the T-2 losses on such facilities despite the fact that less funds were allocated to these facilities under the series II distribution. Overall, the pavement conditions are improved considerably under this option; as it can be expected. However, the volume/capacity ratios generally are higher indicating a greater service loss.
TABLE 37. REVISED URBAN AND RURAL CONDITION INDEX WEIGHTS BY FUNCTIONAL CLASSIFICATION.

<table>
<thead>
<tr>
<th></th>
<th>Urban Weights</th>
<th>Rural Weights</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Principal Arterials</td>
<td>Minor Arterials</td>
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<tr>
<td>CONDITION:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pavement Type</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Pavement Cond.</td>
<td>45</td>
<td>55</td>
</tr>
<tr>
<td>SERVICE:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vol/Cap Ratio</td>
<td>30</td>
<td>20</td>
</tr>
<tr>
<td>SAFETY:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lane Width</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<tr>
<td></td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Functional Classification</th>
<th>T-2</th>
<th>T-6</th>
<th>P-6</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RURAL:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>-10.0</td>
<td>-4.5</td>
<td>-2.5</td>
</tr>
<tr>
<td>Other Principal Arterials</td>
<td>-3.1</td>
<td>-5.7</td>
<td>-4.9</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>-5.8</td>
<td>-6.5</td>
<td>-5.4</td>
</tr>
<tr>
<td>Major Collectors</td>
<td>-18.6</td>
<td>-9.4</td>
<td>-8.1</td>
</tr>
<tr>
<td>Minor Collectors</td>
<td>-27.0</td>
<td>-19.8</td>
<td>-21.2</td>
</tr>
<tr>
<td><strong>URBAN:</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interstate</td>
<td>-10.7</td>
<td>-11.3</td>
<td>-10.1</td>
</tr>
<tr>
<td>Other Freeways and Expressways</td>
<td>-12.5</td>
<td>-13.0</td>
<td>-9.8</td>
</tr>
<tr>
<td>Other Principal Arterials</td>
<td>-9.7</td>
<td>-9.9</td>
<td>-7.7</td>
</tr>
<tr>
<td>Minor Arterials</td>
<td>-18.8</td>
<td>-16.6</td>
<td>-14.5</td>
</tr>
<tr>
<td>Collectors</td>
<td>-15.6</td>
<td>-6.5</td>
<td>-4.4</td>
</tr>
</tbody>
</table>
This option was also run with the PESSIMLONG macroeconomic model to evaluate economic impacts under the revised performance standards. The economic impact results for high volume facilities were much the same as the results observed in Option 1. This indicates that the reduced volume/capacity ratios and commercial VMT values associated with the PESSIMLONG model offset the effects of decreases in capital investments. However, in the lower volume facilities, which generally require more frequent resurfacing, the additional funds allocated to resurfacing improvements with the TRENDLONG model result in significantly improved pavement conditions. This, when considering the increased emphasis on pavement conditions in the series II performance criteria, offsets the lower volume/capacity ratios and commercial VMT values observed with the PESSIMLONG model to a greater degree than was the case with the higher volume facilities. Consequently, the difference in the performance impacts of the two economic models is less conclusive on lower volume facilities. In the case of rural minor collectors, for example, scenario T-6 resulted in better overall pavement condition than those in scenario P-6 and, although the volume/capacity ratios were higher in the former, the overall adverse effect on highway performance was less.

**Option 7**

This option was intended to evaluate the impacts that a reduction in the present peaking characteristics would have on Indiana highway performance. Such reductions can result from car/van pooling,
staggered working hours and so on. It was assumed in this option that the eleven cent per gallon gas tax would be implemented in 1980, the initial performance standards would be in use, and the series II capital outlay distribution would be utilized. In addition, from 1976 to 1990 a 20 percent reduction in the percent of the average daily travel (ADT) occurring during peak periods was applied.

This option resulted in an improved highway performance; the performance levels were considerably higher than those obtained under scenario T-2 which assumed a continuation of present peaking characteristics. This improvement results from the obvious reductions in volume/capacity ratios and the improvement in pavement conditions as more funds were allocated to pavement rehabilitation as the need for widening diminished (see Table 39).

The increased emphasis on pavement rehabilitation resulted in better pavement conditions under scenario T-7 than those in scenario P-7 despite the lower axle load accumulations in the latter. However, the higher volume/capacity ratios of scenario T-7 and their relative importance in estimating highway performance, offsets the improved pavement conditions, and subsequently, highway performance losses were generally less under scenario P-7.

Implications of the Results

It is apparent from the options tested in this chapter, that a general decline in Indiana highway performance can be expected in the future. Alternatives other than additional revenue generation such as the relaxations of performance standards and reductions in peaking

<table>
<thead>
<tr>
<th>FUNCTIONAL CLASSIFICATION</th>
<th>T-2</th>
<th>T-7</th>
<th>P-7</th>
</tr>
</thead>
<tbody>
<tr>
<td>RURAL:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>-10.0</td>
<td>-2.8</td>
<td>-1.1</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-3.1</td>
<td>-2.6</td>
<td>-1.0</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>-5.8</td>
<td>-1.8</td>
<td>-0.6</td>
</tr>
<tr>
<td>MAJOR COLLECTORS</td>
<td>-18.6</td>
<td>-6.5</td>
<td>-3.1</td>
</tr>
<tr>
<td>MINOR COLLECTORS</td>
<td>-27.0</td>
<td>-14.9</td>
<td>-10.9</td>
</tr>
<tr>
<td>URBAN:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INTERSTATE</td>
<td>-10.7</td>
<td>-8.0</td>
<td>-6.2</td>
</tr>
<tr>
<td>OTHER FREEWAYS AND EXPRESSWAYS</td>
<td>-12.5</td>
<td>-6.0</td>
<td>-4.4</td>
</tr>
<tr>
<td>OTHER PRINCIPAL ARTERIALS</td>
<td>-9.7</td>
<td>-5.3</td>
<td>-3.8</td>
</tr>
<tr>
<td>MINOR ARTERIALS</td>
<td>-18.8</td>
<td>-12.4</td>
<td>-3.3</td>
</tr>
<tr>
<td>COLLECTORS</td>
<td>-15.6</td>
<td>-8.1</td>
<td>-2.7</td>
</tr>
</tbody>
</table>
characteristics can minimize future highway performance losses as options six and seven indicate. Realistically, a combination of increased taxes and other non-revenue generating alternatives will likely provide the most acceptable solution to the highway financing problem. This combination will be dependent upon public willingness to accept additional taxation and public tolerance to additional highway performance loss.

Insofar as taxation is concerned, the 20 percent ad valorem gas tax is the most promising option tested in this study, as it neutralizes much of the inflationary pressure afflicting highway disbursements. Regretably, administrative problems and public resistance to an apparently high taxing level may make the implementation of such a tax difficult. An increase in the conventional eight cent per gallon gas tax is a more likely source of additional revenue.

The determination of what the public considers to be a tolerable level of highway performance is difficult, if not impossible to assess. It, therefore, can be argued that the relaxation of performance standards considered in option six, which significantly reduced highway performance loss, may be quite acceptable to the public. There is obviously the need for additional research to determine public willingness to accept trade-offs between the safety, service, and condition attributes of highway performance. Other policies such as the reduction in peaking characteristics, through an effective car/van pool program and other such measures, require public cooperation which will be influenced to a certain extent by government incentives.
In conclusion, although highway performance is likely to decrease in the future, appropriate highway policy decisions can assure that an acceptable level of highway performance is achieved.
CHAPTER 9
SUMMARY AND CONCLUSIONS

This research has considered the interaction between factors such as energy, national economic conditions, fuel efficiency, fuel consumption, population, and legislative options in an effort to evaluate their ultimate impact on the highway financing process in Indiana. This evaluation was achieved by the development of a computer model which utilized the national energy and economic forecasts provided by Data Resources Inc. along with various assumptions relating to legislative options to project a probable range of highway performance in Indiana. The results of the application of this model indicate that the level of Indiana highway performance is likely to decline over the next decade as the funds required to sustain highway performance are staggering. However, appropriate legislative action can limit this decline and assure that an acceptable level of highway performance is realized in the future.

On the basis of the results of the present study the following conclusions can be made.

1. Additional highway revenues must be acquired soon as the continued deferment of needed capital improvement projects will seriously compound future highway problems in Indiana. Such additional revenues can be generated from a number of
sources including additional appropriations from general funds and increases in current fuel tax rates or the enactment of an ad valorem fuel tax.

2. Serious efforts should be made to limit the growth in all non-capital highway disbursements.

3. It is necessary to determine the acceptable trade-offs between highway performance components and the capital funding effort should be adjusted accordingly. For example, public outcry over the condition of pavements may seem to indicate the need for more emphasis on pavement rehabilitation. However, if this is to be done, less resources will be available for widening and other such upgrading improvements causing more congested highways. Therefore, careful evaluation must be made of the appropriate trade-offs such that capital improvement funds can be optimally utilized.

4. Attention should be given on statewide promotion of car/van pooling, public transit, and staggered working hours since the effective implementation of these measures may significantly reduce highway congestion in urban areas. This would allow the capital improvement funds normally spent to increase highway capacity to be allocated to pavement rehabilitation and other less costly improvements.

5. Future increases in permissible axle loads should not be considered unless accompanied by significant increases in truck registration fees, since there is evidence that pavement deterioration rates increase measurably under the higher axle load limits.
LIST OF REFERENCES
LIST OF REFERENCES


APPENDIX A

Program Listing of the HIPERFORM Computer Model
**HIPERFORM I**

**HIGHWAY PERFORMANCE FORECASTING MODEL**

**VERSION I**

**DEVELOPED BY F. MANNERING**

**PURDUE UNIVERSITY**

**MARCH 1979**

```
PROGRAM MAIN(INPUT, OUTPUT, TLONG78, TAPES, TAPEG)
DIMENSION RINC(15), SINC(15), TOMG(15), BI(15), MIN(30), GPI(15), IMP15(30), ITGAS(15), IRECO(15), IRESU(15), IREMO(15), IREA(15), 2RU1(15), TU2(15), GRATE1(16), GRATE2(16), ITREU(16), HG4(3, 5, 105), 3, HG5(3, 6, 105), HGXY(3, 6, 105), HG2(3, 6, 105), ML1(3, 6), HG3(3, 5, 105), 4, AID(15), WSIN(16), TAX
COMMON RINC, SINC, TOMG, BI, MIN, GPI, NYEAR, SAT1, B9, TAX, IMP15, ITGAS, IRECO, IRESU, IREMO, IREA, RU1, RU2, IVOL, GRATE1, GRATE2, ITREU, HG4, HG5, HGXY, HG2, HG3, HG4, KCOV, KSSF, KSFLAG, KBARR, AID, WSIN
KSSF=1
KSFLAG=1
READ(5,1000) KSEED, KCOW
1000 FORMAT(16,1X,12)
DO 1979 I=1, KSEED
1979 SEED=RANF(0)
READ(5,503) (AID(I), I=1, 15)
503 FORMAT(15F4.2)
READ(5,501) (WSIN(I), I=1, 15)
501 FORMAT(15F5.1)
READ(5,1010) (RU1(I), I=1, 15)
READ(5,1010) (RU2(I), I=1, 15)
1010 FORMAT(15F4.2)
DO 3000 N1=1, KCOW
KBARR=N1
IF(N1.EQ.KCOW) KSSF=2
IF(N1.GT.1) KSFLAG=2
CALL PRESC
IF(N1.GT.1) GO TO 510
CALL IPPM
CALL USACO
CALL UMPRO
CALL REUGEN
510 CALL PAVAGE
3000 CONTINUE
STOP
END
```
SUBROUTINE IFFM

******************************************************************************

THIS SUBROUTINE PROJECTS THE INDIANA POPULATION TO THE TARGET YEAR.

DIMENSION MAL(18),NFE1(18),SUM1(18),SUM2(18),SUF1(18),SUF2(18),
1SF(6),SUMM(18),SUMF(18),SUM3(18),SUMF3(18),RMIG(6),MAL1(18),
2HK1(18),N1(6),MMA(30),MMF(30),MINT(30),RINC(15),SINC(15),TOMG(15)
3,15),(GPI(15),WMMG(4),MP15(30),ITGAS(15),IRECO(15),
4RESU(15),IREMO(15),IREA(15),R101(15),UR2(15),H4(3.5,105)
5,HG5(3.6,105),HG0(3.6,105),HG2(3.6,105),ML1(3.6),HG3(3.5,105)
6,GRATE1(16),GRATE2(16),ITREU(16),AIR1(15),WS1N(15),TAX(15)
7,COMMON RINC,SINC,TOMG,B1,M1N,GPI,NYEAR,SAT1,BS,TAX,
8MP15,ITGAS,IRECO,IREA,IREM1,IREP,IEP1,UR1,UR2,IVOL,GRATE1,GRATE2,ITREU
9,PM1,HS1,HG2,ML1,HG3,KG1,KSF,KSFLAG,KBPP,W1N

**** READ SERIES

READ(5,9999) IVOL,NYE11,SAT1
9999 FORMAT(11.1X,12.1X,F4.2)

**** INITIAL COHORTS

DATA(MAL(1),I=1,18)/232479, 268759, 278939, 253127, 195629, 171449,
14834, 13634, 146521, 147852, 132652, 116207, 96179, 74345, 55681,
92, 83293, 22026, 13934/

DATA(NFE1(1),I=1,18)/123197, 260265, 266944, 249113, 219095, 174413,
148775, 143141, 154703, 156684, 141669, 125775, 109405, 92415, 76349,
95, 83775, 37124, 25297/

**** INPUT SURVIVAL RATES

DATA(SUM1(1),I=1,18)/.980656, .996667, .998061, .995056, .990373,
.989901, .990559, .986005, .983123, .972835, .957040, .933833, .899862,
.852301, .790463, .710259, .605016, .408679/

DATA(SUM2(1),I=1,18)/.98475, .996936, .996191, .995322, .99081, .990556,
.990137, .98968, .985007, .975772, .961179, .936856, .906192, .859558,
.807305, .716784, .626165, .42339/

DATA(SUF1(1),I=1,18)/.984683, .997442, .998523, .997784, .996633,
.996368, .955455, .993414, .989859, .991689, .976437, .965977, .95087,
.93079, .855951, .832198, .733181, .496849/

DATA(SUF2(1),I=1,18)/.987552, .997734, .998554, .998019, .997054,
.996034, .996033, .994246, .991076, .995355, .978952, .965316, .955584,
.937323, .905365, .847452, .754904, .508305/

**** FERTILITY RATES

DATA(SF(1),I=1,6)/.71.5, .70, 69.1, 67.1, 64.7, 60.1/

**** ESTIMATED MIGRATION RATES

DATA(RMIG(1),I=1.6)/-.018, -.021, -.009, -.005, -.005/

**** DETERMINE SURVIVAL RATE INCREASE

DO 7070 I=1,18
SUMM(I)=(SUM2(I)-SUM1(I))/4

7070 SUMF(I)=(SUF2(I)-SUF1(I))/4
DO 7078 I=1,2
DO 7077 N=1,18
SUM3(I,N)=SUMM(N)

7077 SUMF(I,N)=SUF1(N)
DO 7078 I=3,6
DO 7078 N=1,18
SUM3(I,N)=SUM1(N)+(I-2)*SUMM(N))
7078 SUM3(I,N)=SUM1(N)+(I-2)*SUMM(N))
C C *** START OF YEARLY PROJECTIONS C
C DO 8182 I=1,18
MAL(I)=MAL1(I)
8182 MFE(I)=MFE1(I)
DO 8080 L=1,6
IYEAR=1975+(L-1)*5
NI(L)=5*L
C C *** BIRTH CALCULATIONS C
C FER2=0
DO 7071 I=4,3
FER1=FLOAT(MFE(I)/1000)*SF(L)
7071 FER2=FER2+FER1
FER2=FER2*5
C C *** SURVIVAL CALCULATIONS C
C DO 7072 I=1,18
MAL(I)=IFIX(FLOAT(MAL(I))*SUM3(I,N))
7072 MFE(I)=IFIX(FLOAT(MFE(I))*SUM3(I,N))
C C *** COHORT ADVANCE C
C MALU=MAL(18)
MFEU=MFE(18)
DO 7073 I=1,17
J=18-I
MAL(J+1)=MAL(J)
7073 MFE(J+1)=MFE(J)
MAL(J)=MAL(J)+MALU
MFE(J)=MFE(J)+MFEU
MAL(I)=IFIX(.515*FER2)
MFE(I)=IFIX(.485*FER2)
C C *** MIGRATION CALCULATIONS C
C DO 7075 I=1,18
MAL(I)=IFIX(FLOAT(MAL(I))*1.05*RUMIG(L))+MAL(I)
7075 MFE(I)=IFIX(FLOAT(MFE(I))*1.05*RUMIG(L))+MFE(I)
HALT=0
MFET=0
DO 7074 I=1,18
MALT=MALT+MAL(I)
MFET=MFET+MFE(I)
7074 IF(L.E.4) MP15(N1(L))=MP15(N1(L))+MAL(I)+MFE(I)
I:POP=MALT+MFET
MMA(N1(L))=MALT
MFN(N1(L))=MFET
MIN(N1(L))=INPOP
IF(L.EQ.1) GO TO 8080
MACD=(MMA(N1(L))-MMA(N1(L-1)))/5
MFCD=(MFN(N1(L))-MFN(N1(L-1)))/5
INCD=(MIN(N1(L))-MIN(N1(L-1)))/5
IF(L.NE.2) GO TO 90
WMIG(I)=.995
WMIG(2)=.9973
WMIG(3)=1.
WMIG(4)=1.003
GO TO 92
90 DO 91 I=1,4
91 WMIG(I)=1.
92 DO 1300 I=1,4
J=NI(L-1)+I
MMA(J)=(MACD+MMA(J-1))*WMIG(I)
HPM 131
HPM 132
HPM 133
HPM 134
HPM 135
HPM 136
HPM 137
HPM 138
HPM 139
HPM 140
HPM 141
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HPM 198
HPM 199
HPM 200
**SUBROUTINE USACO**

This subroutine estimates national auto fleet fuel efficiencies.

```plaintext
DIMENSION PSR(25),ACOR(12),SURU(12),RMPG(12),FMPG(15),
1NUM(15),RNP(15),RINC(15),ZMC(15),TOMG(15),
2NCB(15),BCOR(12),BI(15),TUT(15),PERU(15),HP15(30),
3MIN(30),SINC(15),GPI(15),RU1(15),RU2(15),TAU(15),
4ITGAS(15),IRECO(15),IRESU(15),IREMO(15),IREA(15),GRATE1(16),
5GRATE2(16),ITREU(16),HG4(3,5,105),GPI(15),AID(15),WSIN(16),
6, HG4(3,5,105), HG2(3,6,105), HL1(3,6), HG3(3,5,105),
COMMON RINC,SINC,TOMG,BI,MIN,GPI,NYEAR,SATI,B9,TAX,
1MP15,ITGAS,IRECO,IRESU,IREMO,IREA,GRATE1,GRATE2,ITREU,
2, HG5, HG2, HL1, HG3, HG4, KS, KA, HS, RS, HU, IUL, GRATE1, GRATE2, ITREU
INTEGER ACOR,BCOR,NCB,TAUTO,PDII,BCOR,CHCOR,TUT,PSIX,RACOR,
1, UAUTO
```

****** READ INPUT DATA**

```plaintext
READ(5,101) (RINC(I),I=1,NYEAR)
READ(5,101) (GPI(I),I=1,NYEAR)
READ(5,102) (RNP(I),I=1,NYEAR)
READ(5,102) (BI(I),I=1,NYEAR)
READ(5,102) (SINC(I),I=1,NYEAR)

1001 FORMAT (15(F5.1))
1002 FORMAT (15(F5.1))
```

****** INITIAL PARAMETER VALUES**

```plaintext
USIN=169.7
```

This page contains a subroutine that estimates national auto fleet fuel efficiencies. The subroutine is part of a larger program and involves reading input data and calculating various parameters related to fuel consumption and population estimates. The subroutine definition is followed by specific input data formats and parameter values used in the calculations.
153

**PROJECTIONS OF ECONOMIC PARAMETERS**

DO 1800 I=1,NYEAR
IF(INVOL.EQ.2) GO TO 400
UU1=UU2*(1.+GPI1(I)/100.)*RU1(I)
UU2=UU1-RU1(I)
401 GPI(I)=UU1*USIR/59.
GO TO 1800
400 UU1=(UU2-.04)*(1.+GPI1(I)/100.)*RU1(I)
UU2=UU1-(UU2-.04)*(1.+GPI1(I)/100.)*RU1(I)
GO TO 401
1800 CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1901 TACOR=TACOR+ACOR(I)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CACOR=BCOR(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
CONTINUE
DO 1303 N=1,NYEAR
TACOR=0
DO 1301 I=1,12
1904 BCOR(I)=ACOR(I)*SURU(I)
CAC0R=BC0R(12)
2011 SURV(I)=FLOAT(BCOR(I))/FLOAT(ACOR(I))

C **** COHORT ADVANCE
C DO 1905 I=1,11
J=12-I
1905 BCOR(J+1)=BCOR(J)
BACOR=BCOR(12)
BCOR(1)=KCB(N)
BCOR(12)=BACOR+ACOR
TAUTO=0.
DO 1992 I=1,12
1992 TAUTO=TAUTO+BCOR(I)
TUT(N)=TAUTO
DO 1910 I=1,12
1910 ACOR(I)=BCOR(I)
C **** FLEET MILEAGE CALCULATIONS
C RMPG(12)=(FLOAT(BACOR)*RMPG(11)+FLOAT(CACOR)*RMPG(12))/FLOAT(BCOR(A12))
DO 1911 I=2,11
J=12-I
1911 RMPG(J+1)=RMPG(J)
IF(N.GT.10) FMPG(N)=27.5
RMPG(1)=FMPG(N)
TMPG=0
TTG1=0.
DO 1912 I=1,12
C1=FLOAT(I+1)
R7=1.5935+48125*ALOG(C1)
IF(I.EQ.1) R7=0.
TTG1=FLOAT(BCOR(I))*R7+TTG1
1912 TMPG=TMPG+(FLOAT(BCOR(I))*RMPG(I)*R7)
TOMG(N)=TMPG/TTG1
PPUL=PS(N+1)*1000/FLOAT(TUT(N))
PERU(N)=PPUL
1903 CONTINUE
C **** OUTPUT STATEMENTS
C WRITE(6,101)
101 FORMAT(1X,'U.S. AUTO EFFICIENCY PROJECTIONS',1X, 
'ADJ(1975+I)-,15X,'NEW CAR',14X,'TOTAL NUMBER',14X, 
'B*FLEET',15X,'PERSONS',16X,'YEAR',15X,'SALES 1/14X,'OFTAUTOS 1/14X, 
'C',15X,'HP',15X,'PER AUTO',16X,'96(-)',/)
DO 1913 I=1,NYEAR
NOY=1975+I
NSIN=IFIX(RINC(I)*1000.)
WRITE(6,102) NOY,NSIN,TUT(I),TOMG(I),PERU(I)
1912 FORMAT(16X,14,15X,16,17X,17X,F5.2,15X,F5.2,/, 
1913 CONTINUE
WRITE(6,103)
103 FORMAT(16X,'96(-)')
WRITE(6,104)
104 FORMAT(16X,'1/15X,'1 IN THOUSANDS')
RETURN
END
C SUBROUTINE VMIPRO
C *****************************************************************************************************************
C THIS SUBROUTINE PROJECTS VEHICLE MILES OF TRAVEL IN
C INDIANA BY VEHICLE TYPE.
C
**STEEL PRODUCTION ESTIMATES**

\[
SPRO(I) = 1.22 \times \frac{SINC(I)}{100} \times 17.61
\]

**INTERCITY TON-MILE ESTIMATES**

\[
AITM(I) = 51.4 \times G4 + 8.5205 \times \log(BI(I)) + 8.72447 \times \log(SPRO(I))
\]

\[
AIUM4 = 1900.
\]

\[
ZUAR(I) = TUMT(I) - AIUM(I)
\]

\[
TGAS(I) = \frac{TUMT(I)}{ZMPG(I)}
\]

**VEHICLE MILE CALCULATIONS**

\[
ZUAR(I) = TUMT(I) - AIUM(I)
\]

\[
TGAS(I) = \frac{TUMT(I)}{ZMPG(I)}
\]

**FUEL CONSUMPTION CALCULATIONS**

\[
ZUAR(I) = TUMT(I) - AIUM(I)
\]

\[
TGAS(I) = \frac{TUMT(I)}{ZMPG(I)}
\]

**CONVERSION OF REAL ARRAYS TO INTEGER ARRAYS**

\[
IAUUM(I) = \text{IFIX}(XX3 \times ZVAR(I))
\]

\[
IAUUM(I) = \text{IFIX}(AIUM(I))
\]

\[
ITUMT(I) = \text{IFIX}(TUMT(I))
\]

**REGISTRATION ESTIMATIONS**

\[
DO 2003 I=1,NYEAR
\]

\[
REAUT(I) = \text{FLOAT(MIN(I+5))/(2.0-B9*ALOG(FLOAT(I)))}
\]

\[
RECOM(I) = 38543. \times (1.015)^I \times (1 + 0.21 \times \log(BI(I)/117.8-1))
\]

\[
PC2 = 0.27 \times (1.005^I)
\]

\[
PC3 = 0.0056 \times (1.005^I)
\]

\[
RESU(I) = REAUT(I) + FC2
\]

\[
REBUS(I) = PC3 \times REAUT(I)
\]

\[
REMO(I) = 0.55 \times REAUT(I)
\]

\[
PPV(I) = 0.055 \times REAUT(I)
\]
**CONVERSION OF REAL ARRAYS TO INTEGER ARRAYS**

```fortran
C
**** CONVERSION OF REAL ARRAYS TO INTEGER ARRAYS
C
IREA(I)=IFIX(REALAUT(I))
CREASE(I)=IFIX(REALRESU(I))
IRECO(I)=IFIX(REALRECO(I))
IREG(I)=IFIX(REALREG(I))
0303 IREM(I)=IFIX(REALREM(I))
C
**** OUTPUT STATEMENTS
C
WRITE(6,1)
1 FORMAT('I',1X,29(' ', 'UVT PROJECTIONS', 1X, 29(' '), '/'),)
A21X,90(' '), 40X, 'AUTO', 14X, 'COMBINATION', 12X, 'TOTAL', 16X,
B'FLEET', 21X, 'YEAR', 14X, 'UVT 1', 15X, 'UVT 1', 14X, 'UVT 1', 17X,
C'MPG', 21X, 90(' '), */
NFLAG=1
9 DO 10 I=1,NYEAR
NOY=1975+I
DEL=(CPI(I)-168.7)*.59
IF(NFLAG.EQ.2) GO TO 7
IF(NFLAG.EQ.3) GO TO 17
WRITE(6,2) NOY, IAUV(I), IAUV(I), ITUMT(I), ZMPG(I)
2 FORMAT(21X, I4, 14X, I5, 2(16X, I5), 16X, F5.2, '/)
GO TO 10
7 WRITE(6,4) NOY, IREA(I), IRESU(I), IREC(I), IREG(I), PPUC(I)
GO TO 10
4 FORMAT(11X, I4, 15X, I7, 14X, I6, I5, 15X, I7, 15X, F5.2, '/)
GO TO 10
17 WRITE(6,19) NOY, DEL, ITGAS(I), IAITM(I)
19 FORMAT(30X, I4, 15X, F4.2, 17X, I7, 17X, I5, '/')
CONTINUE
IF(NFLAG.EQ.1) WRITE(6,31)
31 FORMAT(21X, 90(' '))
IF(NFLAG.EQ.1) WRITE(6,40)
40 FORMAT(21X, 90(' '), 1/X, IN MILLIONS OF VEHICLE MILES TRAVELED')
IF(NFLAG.EQ.2) WRITE(6,32)
32 FORMAT(11X, 110(' '))
IF(NFLAG.EQ.3) WRITE(6,33)
33 FORMAT(30X, 72(' '))
IF(NFLAG.EQ.3) WRITE(6,41)
41 FORMAT(21X, 33X, ' 1/X IN THOUSANDS OF GALLONS')
IF(NFLAG.EQ.3) WRITE(6,42)
42 FORMAT(21X, 33X, '2/X IN MILLIONS')
IF(NFLAG.EQ.3) GO TO 10
IF(NFLAG.EQ.3) GO TO 18
WRITE(6,3)
3 FORMAT('I', 1X, 26(' '), 'REGISTRATION PROJECTIONS', 1X, 27(' '), ')
C11X, 'REGISTRATIONS', 3(8X, 'REGISTRATIONS'), 8X, 'PER VEHICLE',
D/11X, 110(' '), ')/
NFLAG=2
GO TO 9
18 WRITE(6,20)
20 FORMAT('I', 1X, 23(' '), 'FUEL CONSUMPTION AND TON-MILE ESTIMATES',
A23(' '), '<<<, 30X, 72(' '), 46X, 'RETAIL GAS', 13X, 'MOTOR FUEL',
B13X, 'INTERGENCY', 30X, 'YEAR', 15X, 'PRICE', 13X, 'CONSUMPTION 1', 9X,
C'TON-MILES 2', 30X, 72(' '), ')
NFLAG=3
GO TO 9
10 RETURN
END
C
SUBROUTINE REUCEN
C
************************************************************
C
}
THIS SUBROUTINE ESTIMATES ALL INDIANA STATE ROAD-USER TAX REVENUES.

DIMENSION MP15(30), ITGAS(15), IRECO(15), IRESU(15), IREM(15), AIREA(15), RIU1(15), RIU2(15), RIU3(15), RIU(15), RU2(15), RINC(15), BSINC(15), TONG(15), BI(15), CPI(15), MIN(30), H1(6), HG4(3,5,105), C, IRLP(2,15), PCTT(2,15), GRATE1(16), GRATE2(16), ITREU(16), DMC(3,6,105), HMG(3,6,105), HG2(3,6,105), ML1(3,6), HG3(3,5,105), E, AID(15), USIN(15), TAX(15), COMMON RINC, SINC, TOMB, BI, MIN, CPI, NYEAR, SAT1, B9, TAX, 1MP15, ITGAS, IRECO, IRESU, IRCO, IREA, RU1, RU2, IVOL, GRATE1, GRATE2, ITREUHPM 564, 2, HG5, HGWY, HG2, ML1, HG3, HG4, KCOL, KSSF, KSFLAG, KBARR, AID, WSIN

C *** READ INPUT DATA

DATA((IRLP(I,J), J=1,15), I=1,2)/16,24,40,65,100,120,175,225,275, H=35,485,500/ DATA((PCTT(I,J), J=1,15), I=1,2)/79.03,05,04,026,05,01,003, A,005,002,004,0011,0025,0,0,0,0,0,0,0,0,015,008,013, B,015,033,03,0356,026,021,114557/ READ(5,1010) (RIU1(I), I=1,NYEAR) READ(5,1010) (RIU2(I), I=1,NYEAR) READ(5,1010) (RIU3(I), I=1,NYEAR) 1010 FORMAT(15(F5.2))

C *** CALCULATION OF POPULATION GREATER THAN 15 YEARS OLD

DO 900 L=1,6 IV(L)=5*L IF(L.LE.1) GO TO 900 MAI=(MP15(N1(L))-MP15(N1(L-1)))/5 DO 901 I=1,4 J=N1(L-1)+I MP15(J)=MAI+MP15(J-1) MP15(J-5)=MP15(J) 901 CONTINUE 900 CONTINUE

C *** REVENUE CALCULATIONS

DO 400 I=1,NYEAR ITR1=0 ITR2=0 DO 4002 L=1,2 DO 4002 L2=1,15 IF(L.LE.1) ITR1=ITR1+IFIX(FLOAT(IRESU(I))*PCTT(1,L2)*FLOAT(IRLP A(1,L2))) IF(L.LE.2) ITR2=ITR2+IFIX(FLOAT(IRESU(I))*PCTT(2,L2)*FLOAT(IRLP A(2,L2))) 4002 CONTINUE IMORE=IFIX(FLOAT(IREMO(I))*RIU1(I))/1000 IAURE=IFIX(FLOAT(IREA(I))*RIU2(I))/1000 ITREU=ITREU+1000 ITR1=ITR1+1000 ITR2=ITR2+1000 RLISC=.85*FLOAT(MP15(I)) LIREU=IFIX(RIUS3(I)*RLISC)/1000 RX=FLOAT(ITGAS(I))*1000 IF(RIVOL.EQ.2) GO TO 410 IGREU=IFIX(R3X*RV1(I))-IFIX(.03*(RX*RV1(I)))/1000 GO TO 411 410 IGREU=IFIX(RX*TAX(I))-03RX*TAX(I))/1000 411 ITREU=ITREU+IMORE+IAURE IAADD=IFIX(AIDC(I))/1,01ADC(I))*FLOAT(IGREU+1TOT))LIREU ITREU(I)=IAADD*IGREU+ITREU NOV=1975+1 IF(I.GT.1) GO TO 40

HPM 551
HPM 552
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HPM 619
HPM 620
**SUBROUTINE PRESCO**

***** THIS SUBROUTINE SIMULATES PRESENT PAVEMENT CONDITIONS BY CREATING A NUMBER OF SAMPLE ROADWAY SECTIONS.*****

**DIMENSION MILE(3,6),UVM(3,2,6),VCR1(5,2,6),VCR2(5,2,6),**

1MAX(3,6),UCAN(6),HG2(3,3,6,105),HG3(3,3,6,105),

2HGC(3,3,6,105),HGO(3,3,6,105),UCON(6),VCR3(5,2,6),**

3WLLN(3,6),ML1(3,6),HTO(3,6),GRAT1(16),GRATE2(16),ITREU(16),**

4RINC(15),SINC(15),TOMG(15),BI(15),MIN(30),GPI(15),**

5MP15(30),ITGAS(15),IRECO(15),IRESU(15),IREMO(15),IREA(15),**

6RUM(15),RU2(15),AID(15),WSIN(15),TAX,15)**

COMMON RING,SINC,TOMG,BI,MIN,GPI,NC(15),ITGAS,IRECO,****

IRESU,IREMO,IREA,RU1,RU2,UIDL,GRAT1,GRATE2,ITREU,MP**

1REAL MILE,MAX****

XARK=17171274321477413155B****

YARK=RANF(XARK)****

IF(KSFLAG.EQ.2) GO TO 4017****

**READING OF INITIAL DATA**

**PAVEMENT CONDITIONS - PCT(RURAL)**

DATA(MILE(1,1),I=1,6)/99..20..128..11..112..110./****

DATA(MILE(1,2),I=1,6)/69..30..11,67..32..11/****

DATA(MILE(1,3),I=1,6)/61..39..0,57..43.,0./****

DATA(MILE(1,4),I=1,6)/49.,47.,44.,49.,45.,6./****

DATA(MILE(1,5),I=1,6)/27.,66.,7.,37.,55.,5./****

DATA(MILE(1,6),I=1,6)/15.,70.,15.,20.,65.,15./****

**PAVEMENT CONDITIONS - PCT(URBAN)**

DATA(MILE(2,1),I=1,6)/99..11..0,94..6.,0./****

DATA(MILE(2,2),I=1,6)/96..4.,0,92..8.,0./****

DATA(MILE(2,3),I=1,6)/51.,48.,1..51.,48.,1./****

DATA(MILE(2,4),I=1,6)/60.,40.,10.,57.,43.,0./****

DATA(MILE(2,5),I=1,6)/53.,41.,6.,53.,38.,6./****

DATA(MILE(2,6),I=1,6)/48.,40.,12.,52.,38.,10./****

**PAVEMENT CONDITIONS - PCT(SMALL URBAN)**

DATA(MILE(3,1),I=1,6)/100.,0.,0,100.,0.,0./****

DATA(MILE(3,2),I=1,6)/92.,8.,0,90.,10.,0./****

DATA(MILE(3,3),I=1,6)/46.,54.,0,46.,54.,0./****

DATA(MILE(3,4),I=1,6)/45.,49.,6.,51.,45.,4./****

DATA(MILE(3,5),I=1,6)/40.,51.,9.,46.,49.,9./****

DATA(MILE(3,6),I=1,6)/35.,55.,10.,40.,50.,10./****

**READING OF ADT MEANS AND STANDARD DEVIATIONS**

DATA(UMM(1,J,K),K=1,6)+J=1,2)/16.4,5.7,5.2,1.2,6.2,6,5.3,5,****

A3.3,6,23,09/
DATA((Umm(2,J,K),K=1,6),J=1,2)/44.00,16.90,17.2,7.46,2.83,.76,16./HPM 691
A7.2.7.5.4.1.1.7.4./HPM 692
DATA((Umm(3,J,K),K=1,6),J=1,2)/27.02,4.00,10.0,5.40,1.87,.56,.10./HPM 693
A1.8.5.1.3.0.1.0,25./HPM 694
C
C **** READING OF U/C RATIOS
C
C **** PCT(RURAL)
DATA((Ucr1(1,J,K),K=1,6),J=1,2)/0.45,.55,0.63,.37,100.,0./HPM 695
A0.,100.,0.0./HPM 696
DATA((Ucr1(2,J,K),K=1,6),J=1,2)/1.28,71.3,1,24,73.83,17./HPM 697
A0.,83,17,0./HPM 698
DATA((Ucr1(3,J,K),K=1,6),J=1,2)/1.24,75,2,40,58,64,36./HPM 699
A0.,68,32,0./HPM 700
DATA((Ucr1(4,J,K),K=1,6),J=1,2)/0.2,98,0.8,92,12,58,30./HPM 701
A21.,99,20./HPM 702
DATA((Ucr1(5,J,K),K=1,6),J=1,2)/0.1,71,49,50,92,8,0./HPM 703
A91.,99,20./HPM 704
C
C **** PCT(URBAN)
DATA((Ucr2(1,J,K),K=1,6),J=1,2)/11,67,22,22,70,3,100.,0./HPM 705
A100.,0,0./HPM 706
DATA((Ucr2(2,J,K),K=1,6),J=1,2)/4,26,70,1,49,50,92,8,0./HPM 707
A0.,12,0,0./HPM 708
DATA((Ucr2(3,J,K),K=1,6),J=1,2)/33,41,26,50,36,14,62,31./HPM 709
A7,62,32,5./HPM 710
DATA((Ucr2(4,J,K),K=1,6),J=1,2)/21,51,28,35,45,20,42,46./HPM 711
A12,42,44,14./HPM 712
DATA((Ucr2(5,J,K),K=1,6),J=1,2)/6,26,68,10,42,48,25,56./HPM 713
A15,20,67,13./HPM 714
C
C **** PCT(SMALL URBAN)
DATA((Ucr3(1,J,K),K=1,6),J=1,2)/0.83,.17,0.91,9,100.,0./HPM 715
A100.,0,0./HPM 716
DATA((Ucr3(2,J,K),K=1,6),J=1,2)/0.22,78,0.23,77,100.,0./HPM 717
A100.,0,0./HPM 718
DATA((Ucr3(3,J,K),K=1,6),J=1,2)/8,63,29,14,67,19,67,22./HPM 719
A11.,96,21,13./HPM 720
DATA((Ucr3(4,J,K),K=1,6),J=1,2)/10,42,48,11,53,36,45,40./HPM 721
A15,47,42,11./HPM 722
DATA((Ucr3(5,J,K),K=1,6),J=1,2)/0,10,90,0,15,85,36,33,31./HPM 723
A41.,35,25./HPM 724
C
C **** READ TOTAL UMT
C
DATA((Max(1,K),K=1,6)/11330,13972,11311,8829,2572,7961./HPM 725
DATA((Max(2,K),K=1,6)/7718,946,11182,9500,2794,4057./HPM 726
DATA((Max(3,K),K=1,6)/508,173,424,3291,953,1623./HPM 727
C
C **** SIMULATION OF PRESENT HIGHWAY CONDITIONS
C
4017 DO 70 K=1,3
DO 70 N=1,6
WLON(K,N)=Max(K,N)/(Umm(K,1,N)/1.2*100.)
IF(WLON(K,N).LT.2.)WLON(K,N)=2.
70 HTO(K,N)=0.
HTOT=0.
DO 3000 I=1,3
DO 3000 J=1,6
ML=0.
CONT=0.
IF(J.EQ.6) GO TO 5010
C
C **** ESTIMATION OF DAILY VOLUMES AND U/C RATIOS
C
DO 3002 I1=1,6
IF(I1.EQ.1) UCAN(I1)=Ucr1(J,1,1)
IF(I1.EQ.2) UCAN(I1)=Ucr2(J,1,1)
IF(I1.EQ.3) UCAN(I1)=Ucr3(J,1,1)
IF(UCAN(I1).NE.0.) GO TO 3007
U1=0.
GO TO 3008
3007 V1=UCAN(4)/UCAN(1))
3008 V2=UCAN(5)/UCAN(2)
U3=UCAN(6)/UCAN(3)
V4=V1*UMM(I,1,J)
V5=V2*UMM(I,1,J)
V6=U3*UMM(I,1,J)
IF(V1.GT.1) V1=1/V1
IF(V2.GT.1) V2=1/V2
IF(V3.GT.1) V3=1/V3
S1=U1*UMM(I,2,J)
S2=V2*UMM(I,2,J)
S3=U3*UMM(I,2,J)
4000 ML=ML+1
IF(I.EQ.1) A2=.8
IF(I.GT.1) A2=.9
H1=I-.95-A2)*RANF(0)+A2
H2=(A2-.31)*RANF(0)+.31
H3=(.31-.2)*RANF(0)+.2
R3=RANF(0)
R3=R3*100.
IF(UCAN(5).GE.UCAN(6).AND.UCAN(5).GE.UCAN(4)) GO TO 3021
IF(UCAN(5).GE.UCAN(6).AND.UCAN(5).GE.UCAN(6)) GO TO 3022
IF(UCAN(5).GE.UCAN(6).AND.UCAN(5).GE.UCAN(6)) GO TO 3023
IF(UCAN(5).GE.UCAN(6).AND.UCAN(4).GE.UCAN(6)) GO TO 3024
3021 IF(R3.LE.(UCAN(4)) GO TO 3040
IF(R3.LE.(UCAN(4).AND.R3.LE.(UCAN(5)+UCAN(4))) GO TO 3041
GO TO 3042
3022 IF(R3.LE.(UCAN(4)) GO TO 3040
IF(R3.LE.(UCAN(6)+UCAN(4))) GO TO 3042
GO TO 3041
3023 IF(R3.LE.(UCAN(6)) GO TO 3042
IF(R3.LE.(UCAN(6)+UCAN(5))) GO TO 3041
GO TO 3040
3024 IF(R3.LE.(UCAN(6)) GO TO 3042
IF(R3.LE.(UCAN(6)+UCAN(4))) GO TO 3040
GO TO 3041
5010 ML=ML+1
80 HGWY(I,J,ML)=GAUSS(UMM(I,2,J),UMM(I,1,J))
NFLAG=1
GO TO 3050
3040 HG3(I,J,ML)=H1
81 HGWY(I,J,ML)=GAUSS(S1,V4)
NFLAG=2
GO TO 3050
3041 HG3(I,J,ML)=H2
82 HGWY(I,J,ML)=GAUSS(S2,V5)
NFLAG=3
GO TO 3050
3042 HG3(I,J,ML)=H3
83 HGWY(I,J,ML)=GAUSS(S3,V6)
NFLAG=4
GO TO 3050
C
C **** ASSIGNMENT OF PAVEMENT CONDITIONS
C
3050 GO TO (1710,1712,1711) I
1710 IF(J.EQ.1.AND.HGKY(I,J,ML).LE.8.) GO TO 1713
IF(J.EQ.2.AND.HGKY(I,J,ML).LE.2.) GO TO 1713
IF(J.EQ.3.AND.HGKY(I,J,ML).LE.1.5) GO TO 1713
IF(J.EQ.4.AND.HGKY(I,J,ML).LE.0.6) GO TO 1713
IF(J.EQ.5.AND.HGKY(I,J,ML).LE.0.4) GO TO 1713
GO TO 1714
1711 IF(J.EQ.1.AND.HGKY(I,J,ML).LE.12.) GO TO 1713
IF(J.EQ.2.AND.HGKY(I,J,ML).LE.2.) GO TO 1713
IF(J.EQ.3.AND.HGKY(I,J,ML).LE.4.) GO TO 1713
IF(J.EQ.4.AND.HGKY(I,J,ML).LE.3.) GO TO 1713
IF(J.EQ.5.AND.HGKY(I,J,ML).LE.0.7) GO TO 1713
GO TO 1714
1712 IF(J.EQ.1.AND.HGKY(I,J,ML).LE.16.) GO TO 1713
IF(J.EQ.2.AND.HGKY(I,J,ML).LE.9.) GO TO 1713
IF(J.EQ.3.AND.HGKY(I,J,ML).LE.8.) GO TO 1713
IF(J.EQ.4.AND.HGWY(I,J,ML).LE.3.) GO TO 1/13
IF(J.EQ.5.AND.HGWY(I,J,ML).LE.1.) GO TO 1/13
GO TO 1714
1713 GO TO(80,81,82,83) NFLAG
1714 IF(HGWY(I,J,ML).LE.0.03) GO TO(80,81,82,83) NFLAG
DEVO=.75
IF(J.EQ.1) DEVO=1.3
IF(J.GT.1.AND.J.LE.3) DEVO=1.05
IF(J.EQ.1.AND.J.LE.2) GO TO 3051
IF(J.GT.2.AND.J.LE.3) GO TO 3051
AI=2.
BI=0.5
GO TO 3052
3051 AI=2.5
BI=2.
IF(J.EQ.1.AND.J.LE.3) BI=1.8
3052 R2=RANF(0)
R2=R2*100.
IF(R2.LE.MILE(I,J)) HG2(I,J,ML)=(A1-B1)*RANF(0)+B1
IF(MILE(I,J).LE.0.03) GO TO(80,81,82,83)
NFLAG
DEU0=.75
IF(J.EQ.1) DEU0=1.3
IF(J.GT.1.AND.J.LE.3) DEU0=1.05
IF(I.EQ.1.AND.J.LE.2) GO TO 3051
IF(I.GE.2.AND.J.LE.3) GO TO 3051
Al=2.
Bl=1.5
GO TO 3052
3053 IF(R2.LE.MILE(I,J,3).AND.R2.LE.(MILE(I,J,3)+MILE(I,J,1))) HG2(I,J,ML)=(3.4-A1)*RANF(0)+A1
3054 HG2(I,J,ML)=(A1,3-B1)*RANF(0)+B1
GO TO 3060
3055 IF(R2.GT.MILE(I,J,3).AND.R2.LE.(MILE(I,J,3)+MILE(I,J,2))) HG2(I,J,ML)=(3.4-A1)*RANF(0)+A1
3056 HG2(I,J,ML)=(A1,3-B1)*RANF(0)+B1
GO TO 3060
3057 IF(R2.GT.MILE(I,J,3).AND.R2.LE.(MILE(I,J,3)+MILE(I,J,1))) HG2(I,J,ML)=(3.4-A1)*RANF(0)+A1
3058 HG2(I,J,ML)=(A1,3-B1)*RANF(0)+B1
GO TO 3060
3059 IF(R2.GT.MILE(I,J,3).AND.R2.LE.(MILE(I,J,3)+MILE(I,J,1))) HG2(I,J,ML)=(3.4-A1)*RANF(0)+A1
3060 HG2(I,J,ML)=(A1,3-B1)*RANF(0)+B1
GO TO 3060
3061 IF(I.EQ.1) VCON(I)=VCR1(I,2,1)
IF(I.EQ.2) VCON(I)=VCR2(I,2,1)
R4=R4*100.
IF(VCON(I).LE.VCON(2).AND.VCON(2).LE.VCON(3)) GO TO 3062
IF(VCON(2).LE.VCON(1).AND.VCON(1).LE.VCON(3)) GO TO 3063
IF(VCON(3).LE.VCON(1).AND.VCON(1).LE.VCON(2)) GO TO 3064
IF(VCON(3).LE.VCON(1).AND.VCON(1).LE.VCON(2)) GO TO 3065
3062 IF(R4.LT.VCON(2)) GO TO 3066
IF(R4.LT.VCON(3)+VCON(2)) GO TO 3067
GO TO 3068
3063 IF(R4.LT.VCON(3)) GO TO 3066
IF(R4.LT.VCON(3)+VCON(1)) GO TO 3068
GO TO 3067
3064 IF(R4.LT.VCON(1)) GO TO 3068
IF(R4.LT.VCON(3)+VCON(1)) GO TO 3066
GO TO 3067
3065 IF(R4.LT.VCON(1)) GO TO 3068
IF(R4.LT.VCON(3)+VCON(1)) GO TO 3066
GO TO 3067
3066 HG4(I,J,ML)=12.
GO TO 3070
3067 HG4(I,J,ML)=10.+RANF(0)
GO TO 3070
3068 HG4(I,J,ML)=9.+RANF(0)
GO TO 3070
C
C **** ASSIGNMENT OF PAVEMENT TYPES
C
3070 GO TO 3080
C
C **** OPTIONAL OUTPUT STATEMENTS
C
3081 DO 3032 ML=1,ML(I,J)
HGWT(I,J,ML)=HTOT+HGWY(I,J,ML)
Hgc(I,J)=HTO(I,J)+HGWY(I,J,ML)
HTOT=HTO+HGWY(I,J,ML)
GO TO 3032
GO TO 3082
IF(J.EQ.6) GO TO 6000
WRITE(6,1000) HGWY(I,J,ML),HG2(I,J,ML),HG3(I,J,ML),HG4(I,J,ML)
1000 FORMAT(I*X,F6.3,5X,F4.2,5X,F4.3,5X,F4.1,5X,F2.0)
GO TO 3082
6000 WRITE(6,1001) HGWY(I,J,ML),HG2(I,J,ML)
1001 FORMAT(I*X,F6.3,5X,F4.2,5X,F4.2,F5)
3082 CONTINUE
GO TO 3000
3080 CONT=CONT+HGUY(I,J,ML)
CONT1=MAX(I,J)/WLON(I,J)
3085 IF( CONT.EQ.6) GO TO 5000
3086 IF(CONT.GE.CONT1) GO TO 3333
3087 GO TO 4000
5000 IF(CONT.GE.CONT1) GO TO 3333
3088 CONT=CONT+HGUY(I,J,ML)
3089 CONT1=MAX(I,J)/WLON(I,J)
5001 IF( CONT.EQ.6) GO TO 5010
5002 CONT=CONT+HGUY(I,J,ML)
5003 CONT1=MAX(I,J)/WLON(I,J)
5004 IF( CONT.GE.CONT1) GO TO 3333
5005 CONT=CONT+HGUY(I,J,ML)
5006 CONT1=MAX(I,J)/WLON(I,J)
5007 IF( CONT.GE.CONT1) GO TO 3333
5008 CONT=CONT+HGUY(I,J,ML)
5009 CONT1=MAX(I,J)/WLON(I,J)
5010 IF( CONT.EQ.6) GO TO 5017
5011 IF( LGON(I,J,EQ.2) CHANG=FLOAT(ML)/(MAX(I,J)/(2.*UMM(I,J)))
5012 GO TO 3081
3000 CONTINUE
RETURN
END

SUBROUTINE PAUAGE
****
THIS SUBROUTINE AGES PAVEMENTS AND PERFORMES CAPITAL
IMPROVEMENTS ON SELECT ROADWAY SECTIONS IF FUNDING
LEVELS PERMIT.

DIMENSION SU(2,3,4),CON(2,3,5),EQUI(2,3),VUL1(3,2,6),HG6(3,6,105),
ASD(3,2,6),TYPE(2,3),HGS(3,6,105),HGWY(3,6,105),HLON1(3,6,105),
BML1(3,6),H(3),EQUI(2,3,6),ED1(3,3,6),ED2(3,3,6),LANE(3,6,105),
EQUI(2,3),EQT1(3,3,6),EQT2(3,3,6),LANE(3,6,105),
CPCON(5),PUAR(5),FUNDS(3,5,105),COST1(3,5,105),
CONST(3,5,8),EPERC(3,5,4),PERCl(3,5,2),EQT(3,5,105),
SAX1(3,6),GAX(15),TFUND1C15),ADMIN(15),AID(15),
HSTRUC(3),LRmEl(l5),GRATE1(16),ITREU(l5),PEAK(3,5,105),
RINC(15),SINC(15),TOMGC15),BI(15),MIN(15),GPI(15),
JMP15,ITGAS.IRECO,IRESU,IREMO,RU1,RU2,UVOL,GRATE1,GRATE2,ITREUH,
2,HGS,HG2,ML1,HG3,HG4,KCOW,KSSF,KSFLAG,KBARR,AID,WSIN,
IF(KSFLAG.EQ.2) GO TO 4017

**** READING OF DATA

**** SYSTEM MILEAGES

DATA(SAX1(1,K),K=1,6)827.,1048.,3032.,8724.,11332.,488859./
DATA(SAX1(2,K),K=1,6)210.,67.,781.,1526.,1193.,6415./
DATA(SAX1(3,K),K=1,6)27.,52.,512.,733.,614.,3460./

**** SINGLE UNITS AND COMBINATION AVG. WEIGHTS AND AXLE PCTS.

DATA((SUX(I,J),J=1,4),I=1,3,K=1,2)/5.5,2.,42.58,10.5,
B34.,14.,28.,72./
DATA(((COM(K,I,J),J=1,5),I=1,3),K=1,2)/22..7..31..37..32,
A25..B..25..25..5..30..4..26..4..34..30..5..27..4..33..39.,
B12..18..34..48..60..14..15..42..43/
C **** PCT. OF TRUCKS ON EACH HIGHWAY SYSTEM
DATA((UUL1(I,J,K),K=1,6),J=1,2),I=1,3)/147..203..203..235,
A.235..021..153..037..077..045..045..009..11..14..16..23..23,
B.17..05..05..04..02..02..04..11..14..16..23..23..17..09..06,
C.04..02..02..02..02..02..02..005..03..04..04..06..06..05..06,
D.02..01..005..005..01..03..03..04..06..06..05..02..02..02,
C.005..005..01/
C **** PCT OF TRUCK TYPES
DATA((TYPE(J,K),K=1,3),J=1,2)/77..13..04..80..15..05/
C **** RELATIVE INCREASE IN HIGHWAY SYSTEM'S VMT
DATA(RELP(I,J),J=1,6),I=1,3)/81..81..72..64..64..64..1.32..2.16,
A1..12..12..12..12..12..12..12..12..12..12..12..12..12..12,
DATA(SAX(I,J),J=1,5),I=1,3)/11330..4972..1311..8829..2572.,
A7718..946..11162..9500..2794..608..173..4284..3291..959/
DATA((PMIL(I,J),J=1,5),I=1,3)/.003..0037..0015..0002..0005,
A.005..033..008..005..003..013..020..012..009..0044/
DO 749 I=1,3
DO 749 J=1,5
DRAPER(I,J)=SAX(I,J)
ERAPER(I,J)=SAX(I,J)
FRAPER(I,J)=SAX(I,J)*UUL1(I,2,J)
DO 749 K=1,ML1(I,J)
RELIN(I,J,K)=GAUSS(0.0,0.015)
749 CONTINUE
READ(5,502)((EFORTC(I,J),J=1,5),I=1,3)
502 FORMAT(15(IX,F4.3))
4017 AAM=242780.
C **** DETERMINATION OF TRAVEL TYPE
C
DO 500 I=1,3
DO 500 J=1,5
500 HUNT(I,J)=0.
MFLAG=1
MKN=0
KCAR=1
DO 850 I=1,3
DO 850 J=1,5
850 IFAM(I,J)=0.
DO 2912 NYEA=1,NYEAR+1
IF(NYEA.GE.2) KCAR=2
MKN=MKN+1
MFLAG=1
MRANK=1
MFLAG=1
IF(MFLAG.EQ.2) GO TO 6754
MTOTAL=MTOTAL+ML1(I,J)
MTO=MTO+ML1(I,J)
DO 2046 K=1,2
DO 2046 J=1,3
2046 EQU(I,J,K)=0.
DO 8020 I=1,3
DO 8020 J=1,3
DO 8020 K=1,6
ET01(I,J,K)=0.
8020 ET02(I,J,K)=0.
KOUNT=0
GO TO 8001
8988 DO 6000 I=1,3
DO 6000 J=1,6
MTOTAL=MTOTAL+ML1(I,J)
C **** SAMPLING TECHNIQUE TO DETERMINE AXLE LOADS
C
PCTS=UUL1(I,1,2)
PCTC=UUL1(I,2,2)
HPM 971
HPM 972
HPM 973
HPM 974
HPM 975
HPM 976
HPM 977
HPM 978
HPM 979
HPM 980
HPM 981
HPM 982
HPM 983
HPM 984
HPM 985
HPM 986
HPM 987
HPM 988
HPM 989
HPM 990
HPM 991
HPM 992
HPM 993
HPM 994
HPM 995
HPM 996
HPM 997
HPM 998
HPM 999
HPM 1000
HPM 1001
HPM 1002
HPM 1003
HPM 1004
HPM 1005
HPM 1006
HPM 1007
HPM 1008
HPM 1009
HPM 1010
HPM 1011
HPM 1012
HPM 1013
HPM 1014
HPM 1015
HPM 1016
HPM 1017
HPM 1018
HPM 1019
HPM 1020
HPM 1021
HPM 1022
HPM 1023
HPM 1024
HPM 1025
HPM 1026
HPM 1027
HPM 1028
HPM 1029
HPM 1030
HPM 1031
HPM 1032
HPM 1033
HPM 1034
HPM 1035
HPM 1036
HPM 1037
HPM 1038
HPM 1039
HPM 1040
PCCA=1-(PCTS+PCT)

DO 87 K=1,2
EQUIV(K,1,J)=PCTS*EQUI(K,1)+PCT*EQUI(K,2)+PCCA*EQUI(K,3)
IF(K.EQ.2) GO TO 86
EQT1(1,I,J)=PCTC*EQUI(K,1)
EQT1(2,I,J)=PCTS*EQUI(K,2)
EQT1(3,I,J)=PCCA*EQUI(K,3)
GO TO 87
86 EOT2(1,I,J)=PCTC*EQUI(K,1)
EOT2(2,I,J)=PCTS*EQUI(K,2)
EOT2(3,I,J)=PCCA*EQUI(K,3)
GO TO 87
87 CONTINUE

6000 CONTINUE
GO TO 6754

8001 WCARS=.8
WCARM=3.3
ICFLAG=1
IFLAG=1
X8=RANF(0)
X9=RANF(0)
KOUNT=KOUNT+1
K1=1
IF(KOUNT.LE.1000.) GO TO 6006
IF(KOUNT.LE.2000.) GO TO 6007
IF(KOUNT.LE.3000.) GO TO 6008
GO TO 8988

6006 IFFLAG=1
IF(X9.LT.0.698) K1=2
IF(X8.LE.TYPEC2.3)) GO TO 6010
IF(X8.LE.(TYPEC2.3)+TYPEC2.2)) GO TO 6011
GO TO 6012

6007 IFFLAG=2
IF(X9.LT.0.506) K1=2
IF(X8.LE.(TYPEC1.3)) GO TO 6013
IF(X8.LE.(TYPEC1.3)+TYPEC1.2)) GO TO 6014
GO TO 6015

C **** COMBINATION WEIGHTS

6010 WATE=GAUSS(COM(K1,1,2),COM(K1,1,1))
IF(WATE.LT.2.5) GO TO 6010
DO 10 I2=1,3
10 W(I2)=WATE*COM(K1,1,I2+2)
GO TO 7000

6011 WATE=GAUSS(COM(K1,2,2),COM(K1,2,1))
IF(WATE.LT.2.5) GO TO 6011
DO 11 I2=1,3
11 W(I2)=WATE*COM(K1,2,I2+2)
IFLAG=2
GO TO 7000

6012 WATE=GAUSS(COM(K1,3,2),COM(K1,3,1))
IF(WATE.LT.2.5) GO TO 6012
DO 12 I2=1,3
12 W(I2)=WATE*COM(K1,3,I2+2)
IFLAG=3
GO TO 7000

C **** SINGLE UNIT TRUCK WEIGHT ESTIMATES

6013 WATE=GAUSS(SU(K1,3,2),SU(K1,3,1))
IF(WATE.LT.2.5) GO TO 6013
W(1)=WATE*SU(K1,3,3)
W(2)=WATE*SU(K1,3,4)
IFLAG=4
GO TO 7000

6014 WATE=GAUSS(SU(K1,2,2),SU(K1,2,1))
IF(WATE.LT.2.0) GO TO 6014
W(1)=WATE*SU(K1,2,3)
W(2)=WATE*SU(K1,2,4)
GO TO 7000
6015 
WATE=GAUSS(SU(K1,1,2),SU(K1,1,1))
   IF(WATE.LT.1.7) GO TO 6015
   W(1)=WATE*SU(K1,1,3)
   W(2)=WATE*SU(K1,1,4)
   GO TO 7000
C
C **** AUTO WEIGHT ESTIMATES
C
6008 IFLAG=3
   WATE=GAUSS(WCARS,WCARM)
   IF(WATE.LT.1.2) GO TO 6008
   W(1)=.6*WATE
   W(2)=.4*WATE
GO TO 7000
C
C **** CALCULATION OF 18K AXLE LOADS
C
7000 I7=2
   IF(IFYLAG.EQ.1) I7=3
9754 DO 7011 I2=1,17
   IF(IFYLAG.EQ.1) GO TO 7020
   IF(I2.EQ.2) GO TO 7012
   IF(I2.EQ.3) GO TO 7016
7020 IF(I2.EQ.2) GO TO 7021
   IF(I2.EQ.3) GO TO 7022
7013 EQI=0.0000062125*(W(I2))**4.16
   GO TO 7015
7012 GO TO(7013,7013,7014,7014) IFLAG
7016 GO TO(7013,7013,7014,7014) IFLAG
7021 GO TO(7013,7013,7017,7017) IFLAG
7022 GO TO(7013,7017,7017) IFLAG
7014 EQI=0.0000047110*(W(I2))**4.155
   GO TO 7015
7017 EQI=0.0000090701*(W(I2))**4.15
7015 EQUI(ICYFLAG,IFYLAG)=EQUI(ICYFLAG,IFYLAG)+EQI
7011 CONTINUE
   IF(IFYLAG.EQ.2) GO TO 8001
   ICFLAG=2
   GO TO 9754
C
C **** CALCULATION OF PAVEMENT DETERIORATION
C
6754 HK2=0.
   DO 250 I=1,3
   HK(I,J)=0.
   DO 290 J=1,5
   HK(I,J)=0.
   CHANG1=RELP(I,J)*GRATE1(NYEA)
   IF(GRATE1(NYEA).LT.0.) CHANG1=(1./RELP(I,J))*GRATE1(NYEA)
   CHANG2=RELP(I,J)*GRATE2(NYEA)
   IF(GRATE2(NYEA).LT.0.) CHANG2=(1./RELP(I,J))*GRATE2(NYEA)
   CHANG2=((DRAPER(I,J)*1.+CHANG2)/(ERAPER(I,J)*1.+PMIL(I,J)))-1
   A(DRAPER(I,J)/ERAPER(I,J))/(ERAPER(I,J)/ERAPER(I,J))
   DRAPER(I,J)=DRAPER(I,J)+(1.+CHANG2)
   ERAPER(I,J)=ERAPER(I,J)+(1.+PMIL(I,J))
   FRAPER(I,J)=FRAPER(I,J)+(1.+CHANG1)
   IF(NYEA.EQ.1) GO TO 748
748 ICAN=2
   IF(I.EQ.1) ICAN=1
   EQUI(ICYCAN,I,J)=EQUI(ICYCAN,I,J)+(1.+CHANG1)/(1.+CHANG2)
   DO 290 K=1,ML1(I,J)
   IF(IFYLAG.EQ.2) GO TO 9117
   EAT(I,J,K)=0.
   IF(I.EQ.1.AND.J.EQ.1) SAR=.183
   IF(I.EQ.1.AND.J.EQ.1) SAR=.183
   IF(I.EQ.1.AND.J.EQ.1) SAR=.183
   IF(I.EQ.1.AND.J.EQ.1) SAR=.183
   IF(I.EQ.1.AND.J.EQ.1) SAR=.183
   MMFLAG=1
379 IF(I.EQ.1) CAP=2.0
   IF(I.EQ.2) CAP=1.6
IF(J.EQ.3) CAP=1.4
IF(J.GT.3) CAP=1.
IF(MNFLAG.GE.2) GO TO 1492
VAR11=((-HGWY(I,J,K)*50)*CAP)+.8
LANE(I,J,K)=IF(VAR11
IF(LANE(I,J,K).LT.1) LANE(I,J,K)=1
IF(LANE(I,J,K).GT.5) LANE(I,J,K)=5
IF(LANE(I,J,K).GE.2) GO TO 4793
IF(J.EQ.1) LANE(I,J,K)=2
IF(J.EQ.2.AND.J.EQ.2) LANE(I,J,K)=2
4793 PEAK(I,J,K)=HG5(I,J,K)+FLOAT(LANE(I,J,K)+CAP)/HGWY
AC(I,J,K)
4792 ICAN=2
IF(J.EQ.1) ICAN=1
IF(J.EQ.1) GO TO 3820
VAR1=(UUL1(I,J)*HGWY(I,J,K)+.25*UUL1(I,J)*HGWY(I,J,K))*1000.
IF(VAR1.GE.100.) HG5(I,J,K)=4.15
IF(VAR1.GE.200.) HG5(I,J,K)=4.4
IF(VAR1.GE.300.) HG5(I,J,K)=4.9
IF(VAR1.GE.500.) HG5(I,J,K)=5.2
IF(VAR1.GE.750.) HG5(I,J,K)=5.5
IF(VAR1.GE.1000.) HG5(I,J,K)=6.
IF(LANIE(I,J,K).AND.VAR1.GE.75.) HG5(I,J,K)=3.95
HG5(I,J,K)=4.9
IF(LANIE(I,J,K).AND.VAR1.GE.50.) HG5(I,J,K)=3.7
IF(LANIE(I,J,K).AND.VAR1.GE.35.) HG5(I,J,K)=2.7
GO TO 3830
IF(MRANK.EQ.2) GO TO 90
3830 IF(VAR1.25) HG5(I,J,K)=3.1
IF(VAR1.GT.25) HG5(I,J,K)=3.45
IF(VAR1.GT.35) HG5(I,J,K)=3.6
IF(VAR1.GT.5) HG5(I,J,K)=2.7
GO TO 3840
IF(VAR1.GT.25) HG5(I,J,K)=3.1
IF(VAR1.GT.25) HG5(I,J,K)=3.45
IF(VAR1.GT.35) HG5(I,J,K)=3.6
IF(VAR1.GT.5) HG5(I,J,K)=2.7
GO TO 3840
3830 IF(VAR1.25) HG5(I,J,K)=3.1
IF(VAR1.GT.25) HG5(I,J,K)=3.45
IF(VAR1.GT.35) HG5(I,J,K)=3.6
IF(VAR1.GT.5) HG5(I,J,K)=2.7
GO TO 3840
3840 IF(VAR1.25) HG5(I,J,K)=3.1
IF(VAR1.GT.25) HG5(I,J,K)=3.45
IF(VAR1.GT.35) HG5(I,J,K)=3.6
IF(VAR1.GT.5) HG5(I,J,K)=2.7
GO TO 3840
9117 ICAN=2
IF(HG5(I,J,K).GT.8.) ICAN=1
REGAL=RELIN(I,J,K)
HGWY(I,J,K)=HGWY(I,J,K)*1.+CHANG2+REGAL
HK(I,J)=HK(I,J)+HGWY(I,J,K)
HK1(I)=HK1(I)+HGWY(I,J,K)
HK2=HK2+HGWY(I,J,K)
EQT9=EDUU(I,ICAI,J)*HGWY(I,J,K)*365.
IF(LANE(I,J,K).LT.2) YRY=2.
IF(LANE(I,J,K).GE.2) YRY=2.5
EQT1(I,J,K)=EQT9/YRY/EQT(I,J,K)
IF(J.EQ.1) GO TO 8111
IF(J.EQ.1) GO TO 8111
BETA=4.**(0.819**3.2)/(HG5(I,J,K)**519)
RDN=10.**5.93*(HG5(I,J,K)**9.36/19**4.79)
8112 AF1=1.5
IF(J.LE.3) AF1=2.0
IF(J.EQ.1.AND.J.EQ.3) AF1=1.8
IF(KCAR.EQ.2) GO TO 1301
HLN=4.6
IF(J.EQ.1) HLN=4.8
IF(J.GT.3) HLN=4.2
EQT(I,J,K)=(EXP(ALOG(ROW)+ALOG((HLM-HG2(I,J,K))/(HLM-AF1))/BETA
A))**EQT(I,J,K)
HG2(I,J,K)=HLN
1301 HG5(I,J,K)=HG2(I,J,K)+HG2(I,J,K)-AF1*(EQT(I,J,K)+ROW)**BETA
1302 HG5(I,J,K)=HG2(I,J,K)-AF1*(EQT(I,J,K)+ROW)**BETA
GO TO 290
8111 BETA=1.**3.63*(19**5.2)/(HG5(I,J,K)**8.46)
RDN=10.**5.85*(HG5(I,J,K)**7.35/19**4.62)
GO TO 8112
C
C **** OPTIONAL OUTPUT STATEMENTS
C
5999 IF(K.EQ.1) PRINT 1,I,J,ML(I,J)
ASX.F7.0,5X.F5.2)
290 CONTINUE
   IF(MFLAG.EQ.2) GO TO 1956
   IF(KSFLAG.EQ.2) GO TO 1956
C
C **** READING OF INITIAL DATA
C
   DO 8016 N=1,16
   DO 8016 I=1,3
   DO 8016 J=1,5
   TM(N,1,1)=0.
   IF(I.EQ.3) TM2(N,J)=0.
   IF(N.EQ.16) GO TO 8016
   RE(N,I,J)=0.
8016 CONTINUE
   DO 8015 N=1,3
   DO 8015 I=1,5
   DO 8015 J=1,3
   DO 8017 K=1,360
8017 KEEL(J,K)=0
C
C **** 1959 COST FOR IMPROVEMENTS
C
   DATA((CONRT(1,J,K),K=1,8),J=1,5) /363.,1722.,126.,631.,326.,173.,
   C145.,35.,185.,89.,40.,18.,16./
   DATA((CONRT(2,J,K),K=1,8),J=1,5) /6244.,3929.,5311.,2021.,1233.,
   AG58.,223.,6796.,5385.,3864.,758.,2826.,1305.,574.,207.,3721.,
   B2367.,1452.,414.,1481.,740.,225.,139.,1355.,1095.,942.,231.,
   DATA((CONRT(3,J,K),K=1,8),J=1,5) /0.,0.,0.,764.,800.,273.,155.,
   C582.,472.,121.,506.,306.,107.,49.,296./
C
C **** PROBABILITY OF REPAIR TYPE
C
   DATA(((PERC(I,J,K),K=1,4),J=1,5),I=1,3) /9.,2.,5.,84.,50.,12.,20.,
   C0.,11.,89.,42.,7.,8.,43.,37.,5.,8.,50.,53.,6.,7.,34.,45.,3.,7.,
   D41./
   DATA(((PERC(I,J,K),K=1,2),J=1,5),I=1,3) /0.,100.,77.,23.,74.,26.,
   A85.,15.,97.,3.,0.,100.,85.,15.,28.,72.,40.,60.,37.,63.,0.,100.,86.,
   B14.,40.,60.,44.,36.,37.,63./
C
C
   DATA(((CONI(I,J,K),K=1,4),J=1,3),I=1,2) /30.,40.,20.,10.,40.,30.,
   B30.,10./
C
C
C **** DETERMINATION OF INITIAL INDEXES
C
1956 DO 1955 I=1,3
1956 DO 1955 J=1,5
1955 DO 1955 K=1,8
   IF(MFLAG.EQ.1) CONST(I,J,K)=1.57*CONRT(I,J,K)
   IF(MFLAG.NE.1) CONST(I,J,K)=CONST(I,J,K)*(1.+WSIN(NYEA)/100.)
1955 CONTINUE
MFLAG=1
TFUND=FLOAT(ITREV(NYEA))
DO 370 I=1,3
   IF(J.LE.2) I2=1
   IF(J.EQ.3) I2=2
   IF(J.GT.3) I2=3
370 IF(I.EQ.1) GO TO 1200
I=1
   IF(J.LE.2) I2=1
   IF(J.EQ.3) I2=2
   IF(J.GT.3) I2=3
HPM 1251
HPM 1252
HPM 1253
HPM 1254
HPM 1255
HPM 1256
HPM 1257
HPM 1258
HPM 1259
HPM 1260
HPM 1261
HPM 1262
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HPM 1299
HPM 1300
HPM 1301
HPM 1302
HPM 1303
HPM 1304
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HPM 1306
HPM 1307
HPM 1308
HPM 1309
HPM 1310
HPM 1311
HPM 1312
HPM 1313
HPM 1314
HPM 1315
HPM 1316
HPM 1317
HPM 1318
HPM 1319
HPM 1320
GO TO 1201
1200 I1=1
   IF(J.LE.3) I2=1
   IF(J.EQ.4) I2=2
   IF(J.EQ.5) I2=3
1201 IF(MC1FAG. EQ.0.2) GO TO 9001
   IF(MFLAG. EQ.0.2) GO TO 973
DO 2000 K=1,ML1(I,J)
973 MFLAG=2
   GO TO 379
1492 I22F=1
   IF(GC4(I,J,K).EQ.12.) GO TO 1493
   I22F=2
   IF(LANE(I,J,K).EQ.1) PTY=1.-24*(12.-HG4(I,J,K))/3.)
   IF(LANE(I,J,K).NE.1) PTY=1.-18*(12.-HG4(I,J,K))/3.)
1493 DELCIC=(HG4(I,J,K)*PEAK(I,J,K))/((FLOAT(LANE(I,J,K))+1)*CAP)
   IF(DELCIC.GT.1.) DELCIC=1.
   PLIE=3.6
   IF(J.EQ.1) PLIE=3.8
   IF(J.GT.3) PLIE=3.2
   CON(I,I2)=1.0-DELCIC.*CON(I,I2,2)/6)
   IF(LPINTER(I,J,K)=0.9) CON(I,I2,2)=CON(I,I2,3)
   IF(PCON(1).LT.0.) PCON(1)=0.
   HELP=HG3(I,J,K)
   PCON(2)=(1.-HG3(I,J,K))*CON(I,I2,2)/6)
   IF(HG3(I,J,K).LT.0.4) PCON(2)=CON(I,I2,2)
   PCON(3)=(HG4(I,J,K)-9.)*CON(I,I2,3)/3.
   PARA=HG5(I,J,K)
   IF(PARA.EQ.11.) PARA=7.
   PCON(5)=(PARA-2.6)*CON(I,I2,4)/4.4
   PCON(4)=PCON(2)
   IF(LANE(I,J,K).EQ.5) PCON(2)=CON(I,I2,2)
   IF(MFLAG. EQ.0.2) GO TO 371
   SMCI(I,J,K)=PCON(1)+PCON(2)+PCON(3)+PCON(5)
   SMCC(I,J,K)=SMCI(I,J,K)+PCON(1)+PCON(3)+PCON(4)+PCON(5)*HG4
   I(I,J,K)
   IF(NYEA.EQ.(NYEAR+1)) GO TO 2000

C **** DETERMINATION OF IMPROVEMENT TYPE
C
X70=RANF(0)*100.
   IF(PERC(I,J,4).GT.PERC(I,J,1).AND.PERC(I,J,1).GE.PERC(I,J,3))
    AGO TO 2010
   IF(PERC(I,J,1).GT.PERC(I,J,3).AND.PERC(I,J,3).GT.PERC(I,J,4))
    AGO TO 2011
   IF(PERC(I,J,1).GT.PERC(I,J,4).AND.PERC(I,J,4).GT.PERC(I,J,3))
    AGO TO 2012
   IF(PERC(I,J,4).GT.PERC(I,J,1)) GO TO 2013
    GO TO 2014

C
2010 IF(X70.LE.PERC(I,J,2)) GO TO 2020
   IF(X70.LE.(PERC(I,J,2)+PERC(I,J,3))) GO TO 2021
   IF(X70.LE.(PERC(I,J,2)+PERC(I,J,3)+PERC(I,J,1))) GO TO 2022
   GO TO 2023
2011 IF(X70.LE.PERC(I,J,2)) GO TO 2020
   IF(X70.LE.(PERC(I,J,2)+PERC(I,J,4))) GO TO 2023
   IF(X70.LE.(PERC(I,J,2)+PERC(I,J,4)+ PERC(I,J,3))) GO TO 2021
   GO TO 2020
2012 IF(X70.LE.PERC(I,J,3)) GO TO 2021
   IF(X70.LE.(PERC(I,J,3)+PERC(I,J,2))) GO TO 2020
   IF(X70.LE.(PERC(I,J,3)+PERC(I,J,2)+PERC(I,J,4))) GO TO 2023
   GO TO 2022
2013 IF(X70.LE.PERC(I,J,3)) GO TO 2021
   GO TO 2023
2014 IF(X70.LE.PERC(I,J,2)) GO TO 2020
   IF(X70.LE.(PERC(I,J,2)+PERC(I,J,3))) GO TO 2021
   IF(X70.LE.(PERC(I,J,2)+PERC(I,J,3)+PERC(I,J,4))) GO TO 2023
GO TO 2022
2020 COST(I,J,K)=CONST(I,J,3)
GO TO 2030
2021 COST(I,J,K)=CONST(I,J,6)
GO TO 2030
2022 COST(I,J,K)=CONST(I,J,2)
GO TO 2030
2023 COST(I,J,K)=CONST(I,J,7)
C **** DETERMINATION OF WIDENING COSTS
2030 X71=RNDF(0)*100.
IF(PERC(I,J,2).GE.PERC(I,J,1)) GO TO 2031
GO TO 2032
2031 IF(X71.LE.PERC(I,J,1)) COST2(I,J,K)=CONST(I,J,1)
IF(X71.GT.PERC(I,J,1)) COST2(I,J,K)=CONST(I,J,4)
GO TO 371
2032 IF(X71.LE.PERC(I,J,2)) COST2(I,J,K)=CONST(I,J,4)
IF(X71.GT.PERC(I,J,2)) COST2(I,J,K)=CONST(I,J,1)
C **** DETERMINATION OF COST-EFFECTIVENESS OF IMPROVEMENTS
371 PARK=4.6
IF(J.EQ.1) PARK=4.8
IF(J.GT.3) PARK=4.2
REV=(PARK-1.)*(CONI(I1,I2,1)/PLIE)
IF(I2F.EQ.2) DART=(1.-HG3(I,J,K)*PTY1)*(CONI(I1,I2,2)/6)
IF(I2F.EQ.2.AND.(HG3(I,J,K)*PTY1).LT.0.4) DART=CONI(I1,I2,2)
PVAR(I1)=((REU-PCON(1))*HGWY(I,J,K)*RELPI(I,J))/COST1(I,J,K)
AC(I,J,K)
PVAR(2)=((CONI(I1,I2,5)-PCON(2)+REU-PCON(1)+CONI(I1,I2,3)
A)-PCON(3))*HGWY(I,J,K)*RELPI(I,J))/COST2(1,J,K)
PVAR(3)=((CONI(I1,I2,3)-PCON(3)+REU-PCON(1))*HGWY(I,J,K)*RELPI
AC(I,J,K))
IF(I2F.EQ.2) PVAR(3)=((CONI(I1,I2,3)-PCON(3)+REU-PCON(1)-PCON
A(2)+DART)*HGWY(I,J,K)*RELPI(I,J))/CONST(I,J,5)
PVAR(4)=PVAR(2)
IF(LANE(I,J,K).EQ.5) PVAR(2)=0.
IF(MFLAG.EQ.2) GO TO 372
DELC(I,J,K)=PVAR(1)+PVAR(2)+PVAR(3)
2000 CONTINUE
IF(NYEA.EQ.(NYEAR+1)) GO TO 710
C **** DETERMINATION OF MAINTAINANCE
AAM=AAM*(1.+WSIN(NYEA)/400.)
TFUND2=((TFUND-AAM).*67)/1.03
FUND(NYEA)=AAM
TFUND1(NYEA)=.33*(TFUND-AAM)
ADMIN(NYEA)=TFUND2*1.03
GO TO 2950
7281 MFLAG=2
DO 90 I=1,3
DO 90 J=1,5
K1=0
TCOST=0.
FUNDS(I,J)=EFORT(I,J)*TFUND2+HUNT(I,J)
IFAM(I,J)=IFAM(I,J)+IFIX(FUNDS(I,J)-HUNT(I,J))
IKON=0
JFLAG=1
DO 1254 K=1,ML1(I,J)
PMIN=1.2
IF(J.LE.3) PMIN=1.5
IF(I,EQ.1.AND.J.EQ.3.AND.HG1H(I,J,K).LT.6.) PMIN=1.3
IF(HG5(I,J,K).LT.PMIN) GO TO 1254
ICAN=2
IF(HG5(I,J,K).LT.9.) ICAN=1
IF(I.EQ.1) GO TO 6100
BETA=.4*(0.01*19.*3.23)/((HG5(I,J,K))*5.19)
ROW=10.**5.93*(HG5(I,J,K))**9.36/19.**4.79
1254 CONTINUE
C ***** REVISION OF INDEXES AFTER MAINTENANCE

380 IF(IR1.EQ.2) GO TO 383
1816 IF(IR1.NE.2) DELCI(I,J,K)=DELCI(I,J,K)-PUAR(IR1)
     IF(IR1.EQ.2) DELCI(I,J,K)=DELCI(I,J,K)-PUAR(I)-PUAR(3)
     IF(IR1.EQ.1) SMCI(I,J,K)=SMCI(I,J,K)-PCON(I)+REV
     IF(IR1.EQ.3) SMCI(I,J,K)=SMCI(I,J,K)-PCON(3)+CON(I1,I2,J)
     A3)+REV
     IF(IR1.EQ.3.AND.IIZF.EQ.2) SMCI(I,J,K)=SMCI(I,J,K)-PCON(2)+DART
     IF(IR1.EQ.2) SMCI(I,J,K)=SMCI(I,J,K)-PCON(1)+REV-
     APCON(3)+CON(I1,I2,J)-PCON(2)+CON(I1,I2,J)
     GO TO 1819
383 LANE(I,J,K)=LANE(I,J,K)+1
     D1=(HGUY(I,J,K)*PEAK(I,J,K))/((LANE(I,J,K)+1)*CAP)
     IF(D1.GT.1.) D1=1.
     D2=(1.-D1)*CON(11,12,2)/6.
     IF(D1.LT.0.) D2=CON(11,12,2)
     DELCI(I,J,K)=DELCI(I,J,K)-((D2-CON(I1,12,5))*HGUY(I,
     AJ,J,K)*RELP(I,J))/COST2(I1,J,K)
     GO TO 1819
1819 MRANK=2
     GO TO 4792
190 PARA=HG5(I,J,K)
     IF(PARA.EQ.11.) PARA=7.
     SMCI(I,J,K)=SMCI(I,J,K)-CON(5)+((PARA-2.6)*CON(I1,12,4)/4.4)
     EQT(I,J,K)=0.
     IF(I2F.EQ.2) HG3(I,J,K)=PTY1*HG3(I,J,K)
     IF(I2F.EQ.2) PEAK(I,J,K)=PTY1*PEAK(I,J,K)
     IF(IR1.EQ.2) HG3(I,J,K)=DELCIC
     IF(IR1.EQ.2) HG4(I,J,K)=12.
     HG5(I,J,K)=4.6
     IF(I.EQ.1) HG6(I,J,K)=4.8
     IF(I.GT.3) HG6(I,J,K)=4.2
     DELC(I,J,K)=0.
     SMCON9(I,J)=0.
     DO 2002 MC=1,ML1(I,J)
     SMCON9(I,J)=SMCON9(I,J)+SMCI(I,J,MKE)
     2002 DELC(I,J)=DELC(I,J)+DELCI(I,J,MKE)
     GO TO 352
381 HUNT(I,J)=FUNDS(I,J)-(TCOST-COSTA)
     DO 9973 K=1,ML1(I,J)
     IF(J.EQ.3) RINTO=2.6
     IF(I.EQ.1.AND.J.EQ.3.AND.HGWY(I,J,K).LT.6.) RINTO=2.1
     IF(J.GT.3) RINTO=2.1
     IF(HG6(I,J,K).LE.RINTO) K11=K11+1
     9973 CONTINUE
     RPAD(NYEA=I,J)=FLOAT(K11)/FLOAT(ML1(I,J))+RPAD(NYEA=I,J)
     90 CONTINUE
     IF(MK,N.EQ.0) GO TO 70
     NOY=1974+NYEA+1
     M=1
1985 IF(N0Y.EQ.1980) KFK=1
     IF(N0Y.EQ.1983) KFK=2
     IF(N0Y.EQ.1986) KFK=3
     DO 1984 I=1,3
     DO 1984 J=1,5
     IA1(N,I,J)=0
     IA2(N,I,J)=0
     IA3(N,I,J)=0
     IB1(N,I,J)=0
     IB2(N,I,J)=0
     IB3(N,I,J)=0
     IC1(N,I,J)=0
     IC2(N,I,J)=0
     IC3(N,I,J)=0
     ID1(N,I,J)=0
     ID2(N,I,J)=0
     ID3(N,I,J)=0
     DO 1984 K=1,ML1(I,J)
N1=1
IF(N.EQ.2) N1=IFIX(HGUY(I,J,K)+1000.)

C **** PERC. OF PAVEMENT TYPES
C IF(HG5(I,J,K).LT.3.65) IA1(I,J,K)=IA1(I,J,K)+N1
A=N1
IF(HG5(I,J,K).GT.4.0) IA3(I,J,K)=IA3(I,J,K)+N1

C **** PERC. OF PAVEMENT CONDITIONS
C BGC=.2.
IF(I.EQ.1.AND.J.LE.2) BGC=2.5
IF(I.GT.1.AND.J.LE.3) BGC=2.5
A=N1
IF(HG5(I,J,K).GT.4.0) IB3(I,J,K)=IB3(I,J,K)+N1

C **** U/C RATIOS
C BPG=.8
IF(I.NE.1) BPG=9
IF(HG3(I,J,K).LT.0.31) IC1(I,J,K)=IC1(I,J,K)+N1
IF(HG3(I,J,K).GE.0.31.AND.HG3(I,J,K).LT.BPG) IC2(I,J,K)=IC2(I,J,K)+N1
A=N1
IF(HG3(I,J,K).GE.BPG) IC3(I,J,K)=IC3(I,J,K)+N1

C **** LANE WIDTHS
A=N1
1984 CONTINUE

C **** APPLICATION OF WEIGHTING FACTORS
C DO 1986 I=1,3
DO 1986 J=1,5
IF(N.EQ.2) IFAM(I,J)=IFIX(FLOAT(IFAM(I,J))/5.)
IF(N.EQ.2) KFAM(KFK,I,J)=KFAM(KFK,I,J)/IFAM(I,J)
ARK=FL0AT(ML1(I,J))
IF(N.EQ.2) ARK=HK(I,J)*1000.
IA1(I,J)=IFIX((FLOAT(IA1(I,J))/ARK*100.))+.5
IA2(I,J)=IFIX((FLOAT(IA2(I,J))/ARK*100.))+.5
IA3(I,J)=IFIX((FLOAT(IA3(I,J))/ARK*100.))+.5
IB1(I,J)=IFIX((FLOAT(IB1(I,J))/ARK*100.))+.5
IB2(I,J)=IFIX((FLOAT(IB2(I,J))/ARK*100.))+.5
IB3(I,J)=IFIX((FLOAT(IB3(I,J))/ARK*100.))+.5
IC1(I,J)=IFIX((FLOAT(IC1(I,J))/ARK*100.))+.5
IC2(I,J)=IFIX((FLOAT(IC2(I,J))/ARK*100.))+.5
IC3(I,J)=IFIX((FLOAT(IC3(I,J))/ARK*100.))+.5
IB1(I,J)=IFIX((FLOAT(IB1(I,J))/ARK*100.))+.5
IB2(I,J)=IFIX((FLOAT(IB2(I,J))/ARK*100.))+.5
IB3(I,J)=IFIX((FLOAT(IB3(I,J))/ARK*100.))+.5
1986 CONTINUE
IF(N.EQ.2) GO TO 4056
N=2
GO TO 1985

C **** AVERAGING VARIABLES
C 4056 IK=0
IK=IK+1
4055 DO 4055 N=1,2
DO 4055 I=1,3
DO 4055 J=1,5
IK=IK+1

GO TO(20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31) 137
20 KBEL(KFK, IK) = IA1(N, I, J)+KBEL(KFK, IK)
GO TO 4050
21 KBEL(KFK, IK) = IA2(N, I, J)+KBEL(KFK, IK)
GO TO 4050
22 KBEL(KFK, IK) = IA3(N, I, J)+KBEL(KFK, IK)
GO TO 4050
23 KBEL(KFK, IK) = IB1(N, I, J)+KBEL(KFK, IK)
GO TO 4050
24 KBEL(KFK, IK) = IB2(N, I, J)+KBEL(KFK, IK)
GO TO 4050
25 KBEL(KFK, IK) = IB3(N, I, J)+KBEL(KFK, IK)
GO TO 4050
26 KBEL(KFK, IK) = IC1(N, I, J)+KBEL(KFK, IK)
GO TO 4050
27 KBEL(KFK, IK) = IC2(N, I, J)+KBEL(KFK, IK)
GO TO 4050
28 KBEL(KFK, IK) = IC3(N, I, J)+KBEL(KFK, IK)
GO TO 4050
29 KBEL(KFK, IK) = ID1(N, I, J)+KBEL(KFK, IK)
GO TO 4050
30 KBEL(KFK, IK) = ID2(N, I, J)+KBEL(KFK, IK)
GO TO 4050
31 KBEL(KFK, IK) = ID3(N, I, J)+KBEL(KFK, IK)
GO TO 4050
4050 CONTINUE
I37 = I37 + 1
IF(I37 NE 13) GO TO 4055
IF(KSSF EQ 1) GO TO 1951
IF(KSSF EQ 2) GO TO 1987
GO TO 70
C
C *** HEADING AND OUTPUT STATEMENTS
C
1987 IK = 0
I37 = 1
4065 DO 4060 N = 1, 2
DO 4060 I = 1, 3
DO 4060 J = 1, 5
IK = IK + 1
GO TO(32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43) 137
32 IA1(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
33 IA2(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
34 IA3(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
35 IB1(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
36 IB2(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
37 IB3(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
38 IC1(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
39 IC2(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
40 IC3(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
41 ID1(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
42 ID2(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
43 ID3(N, I, J) = KBEL(KFK, IK) / KC0W
GO TO 4060
4060 CONTINUE
I37 = I37 + 1
IF(I37 NE 13) GO TO 4065
DO 1502 I = 1, 3
DO 1502 J = 1, 5
1502 IFAM(I, J) = KFAM(KFK, I, J) / KC0W
DO 1988 I = 1, 3
GO TO (7,8,9) 1

1989 BPG=.80
IF(I,NE.1) BPG=.90
WRITE(6,101)((IA3(N,I,K),N=1,2),K=1,5),((IA2(N,I,K),N=1,2),K=1,5),AS)

101 FORMAT(7X,'PAVEMENT TYPE: ',/9X,'HIGH',16X,5(I3,7X,13,7X),/9X,')
A,'INTERM',14X,5(I3,7X,13,7X),/9X,'LOW',17X,5(I3,7X,13,7X),/)
WRITE(6,102)((IBI(N,I,K),N=1,2),K=1,5),((IB2(N,I,K),N=1,2),K=1,5)

102 FORMAT(7X,'PAVEMENT CONDITION:1',/9X,'POOR',16X,5(I3,7X,13,7X),)
A,'FAIR',16X,5(I3,7X,13,7X),/9X,'GOOD',16X,5(I3,7X,13,7X),/)
WRITE(6,103)((ICI(N,I,K),N=1,2),K=1,5),BPG((IC2(N,I,K),N=1,2),K=1,5)

103 FORMAT(7X,'VOL/CAP RATIOS:2',/9X,'< .3',15X,5(I3,7X,13,7X),/9X,')
B13,7X),/)
WRITE(6,104)((IDI(N,I,K),N=1,2),K=1,5),((ID2(N,I,K),N=1,2),K=1,5)

104 FORMAT(7X,'LANE WIDTH (FT):',/9X,'< 10',16X,5(I3,7X,13,7X),/9X,')
A,'10 - 11',13X,5(I3,7X,13,7X),/9X,')>',11',16X,5(I3,7X,13,7X),/)
WRITE(6,105)((IFAM(I,K),K=1,5)

105 FORMAT(7X,'ANNUAL AVERAGE',1751,17G7,17G4,17G1,1758
1775,1773,1772,1758
1788,1787,1784,1783,174

1988 CONTINUE
1991 DO 851 I=1,3
DO 851 J=1,5
851 IFAM(I,J)=0
GO TO 7
7 WRITE(6,5000) NOY
5000 FORMAT('1'),1X,24(' ',)I4,2X,'RURAL SUMMARY IN PERCENTS',24(' ',)HM
A,31X,'INTERSTATE',8X,'OTHER PRIN ART',6X,'MINOR ART',8X,'COLLECTOR',6X
C,5X,'TRAVEL',3X,)
GO TO 1988
8 WRITE(6,5001) NOY
5001 FORMAT('1'),1X,24(' ',)I4,2X,'URBAN SUMMARY IN PERCENTS',24(' ',)HM
A,31X,'INTERSTATE',8X,'OTHER FWY & EXPY',6X,'OTHER PRIN ART',8X
B,6X,'MINOR ART',8X,'COLLECTOR',6X,'TRAVEL',6X
C,3X,)
GO TO 1989
9 WRITE(6,5002) NOY
5002 FORMAT('1'),1X,24(' ',)I4,2X,'SMALL URBAN SUMMARY IN PERCENTS',24(' ',)HM
A,31X,'INTERSTATE',8X,'OTHER FWY & EXPY',6X,'OTHER PRIN ART',8X
B,6X,'MINOR ART',8X,'COLLECTOR',6X,'TRAVEL',6X
C3X,)
GO TO 1989
70 MFLAG=2
2912 CONTINUE
700 WRITE(6,1234)
1234 FORMAT(10X,'THRESHOLD REQUIRES REVISION')
C1=SUMC(I,J)/FLOAT(MLI(I,J))
C2=DELCON(I,J)/FLOAT(MLI(I,J))
PRINT,SMCONS
PRINT,DELCON
PRINT,I,J,MLI(I,J)
PRINT,C1,C2
SMCONS(I,J)=D0
DELCON(I,J)=D0
DO 91 K=1-MLI(I,J)
SMCONS(I,J)=SMCONS(I,J)+SMC(I,J,K)
DELCON(I,J)=DELCON(I,J)+DELKI(J,K)
91 PRINT,SMC(I,J,K),DELKI(J,K)
GO TO 1235
C
C **** OUTPUT STATEMENTS
C
HPM 1741
HPM 1742
HPM 1743
HPM 1744
HPM 1745
HPM 1746
HPM 1747
HPM 1748
HPM 1749
HPM 1750
HPM 1751
HPM 1752
HPM 1753
HPM 1754
HPM 1755
HPM 1756
HPM 1757
HPM 1758
HPM 1759
HPM 1760
HPM 1761
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HPM 1794
HPM 1795
HPM 1796
HPM 1797
HPM 1798
HPM 1799
HPM 1800
HPM 1801
HPM 1802
HPM 1803
HPM 1804
HPM 1805
HPM 1806
HPM 1807
HPM 1808
HPM 1809
HPM 1810
2950 IF(NYEA.EQ.5) GO TO 2989
  IF(NYEA.EQ.10) GO TO 2989
  IF(NYEA.EQ.15) GO TO 2989
  GO TO 710
2989 MKN=0
710 DO 720 I=1,3
  DO 720 J=1,5
    SM1(NYEA,J)=SMCON1(I,J)+HK(I,J)
720 CONTINUE
726 TM1(NYEA,J)=SM1(NYEA,J)+TM1(NYEA,J)
730 DO 900 I=1,5
    SM1(NYEA,J)=SM1(NYEA,J)*HK1(I)+SM1(NYEA,J)*HK1(I)
  A(HK1(I))=HK1(I)
  TM1(NYEA,J)=TM1(NYEA,J)+TM2(NYEA,J)
900 CONTINUE
727 IF(KS5F.EQ.2) GO TO 728
  GO TO 1235
728 DO 729 N=2,NYEAR+1
  DO 729 J=1,5
    SM1(N,J)=TM1(N,J)/KCM
  DO 752 I=1,2
    IF(I.EQ.2) GO TO 5
    WRITE(6,1092)
61092 FORMAT('15X,25(* ','RURAL CONDITION INDICES',26('(* '),/)
  ASX,9X,'ARTERIAL',12X,'MINOR',12X,'MAJOR',12X,'MINOR',/)
  BSX,9X,'YEAR',9X,'INTERSTATE',8X,'PRIN ART',10X,'ARTERIAL',8X
  C,'COLLECTOR',8X,'12X,92('- '),/)
  GO TO 9091
5 WRITE(6,1079)
1079 FORMAT('15X,24('(* '),TOTAL URBAN CONDITION INDICES',24('(* ')'),/)
  A00X,92('- '),5X2,92,'OTHER',12X,'MINOR',12X,'MAJOR',12X,'MINOR',/)
  B00X,9X,'INTERSTATE',9X,'EXPWY',9X,'PRIN ART',8X
  C,'ARTERIAL',9X,'COLLECTOR',20X,92('- '),/)
9091 DO 721 NY=1,NYEAR
  NDY=1974+NY+1
  N=NY+1
  WRITE(6,1007) NDY,SM1(N,1),SM1(N,2),SM1(N,3),SM1(N,4),SM1(N,5)
1007 FORMAT(15X,'12X,92('- '),/)
721 CONTINUE
726 WRITE(6,1080)
1080 FORMAT(20X,92('- '))
752 CONTINUE
GO TO 508
C
C ***** OPTIONAL OUTPUT STATEMENTS
C
7 DO 6250 I=1,3
  GO TO(6251,6252,6253) I
6251 WRITE(6,6280)
6260 FORMAT('15X,16('(* '),PERCENT OF RURAL PAVEMENTS WITH PSR BELOW'/',
  ANOIMUM TOLERABLE LEVELS',16('(* '),/)
  BOTH HWY',12X,'MINOR',12X,'MAJOR',12X,'MINOR',/)
  CINTERSTATE',8X,'PRIN ART',10X,'ARTERIAL',8X
  D0X,'COLLECTOR',20X,92('- '),/)
  GO TO 6255
6252 WRITE(6,6281)
6281 FORMAT('15X,16('(* '),PERCENT OF URBAN PAVEMENTS WITH PSR BELOW'/',
  ANOIMUM TOLERABLE LEVELS',16('(* '),/)
  BOTH HWY',11X,'OTHER',12X,'MINOR',/)
  C5X,'& EXPWY',9X,'PRIN ART',8X,'ARTERIAL',9X
  D0X,'COLLECTOR',92('- '),/)
  GO TO 6255
6253 WRITE(6,6282)
6282 FORMAT('15X,16('(* '),PERCENT OF SMALL URBAN PAVEMENTS WITH PSR BELOW'/',
  ANOIMUM TOLERABLE LEVELS',15('(* '),/)
  B5X,'OTHER HWY',11X,'OTHER',12X,'MINOR',/)
  C,9X,'YEAR',9X
  D0X,'COLLECTOR',92('- '),/)
  GO TO 6255
6254 WRITE(6,6283)
DO 'COLLECTOR',/20X,92(''-'),/
6255 DO 6260 N=1,NYEAR
   DO 6260 K=1,5
   RPAD(N,I,K)=RPAD(N,I,K)/K*100.
   DO 6261 NY=1,NYEAR
      NOY=1975+NY
      WRITE(6,6262) NOY,(RPAD(NY,I,J),J=1,5)
   WRITE(6,6270)
   CONTINUE
6262 FORMAT(20X,6I5,13X,2G5.2)
6261 CONTINUE
507 FORMAT(1',1X,26('*'),',SUMMARY OF DISBURSEMENTS',1X,26('*'),///HPM 1894
   A/19X,92(''-'),/37X,'ADMIN',16X,'LOCAL',14X,'NON-LOCAL',11X,HPM 1895
   B'PRICE',/19X,'YEAR',15X,'& OTHER',14X,'CAPITAL OUTLAYS',5X,HPM 1896
   C'CAPITAL OUTLAYS',7X,'DEFLATOR',/19X,92(''-'),/)
   AKER=1.
   DO 16 I=1,NYEAR
   AKER=AKER*1.+WSIN(I)/100.
   NOY=1975+I
   NZ1=IFIX(FUND(I))
   NZ2=IFIX(TFUND(I))
   NZ3=IFIX(ADMIN(I))
   WRITE(6,15) NOY,NZ1,NZ2,NZ3,AKER
   CONTINUE
   WRITE(6,17)
15 FORMAT(19X,4,16X,8X,18X,14X,15X,IS.,F4.2,/
   16 CONTINUE
   WRITE(6,17)
17 FORMAT(19X,92(''-'))
1235 RETURN
END
APPENDIX B

Sample HIPERFORM Output

(Scenario T-4)
INDIANA POPULATION ESTIMATES

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1/ IN THOUSANDS
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\(1/\) IN MILLIONS OF VEHICLE MILES TRAVELED
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## FUEL CONSUMPTION AND TON-MILE ESTIMATES

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1/ IN THOUSANDS OF GALLONS

2/ IN MILLIONS
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5 Year Average
Annual Capital Outlays:
(In thousands) 3/ $20,522 $24,453 $42,533 $15,466 $15,466

1/ Poor - PSR < 2.0 (<2.5 Principal Arterial); Fair - PSR 2.0 to 3.4; Good - PSR > 3.4.
2/ Travel is for peak hour, one direction only.
3/ Excluding structure costs.
**1990 URBAN SUMMARY IN PERCENTS**

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<th>Oth FWY &amp; Expy Travel</th>
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<th>Other PRIN Art Travel</th>
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<td>51</td>
<td>45</td>
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</table>

<table>
<thead>
<tr>
<th>Lane Width (FT):</th>
<th>&lt; 10</th>
<th>10 - 11</th>
<th>&gt; 11</th>
</tr>
</thead>
<tbody>
<tr>
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<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Lane Width Travel</td>
<td>0</td>
<td>5</td>
<td>95</td>
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<table>
<thead>
<tr>
<th>5 Year Average</th>
<th>Annual Capital Outlays:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(In thousands)</td>
</tr>
<tr>
<td>Interstate</td>
<td>$46399</td>
</tr>
<tr>
<td>Oth FWY &amp; Expy</td>
<td>$18044</td>
</tr>
<tr>
<td>Other PRIN Art</td>
<td>$30933</td>
</tr>
<tr>
<td>Minor Arterial</td>
<td>$14177</td>
</tr>
<tr>
<td>Collector</td>
<td>$7732</td>
</tr>
</tbody>
</table>

1/ Poor - PSR <2.0 (<<2.5 Principal Arterial); Fair - PSR 2.0 to 3.4; Good - PSR>3.4.
2/ Travel is for peak hour, one direction only.
3/ Excluding structure costs.
<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>Other Freeway &amp; Expwy Miles</th>
<th>Other Freeway &amp; Expwy Travel</th>
<th>Other Principal Artery Miles</th>
<th>Other Principal Artery Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Collector Miles</th>
<th>Collector Travel</th>
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</thead>
<tbody>
<tr>
<td>High</td>
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<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>68</td>
<td>81</td>
</tr>
<tr>
<td>Interim</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

| Pavement Condition:1/ |                |                   |                            |                              |                            |                              |                      |                      |                 |                  |
| Poor                 | 0               | 0                 | 2                          | 3                            | 8                           | 8                            | 13                   | 11                   | 13              | 13               |
| Fair                 | 0               | 0                 | 13                         | 10                           | 42                          | 41                           | 48                   | 45                   | 46              | 45               |
| Good                 | 100             | 100               | 84                         | 87                           | 49                          | 50                           | 39                   | 43                   | 40              | 41               |

| Vol/Cap Ratios:2/    |                |                   |                            |                              |                            |                              |                      |                      |                 |                  |
| < .31               | 0               | 0                 | 42                         | .45                          | 10                          | 6                            | 23                   | 19                   | 52              | 50               |
| .31 - .50           | 70              | 74                | 53                         | 50                           | 62                          | 59                           | 56                   | 60                   | 42              | 42               |
| > .50               | 30              | 26                | 5                          | 4                            | 27                          | 35                           | 20                   | 21                   | 5               | 7                |

| Lane Width (ft):     |                |                   |                            |                              |                            |                              |                      |                      |                 |                  |
| < 10                | 0               | 0                 | 0                          | 0                            | 11                          | 10                           | 14                   | 13                   | 25              | 30               |
| 10 - 11             | 0               | 0                 | 0                          | 0                            | 15                          | 14                           | 33                   | 36                   | 38              | 38               |
| > 11                | 100             | 100               | 100                        | 100                          | 73                          | 76                           | 52                   | 50                   | 36              | 34               |

5 Year Average  
Annual Capital Outlays:  
(In Thousands) 3/  
$ 1288  $ 2577  $ 7732  $ 5155  $ 5155

1/ Poor - PSR <2.0 (<2.5 Principal Artery); Fair - PSR 2.0 to 3.4; Good - PSR>3.4.  
2/ Travel is for peak hour, one direction only.  
3/ Excluding structure costs
### 1985 Rural Summary in Percentages

<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Other Prin Ar</th>
<th>Minor Arterial Miles</th>
<th>Major Collector Miles</th>
<th>Minor Collector Miles</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>37</td>
</tr>
<tr>
<td></td>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>60</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Low</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>16</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Pavement Condition:</th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Poor</td>
<td>4</td>
<td>2</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Fair</td>
<td>9</td>
<td>8</td>
<td>20</td>
<td>21</td>
</tr>
<tr>
<td>Good</td>
<td>87</td>
<td>89</td>
<td>74</td>
<td>74</td>
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</table>

<table>
<thead>
<tr>
<th>Vol/Cap Ratios:</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; .31</td>
<td>12</td>
<td>7</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>.31 - .80</td>
<td>66</td>
<td>67</td>
<td>67</td>
<td>66</td>
</tr>
<tr>
<td>&gt; .80</td>
<td>22</td>
<td>25</td>
<td>9</td>
<td>17</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane Width (FT):</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10 - 11</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>&gt; 11</td>
<td>100</td>
<td>100</td>
<td>98</td>
<td>62</td>
</tr>
</tbody>
</table>

5 Year Average Annual Capital Outlays: (in thousands)

- Interstate: $37266
- Other: $44253
- Minor Arterial: $76862
- Major Collector: $27949
- Minor Collector: $27949

---

1/ Poor - PSR < 2.0 (< 2.5 PRINCIPAL ARTERIAL); Fair - PSR 2.0 to 3.4; Good - PSR > 3.4.

2/ Travel is for peak hour, one direction only.

3/ Excluding structure costs
### 1985 Urban Summary in Percents

<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>OTH FWY &amp; EXPY Miles</th>
<th>OTH FWY &amp; EXPY Travel</th>
<th>OTHER PRIN ART Miles</th>
<th>OTHER PRIN ART Travel</th>
<th>MINOR ARTERIAL Miles</th>
<th>MINOR ARTERIAL Travel</th>
<th>COLLECTOR Miles</th>
<th>COLLECTOR Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
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<td>87</td>
<td>94</td>
</tr>
<tr>
<td>Interim</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Low</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pavement Condition:</th>
<th>Poor</th>
<th>Fair</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0</td>
<td>3</td>
<td>97</td>
</tr>
<tr>
<td>Travel</td>
<td>0</td>
<td>2</td>
<td>97</td>
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</table>

<table>
<thead>
<tr>
<th>Vol/Cap Ratios:</th>
<th>&lt; .31</th>
<th>.31 - .90</th>
<th>&gt; .90</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0</td>
<td>66</td>
<td>34</td>
</tr>
<tr>
<td>Travel</td>
<td>0</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane Width (FT):</th>
<th>&lt; 10</th>
<th>10 - 11</th>
<th>&gt; 11</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miles</td>
<td>0</td>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>Travel</td>
<td>0</td>
<td>5</td>
<td>95</td>
</tr>
</tbody>
</table>

5 Year Average Annual Capital Outlays:
(In Thousands) 3/ $83849 $32608 $55899 $25620 $13974

1/ Poor = PSR <2.0 (≤2.5 Principal Arterial); Fair = PSR 2.0 to 3.4; Good = PSR>3.4.
2/ Travel is for peak hour. One direction only.
3/ Excluding structure costs
### 1985 Small Urban Summary in Percent*

<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>Other Fwy &amp; Expwy Miles</th>
<th>Other Fwy &amp; Expwy Travel</th>
<th>Other Prin Art Miles</th>
<th>Other Prin Art Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Collector Miles</th>
<th>Collector Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>72</td>
<td>84</td>
</tr>
<tr>
<td>Interim</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>24</td>
<td>15</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>3</td>
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### Pavement Condition: 1/

<table>
<thead>
<tr>
<th>Condition</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>Other Fwy &amp; Expwy Miles</th>
<th>Other Fwy &amp; Expwy Travel</th>
<th>Other Prin Art Miles</th>
<th>Other Prin Art Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Collector Miles</th>
<th>Collector Travel</th>
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<tbody>
<tr>
<td>Poor</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>12</td>
<td>11</td>
<td>13</td>
<td>12</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Fair</td>
<td>0</td>
<td>0</td>
<td>26</td>
<td>18</td>
<td>33</td>
<td>33</td>
<td>52</td>
<td>51</td>
<td>40</td>
<td>41</td>
</tr>
<tr>
<td>Good</td>
<td>100</td>
<td>100</td>
<td>73</td>
<td>61</td>
<td>55</td>
<td>56</td>
<td>34</td>
<td>36</td>
<td>50</td>
<td>47</td>
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</table>

### Vol/Cap Ratios: 2/

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<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>Other Fwy &amp; Expwy Miles</th>
<th>Other Fwy &amp; Expwy Travel</th>
<th>Other Prin Art Miles</th>
<th>Other Prin Art Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Collector Miles</th>
<th>Collector Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; .31</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>15</td>
<td>12</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>.31 - .90</td>
<td>65</td>
<td>67</td>
<td>84</td>
<td>88</td>
<td>57</td>
<td>51</td>
<td>58</td>
<td>60</td>
<td>65</td>
<td>67</td>
</tr>
<tr>
<td>&gt; .90</td>
<td>35</td>
<td>32</td>
<td>5</td>
<td>4</td>
<td>36</td>
<td>45</td>
<td>26</td>
<td>27</td>
<td>5</td>
<td>7</td>
</tr>
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</table>

### Lane Width (ft):

<table>
<thead>
<tr>
<th>Width</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>Other Fwy &amp; Expwy Miles</th>
<th>Other Fwy &amp; Expwy Travel</th>
<th>Other Prin Art Miles</th>
<th>Other Prin Art Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Collector Miles</th>
<th>Collector Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>11</td>
<td>10</td>
<td>14</td>
<td>13</td>
<td>23</td>
<td>26</td>
</tr>
<tr>
<td>10 - 11</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>14</td>
<td>13</td>
<td>32</td>
<td>34</td>
<td>37</td>
<td>37</td>
</tr>
<tr>
<td>&gt; 11</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>74</td>
<td>77</td>
<td>55</td>
<td>52</td>
<td>39</td>
<td>39</td>
</tr>
</tbody>
</table>

### 5-Year Average Annual Capital Outlays (in thousands):

| Category                     | $ 2328 | $ 4657 | $ 13974 | $ 9316 | $ 9316 |

---

1/ Poor - PSR <2.0 (<2.5 Principal Arterial); Fair - PSR 2.0 to 3.4; Good - PSR>3.4.
2/ Travel is for peak hour. One direction only.
3/ Excluding structure costs.
### 1990 Rural Summary in Percentages

<table>
<thead>
<tr>
<th>Pavement Type:</th>
<th>Interstate Miles</th>
<th>Interstate Travel</th>
<th>Other Principal Miles</th>
<th>Other Principal Travel</th>
<th>Minor Arterial Miles</th>
<th>Minor Arterial Travel</th>
<th>Major Collector Miles</th>
<th>Major Collector Travel</th>
<th>Minor Collector Miles</th>
<th>Minor Collector Travel</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>43</td>
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<td>0</td>
<td>0</td>
<td>0</td>
<td>15</td>
<td>6</td>
<td>52</td>
<td>39</td>
</tr>
</tbody>
</table>

### Pavement Condition:

- Poor:
  - 2
  - 32

- Fair:
  - 1
  - 1
  - 1
  - 1
  - 2
  - 3
  - 32
  - 35

- Good:
  - 92
  - 3
  - 9
  - 32

### Volume/Capacity Ratios:

- Less than .31:
  - 73
  - 6

- .31 to .80:
  - 70
  - 7
  - 81
  - 82
  - 69
  - 62
  - 77
  - 71
  - 88
  - 84

- Greater than .80:
  - 25
  - 3

### Lane Width (ft):

- Less than 10:
  - 0
  - 0

- 10 to 11:
  - 0
  - 1
  - 1
  - 1
  - 12
  - 8
  - 58
  - 62
  - 48
  - 46

- Greater than 11:
  - 100
  - 99
  - 93
  - 87
  - 91
  - 5
  - 7
  - 3

### 5 Year Average Annual Capital Outlays:

<table>
<thead>
<tr>
<th>Type</th>
<th>(In Thousands)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interstate Miles</td>
<td>$49080</td>
</tr>
<tr>
<td>Interstate Travel</td>
<td>$58283</td>
</tr>
<tr>
<td>Other Principal Miles</td>
<td>$101229</td>
</tr>
<tr>
<td>Other Principal Travel</td>
<td>$36810</td>
</tr>
<tr>
<td>Minor Arterial Miles</td>
<td>$101229</td>
</tr>
<tr>
<td>Minor Arterial Travel</td>
<td>$36810</td>
</tr>
<tr>
<td>Major Collector Miles</td>
<td>$36810</td>
</tr>
<tr>
<td>Major Collector Travel</td>
<td>$36810</td>
</tr>
<tr>
<td>Minor Collector Miles</td>
<td>$36810</td>
</tr>
<tr>
<td>Minor Collector Travel</td>
<td>$36810</td>
</tr>
</tbody>
</table>

1/ Poor - PSR < 2.0 (<2.5 Principal Arterial); Fair - PSR 2.0 to 3.4; Good - PSR > 3.4.
2/ Travel is for peak hour. One direction only.
3/ Excluding structure costs.
### 1990 Urban Summary in Percentages

| Pavement Type: | Interstate Miles | Interstate Travel | OTH FWY & Expwy Miles | OTH FWY & Expwy Travel | Other Prin Arterial Miles | Other Prin Arterial Travel | Minor Arterial Miles | Minor Arterial Travel | Collector Miles | Collector Travel |
|----------------|------------------|-------------------|-----------------------|------------------------|---------------------------|---------------------------|---------------------|---------------------|----------------|----------------|----------------|
| High           | 100              | 100               | 100                   | 100                    | 100                       | 100                       | 100                 | 100                 | 89             | 95             |
| Interim        | 0                | 0                 | 0                     | 0                      | 0                         | 0                         | 0                   | 0                   | 10             | 4              |
| Low            | 0                | 0                 | 0                     | 0                      | 0                         | 0                         | 0                   | 0                   | 0              | 0              |

<table>
<thead>
<tr>
<th>Pavement Condition:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poor</td>
</tr>
<tr>
<td>Fair</td>
</tr>
<tr>
<td>Good</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Vol/Cap Ratios:</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 0.31</td>
</tr>
<tr>
<td>0.31 - 0.90</td>
</tr>
<tr>
<td>&gt; 0.90</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Lane Width (ft):</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10</td>
</tr>
<tr>
<td>10 - 11</td>
</tr>
<tr>
<td>&gt; 11</td>
</tr>
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5 Year Average
---
Annual Capital Outlays:
- (In Thousands) 3/ | $110431 | $42945 | $73621 | $33742 | $18405

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1/ Poor - PSR <2.0 (2.5 Principal Arterial): Fair - PSR 2.0 to 3.4; Good - PSR >3.4.
2/ Travel is for peak hour, one direction only.
3/ Excluding structure costs
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5 Year Average
Annual Capital Outlays:
(In Thousands) 3/ $ 3067 $ 6134 $ 19405 $ 12270 $ 12270

1/ Poor - PSR <2.0 (<2.5 Principal Arterial); Fair - PSR 2.0 to 3.4; Good - PSR >3.4.
2/ Travel is for Peak Hour, One Direction Only.
3/ Excluding Structure Costs
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