Statewide Transportation Analysis & Research

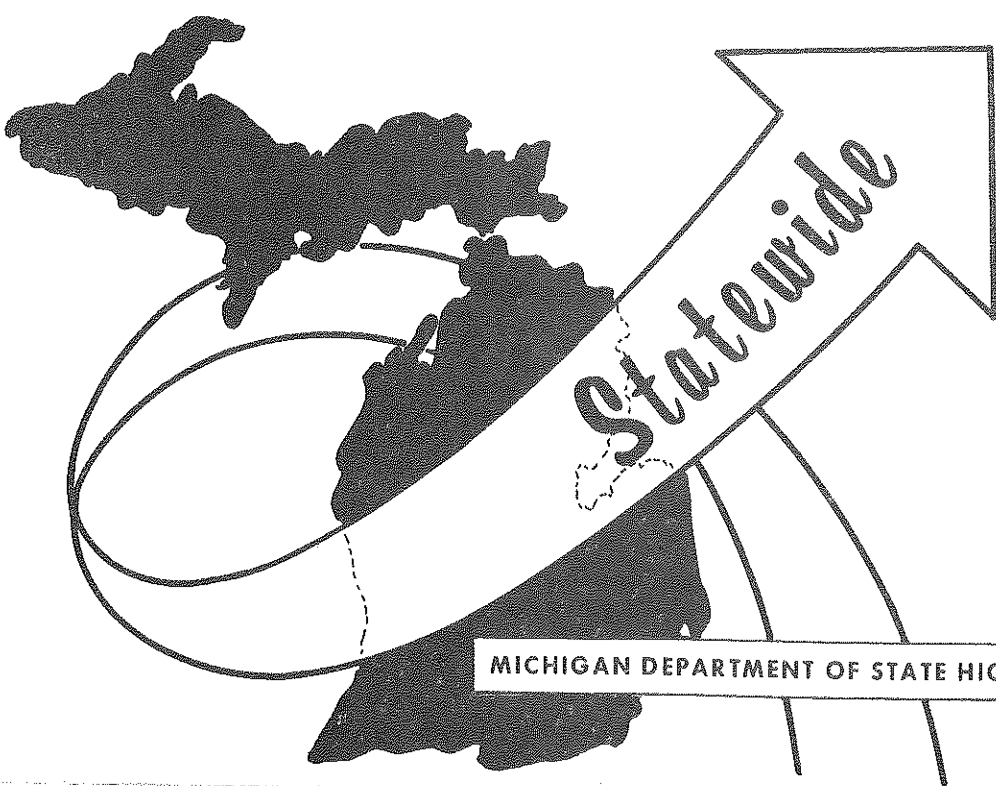
MICHIGAN STATEWIDE
TRANSPORTATION MODELING SYSTEM
VOLUME I-M

RESPONDING TO THE GOVERNOR'S
SPECIAL COMMISSION ON ENERGY:

MODELING GASOLINE CONSUMPTION

STATEWIDE PROCEDURES SECTION

DECEMBER, 1974
REVISED FEBRUARY, 1978



MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

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BUREAU OF TRANSPORTATION PLANNING

MICHIGAN STATEWIDE
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DECEMBER, 1974
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STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

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JOHN P. WOODFORD, DIRECTOR

February 9, 1978

Mr. Sam F. Cryderman
Deputy Director
Bureau of Transportation Planning
Department of State Highways
and Transportation

Dear Mr. Cryderman:

The Highway Planning Division is pleased to present Volume I-M in the Statewide Transportation Modeling System Series. It documents a first step in transportation planning for energy needs: modeling gasoline consumption.

The consumption of gasoline at the statewide level is an important factor in the State's energy planning. The model described herein will not model total gasoline demand in the State, but it will provide a comparative measure of gasoline consumption on state trunklines between various highway altern[illegible]es within a region or the State. As such, it can fill a function tod[illegible] of providing highway planners with an energy indicator.

This report was prepared by Mr. Lawrence G. Scott and updated by Mr. David R. Schade of the Statewide Procedures Section, under the supervision of Mr. Richard E. Esch.

Sincerely,

William M. Lepczyk
Acting Administrator
Highway Planning Division

TABLE OF CONTENTS

RESPONDING TO THE GOVERNOR'S SPECIAL COMMISSION ON ENERGY:

MODELING GASOLINE CONSUMPTION

BY LAWRENCE G. SCOTT

UPDATED BY DAVID R. SCHADE

PREFACE

PREFACE

The "energy crisis" of winter 1974 marked the beginning of consciousness of energy consumption for the world's western industrial nations. Although fuel supplies have now returned to normal pre-crisis levels in the state and nation, energy planners predict that the overall energy situation will never return to the old concept of normal. The most obvious indicator of the new energy situation is the higher price for fuels of all sorts; a secondary indicator is the very real possibility that shortages could recur. These indicators have important consequences in governmental planning for the needs of its citizens.

The consequences of the new energy consciousness are reflected in the report of the Governor's Special Commission on Energy, which recommended the establishment of the State Energy Office, to deal specifically with future energy problems in Michigan. The new agency, said the commission report, "needs to have more sophisticated analytical tools to project the state's energy demands. . . . and these should include an energy supply and demand model." One of the agency's functions is to collect information on energy supply and demand from energy transporters, wholesalers, and distributors and from other state agencies which have information to supply.

Gasoline is a vital fuel in our society, since it is the energy source for most of the nation's transportation and the capability for projecting its usage, i.e. demand, is desirable from the governmental planning viewpoint. Supplied with information on present and probable future gasoline consumption, the State Energy Office will have a significant portion of its task made simpler, and the state's energy planning will be facilitated. Equally important, the Department of State Highways and Transportation must consider costs, both social and individual, in planning for future transportation needs. As gasoline prices rise or supply tightens, gasoline usage will become a more important consideration in evaluating alternate transportation proposals.

The component of Michigan's Statewide Transportation Planning Modeling System described herein assesses gasoline consumption based on the changes in speed and congestion associated with various highway proposals. Projections of gasoline consumption for various highway jurisdictions and factors that increase or decrease consumption are the main outputs of the analysis process described in this report.

This report is Volume I-M in the statewide series of publications. Previous reports in the series are listed on the following pages.

SYSTEM DEVELOPMENT REPORTS

Volume I	- Objectives and Work Program
Volume I-A	- Region 4 Workshop Topic Summaries
Volume I-B	- Single and Multiple Corridor Analysis
Volume I-C	- Turnbacks
Volume I-D	- Proximity Analysis
Volume I-E	- Model Applications: Cost-Benefit Analysis
Volume I-F	- Air and Noise Pollution
Volume I-G	- Psychological Impact Model
Volume I-H	- Level of Service Model
Volume I-I	- Statewide Socio-Economic and Transportation Resources and Their Role in Intercity Transportation Decisions
Volume I-J	- Service Area Model
Volume I-K	- Effective Speed Model
Volume I-L	- System Impact Analysis Graphic Display
Volume I-M	- Modeling Gasoline Consumption
Volume I-O	- Accident Rates 547 Zone System
Volume I-P	- Population Projections 547 Zone System
Volume II	- Development of Network Models
Volume II-A	- Efficient Network Updating with Interactive Graphics
Volume II-B	- Tree Plotting with Interactive Graphics
Volume III	- Segmental Model
Volume III-A	- Semi-Automatic Network Generator Using a "Digitizer"
Volume III-B	- Automatic Network Generator Using Interactive Graphics
Volume IV	- AASHTO Report
Volume IV-A	- Michigan Statewide Modeling System - Synopsis
Volume V	- Part A - Reformation - Trip Data Bank Preparation
Volume V	- Part B - Development of Socio-Economic Data Bank for Trip Generation - Distribution
Volume V-A	- Single Station O & D Procedures Manual
Volume V-B	- External O & D Procedures Manual
Volume VI	- Corridor Location Dynamics
Volume VI-A	- Environmental Sensitivity Computer Mapping
Volume VII	- Design Hour Volume Model
Volume VII-A	- Capacity Adequacy Forecasting Model
Volume VII-B	- Modeling Major Facility Opening Impact on DHV
Volume VIII	- Public and Private Facility File
Volume VIII-A	- Conversion of Industrial Expansion File
Volume IX	- Socio-Economic Data File
Volume IX-A	- Mapping Socio-Economic Data with SYMAP
Volume IX-B	- Conversion of the Agricultural Census File
Volume IX-C	- Tax Rate and Assessed Valuation Information
Volume IX-D	- School District Data File
Volume X-A	- Travel Impact Analysis Procedures
Volume X-A-1	- Automated Desireline Plotting
Volume X-B	- Social Impact Analysis Procedures
Volume X-C	- Economic Impact Analysis Procedures
Volume XI	- Computer Run Times
Volume XIII	- Michigan Goes Multi-Modal
Volume XIII-A	- Multi-Modal Mobility and Accessibility Analysis
Volume XIII-B	- 1972 Statewide Rail Network - Summary Tabulations
Volume XIV-A	- Commodity Flow Matrix - Ann Arbor Railroad
Volume XIV-B	- Commodity Flow Matrix - Penn Central Railroad

Volume XIV-C	- Commodity Flow Matrix - Michigan Railroads 1% Sample
Volume XV-A	- Railroad Financial Impact Analysis
Volume XV-B	- Railroad Community Impact Analysis
Volume XVI	- Dial-A-Ride
Volume XVII	- Intermodal Impact Analysis - Truck and Railroad
Volume XVIII	- Cutline Analysis Program

STATEWIDE SYSTEM APPLICATION REPORTS

Report #1 — Community College Service - Area Analysis

Report #2 — Proximity of People to General Purpose Hospitals

Report #3 — Industrial Park Proximity Analysis

Report #4 — Proximity of Automobile Injury Accidents to Hospitals

Report #5 — Proximity of Airports with Scheduled Service to Population

Report #6 — Regional Park Proximity Analysis

Report #7 — Rifle Range Proximity Analysis

Report #8 — Ambulance Service - Area Analysis

Report #9 — Comprehensive Statewide Planning

Report #10 — Graphic Display of Fixed-Object Accident Data

Report #11 — Preliminary Investigation: A Technique for the Projection of Accident Rates

Report #12 — Impact of 50, 55, or 60 M.P.H. Statewide Speed Limit

Report #13 — A Method for Functionally Classifying Rural Arterial Highways

Report #14 — Economic and Travel Impacts of Speed Limit Reduction Using a Statewide Transportation Modeling System

Report #15 — I-69 Impact on the Accessibility of Health, Fire, and Ambulance Services to Residential Areas

Report #16 — Crisis and Opportunity: Application of an Operational Statewide Transportation Modeling System

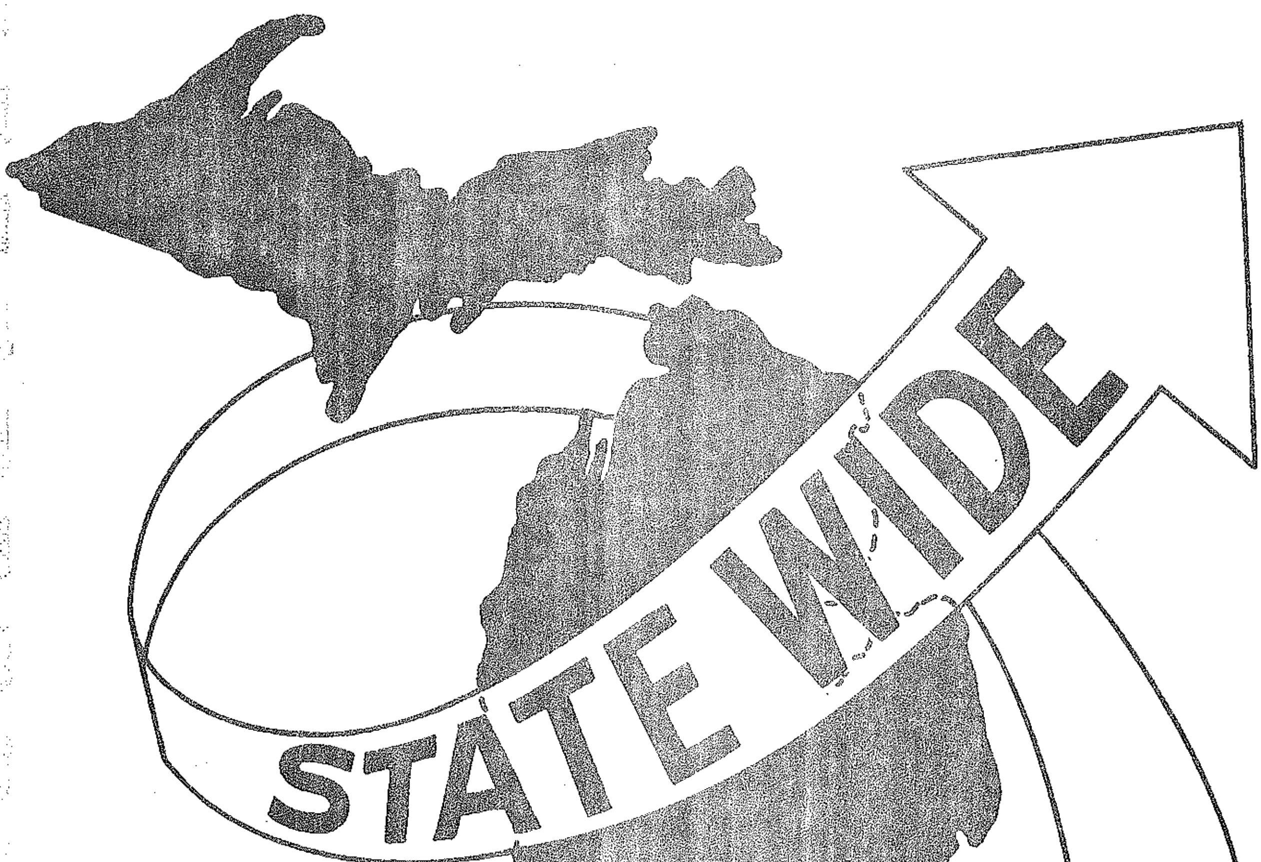
Report #17 — US-23 Corridor Location Study - Preliminary Travel Impact Analysis

Report #19 — Graphic Display of Accident Data

Report #20 — Demographic Information for the Northwest Region

Report #21 — AMTRAK Market Area Analysis - System Application

INTRODUCTION



INTRODUCTION

The capacity for projecting gasoline demand as the result of various transportation planning policies is important in planning for energy needs. This report describes an operational model with that capability which can be applied to evaluate alternate highway system proposals. The major parameters in the calculation are a measure of traffic volume on each link in the highway network, the speeds on the links, and an estimate for gasoline consumption at various speeds. The measure of traffic volume is related to the Annual Average Daily Traffic (AADT) figure for each link. The user has an option in selecting the type of speed to be used in each system evaluation. He may use the network's planned speeds. The effective speed may also be used to take traffic congestion into account (see Volume I-K, Effective Speed Model: A Public Interaction Tool). The measure of gasoline consumption is taken from Economic Analysis for Highways (1969) by Robley Winfrey.

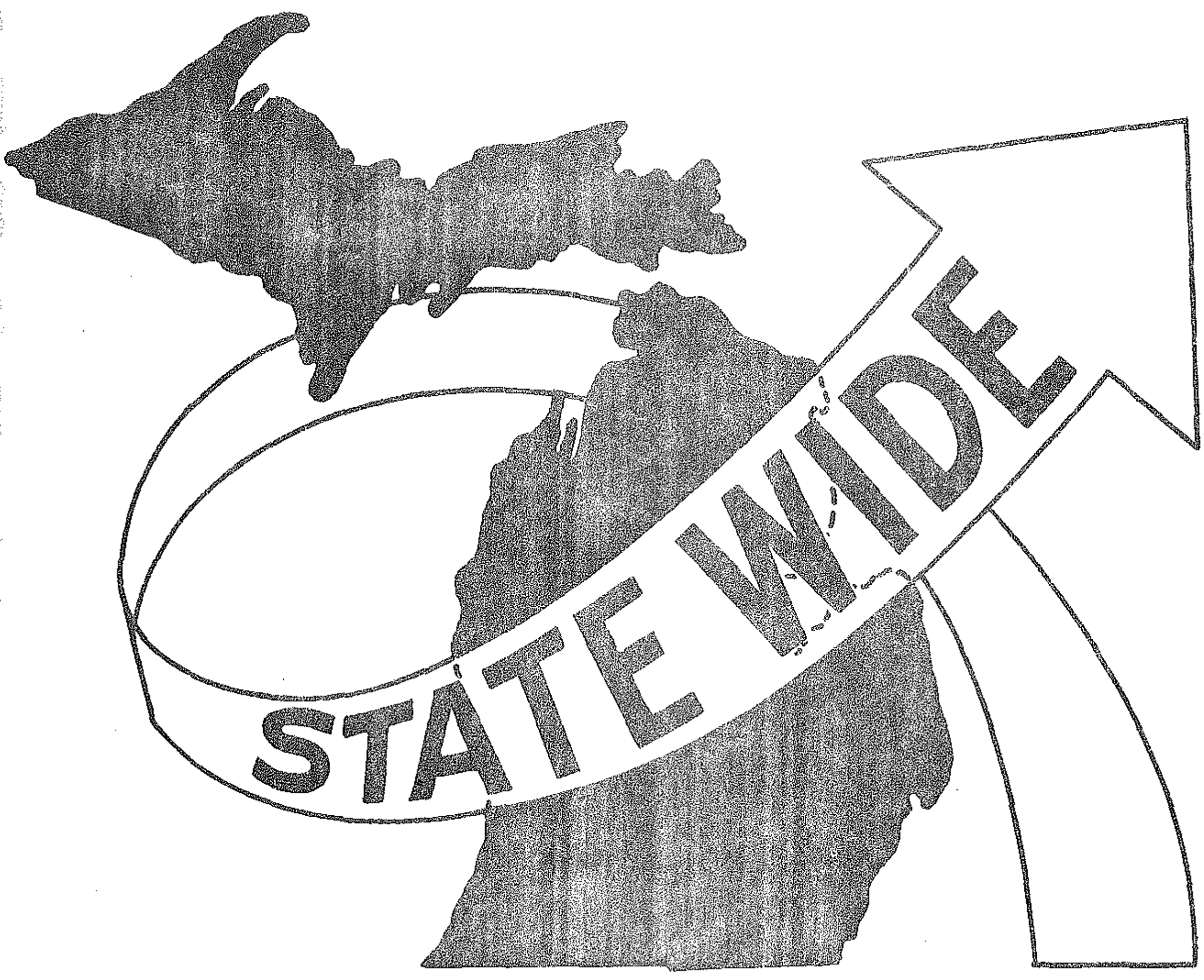
The output of the gasoline consumption model component is the projected number of gallons annually consumed on each alternate highway system proposal at whatever speeds are to be examined. The result is separated into interstate, federal aid primary, and federal aid secondary highways, and yields a total for all three, at county, regional, and statewide levels.

The simple modeling of gasoline consumption is a measure which will facilitate governmental planning at two levels. The measure of future demand is essential for planning within the State Energy Office and Transportation Department. Furthermore, it is easily comprehended by the layman and should be an aid in public understanding and involvement in the planning process.

RESPONDING TO THE GOVERNOR'S SPECIAL COMMISSION ON ENERGY

MODELING GASOLINE CONSUMPTION

SYSTEM OPERATION



RESPONDING TO THE GOVERNOR'S SPECIAL COMMISSION ON ENERGY:

MODELING GASOLINE CONSUMPTION SYSTEM OPERATION

Although measurement of gasoline consumption is output at the system level, the basic calculation is done at the most elementary level of the modeling system, the "link". A link is a representation of a section of the highway network, which is identified by its end points, the "A-node" and "B-node" For example the link with A-node 1475 and B-node 1505 is named link 1475-1505. Figure 1 is a diagram of links and nodes.

Each link in the highway network has information associated with it. Such information as link type, annual average daily traffic, design hour volume, lane width, and many others for that section of highway are stored in "volume fields" on magnetic tape records associated with the link's A-node and B-node. A volume field is nothing more than a descriptive way of referencing a physical space on a computer tape in which information is stored.

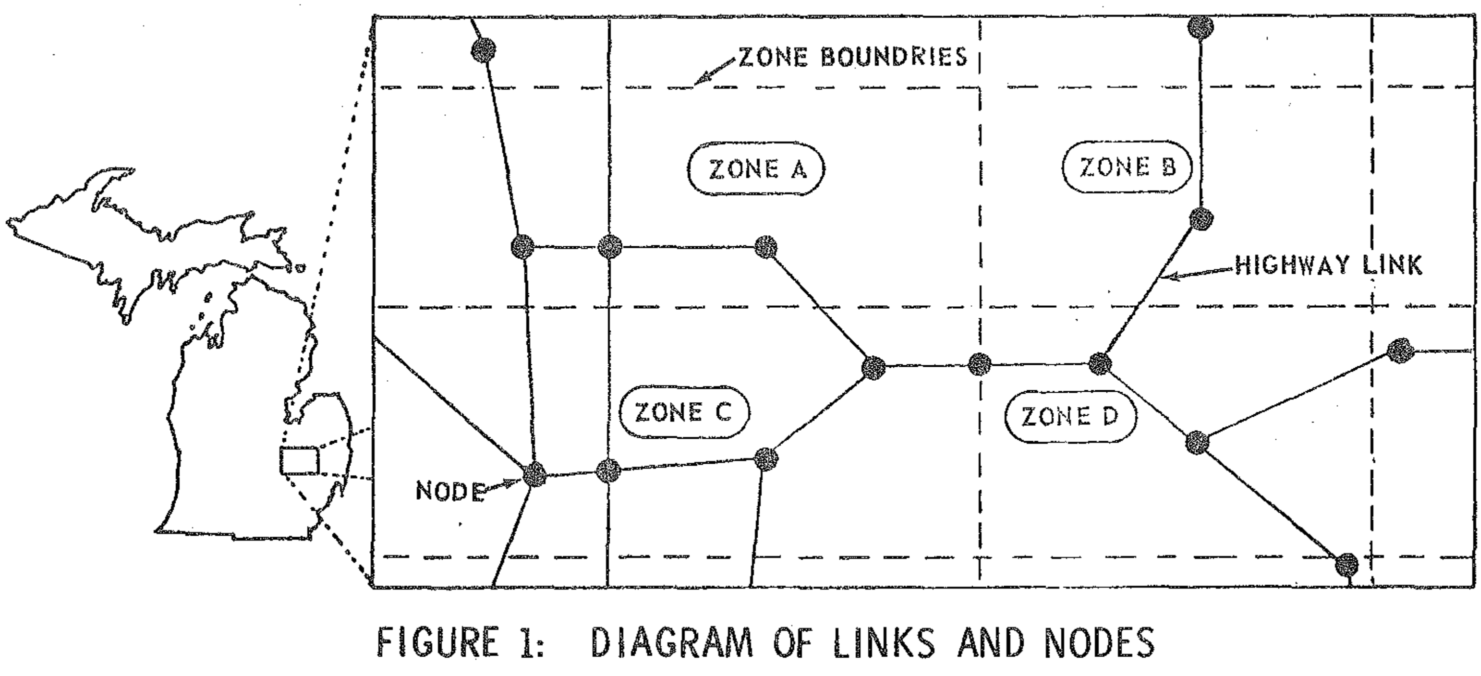


FIGURE 1: DIAGRAM OF LINKS AND NODES

To evaluate alternate highway system proposals, new links and nodes are coded into the existing highway network to produce hypothetical alternates. The Transportation Modeling System is then run on each alternate to assess the alternate's impacts on travel volume and operating speed. The annual consumption of gasoline is then calculated using the model's output.

The basic formula used for determining annual gasoline consumption for a link is the product of the annual vehicle miles traveled on the link times a measure of the number of gallons of gasoline consumed per vehicle mile at the speed which is traveled on the link. The annual vehicle miles traveled is the product of the length of the link in miles times the number of vehicles which travel the link in one year. The latter figure is the result of simulating the network on the trip generation component of the Modeling System. (For detailed understanding of the trip generation model, see A Computer Model for Determining Future Highway Requirements of the State of Michigan, Volume I, 1966, by Arthur Little, Inc.) Due to other factors that considerably effect gasoline consumption, it was necessary to expand this basic formula.

Coded into volume fields are two possible speeds which can be used to determine the rate of gasoline consumption: the planned speed and the effective speed. The first is the speed for which a lane of highway is designed. Actually, as most drivers recognize, the planned speed may not always be attained, due to traffic conditions. The effective speed model automates the process of determining the effect of congestion on driving speed.

When congestion occurs on a segment of road, there is an impact on the consumption of gasoline. To effectively measure this congestion and the effect it has on traffic speed, it is necessary to use the Effective Speed Model (Volume I-K) to determine the true speed of the traffic.

This effective speed is then used to measure the speed change cycle. A speed change cycle is the number of times a vehicle will decrease its speed and then return back to the original speed based on the congestion on a specific link. This, with the magnitude of the cycle (how much the speed changes) will determine excess gallons consumed.

To help analyze gas consumption, there are four curves that should be recognized (Figures 2A-D). Curves A and B are for gas consumption per 1000 vehicle miles as a function of speed for urban and rural road types.

Curves C and D are also for urban and rural road types, showing the annual gas consumption as a function of congestion and speed for a distance of two miles.

The equations for all four curves were taken from the Highway Investment Analysis Package, Appendix B, with all curves having excess gas consumption caused by stops and slows included in calculations.

The data used to estimate gasoline consumption was obtained from Appendix A of a text book by Robley Winfrey entitled Economic Analysis for Highways (1969). The gasoline consumption rates used are for an average 4,000 lb. passenger car and are shown in Figure 3. It has been assumed for this study that all grades are level as no information was available on grades by highway type. No differentiation was made for cars and trucks in this analysis but a future modification of the gasoline consumption projection will differentiate.

Since the publishing of Winfrey's book in 1969, trends in the auto industry have both increased and decreased gasoline consumption at various speeds. In the early seventies, federal emissions controls generally increased the consumption levels of new autos at all speeds. However, the energy crisis in early 1974 created a trend toward manufacture and sales of autos with lower gasoline consumption. Intuitively, it would seem, therefore, that the two trends have concelled each other and that Winfrey's table still retains validity. In any case, the consumption data for various speeds can easily be updated if a new trend in gasoline consumption predominates and new data becomes available.

After the annual gasoline consumption has been calculated for each link, a summary program accumulates the measure for counties, for a multi-county region, and for the state. Gasoline consumption and several other impacts can be examined on system impact summary

GAS CONSUMPTION PER 1,000 VEHICLE MILES AS A FUNCTION OF SPEED

(EQUATIONS ARE TAKEN FROM HIGHWAY INVESTMENT ANALYSIS PACKAGE, APPENDIX B)

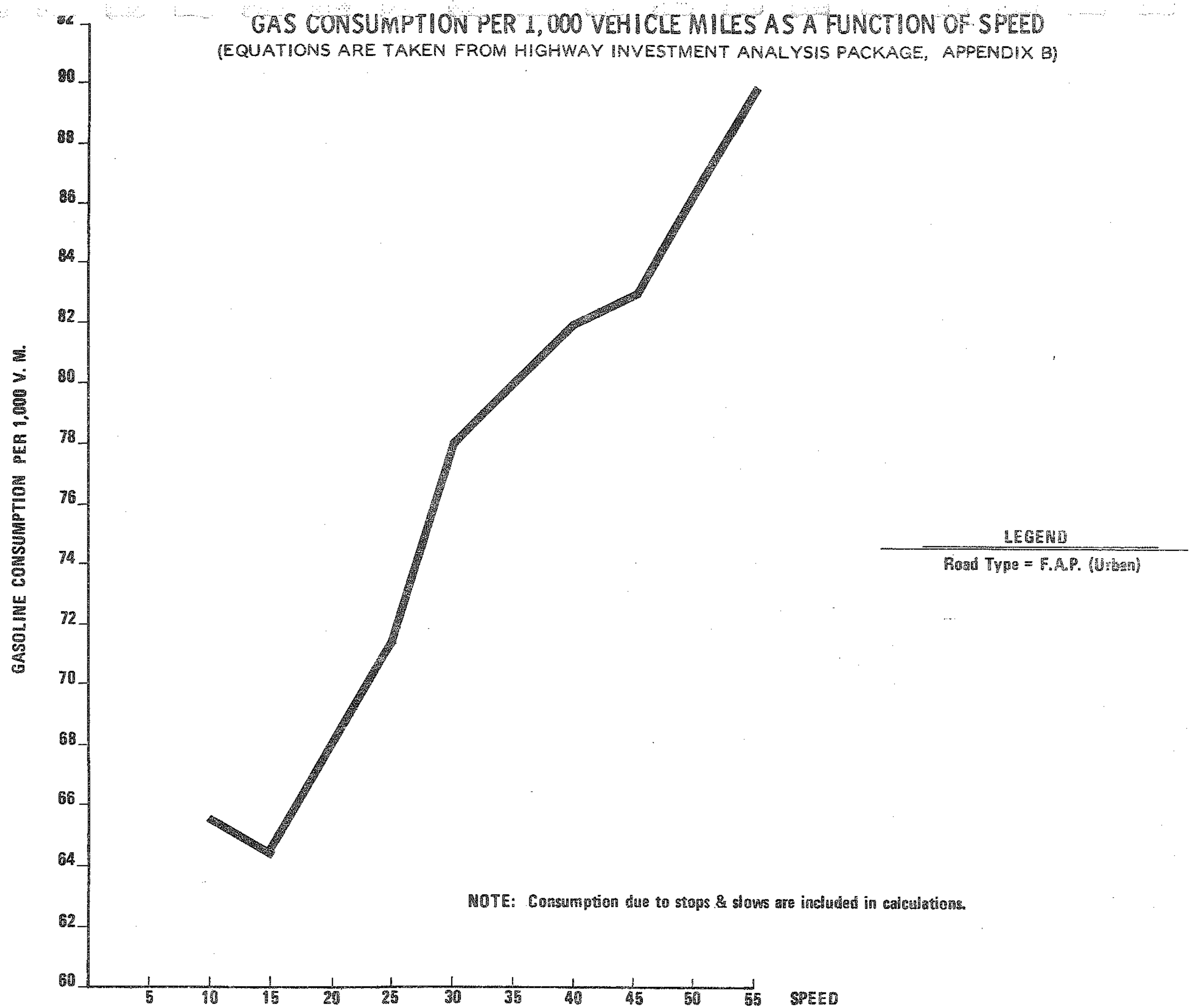


FIGURE 2A

GAS CONSUMPTION PER 1,000 VEHICLE MILES AS A FUNCTION OF SPEED

(EQUATIONS ARE TAKEN FROM HIGHWAY INVESTMENT ANALYSIS PACKAGE, APPENDIX B)

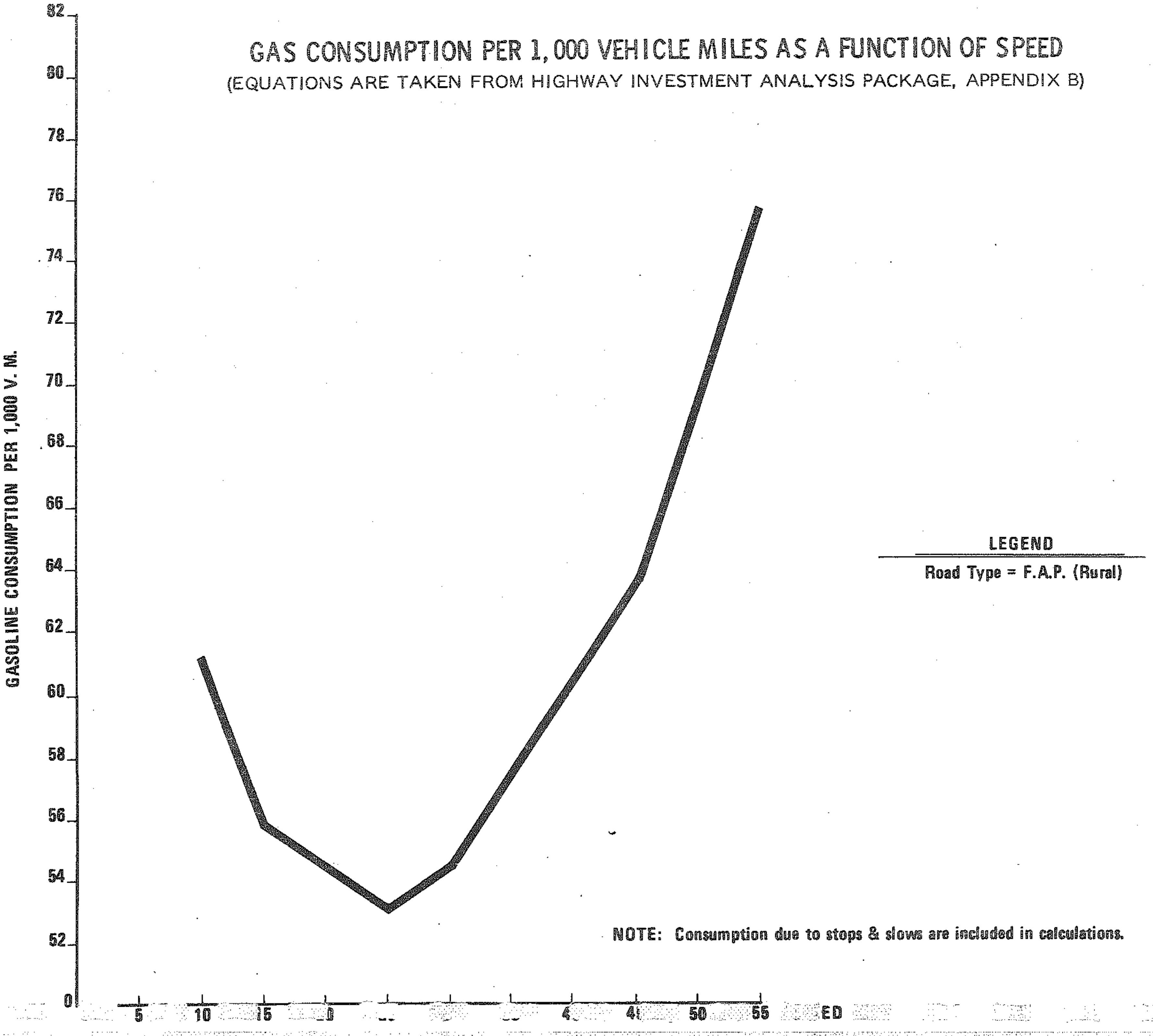


FIGURE 2B

GAS CONSUMPTION AS A FUNCTION OF CONGESTION & SPEED
(EQUATIONS ARE TAKEN FROM HIGHWAY INVESTMENT ANALYSIS PACKAGE, APPENDIX B)

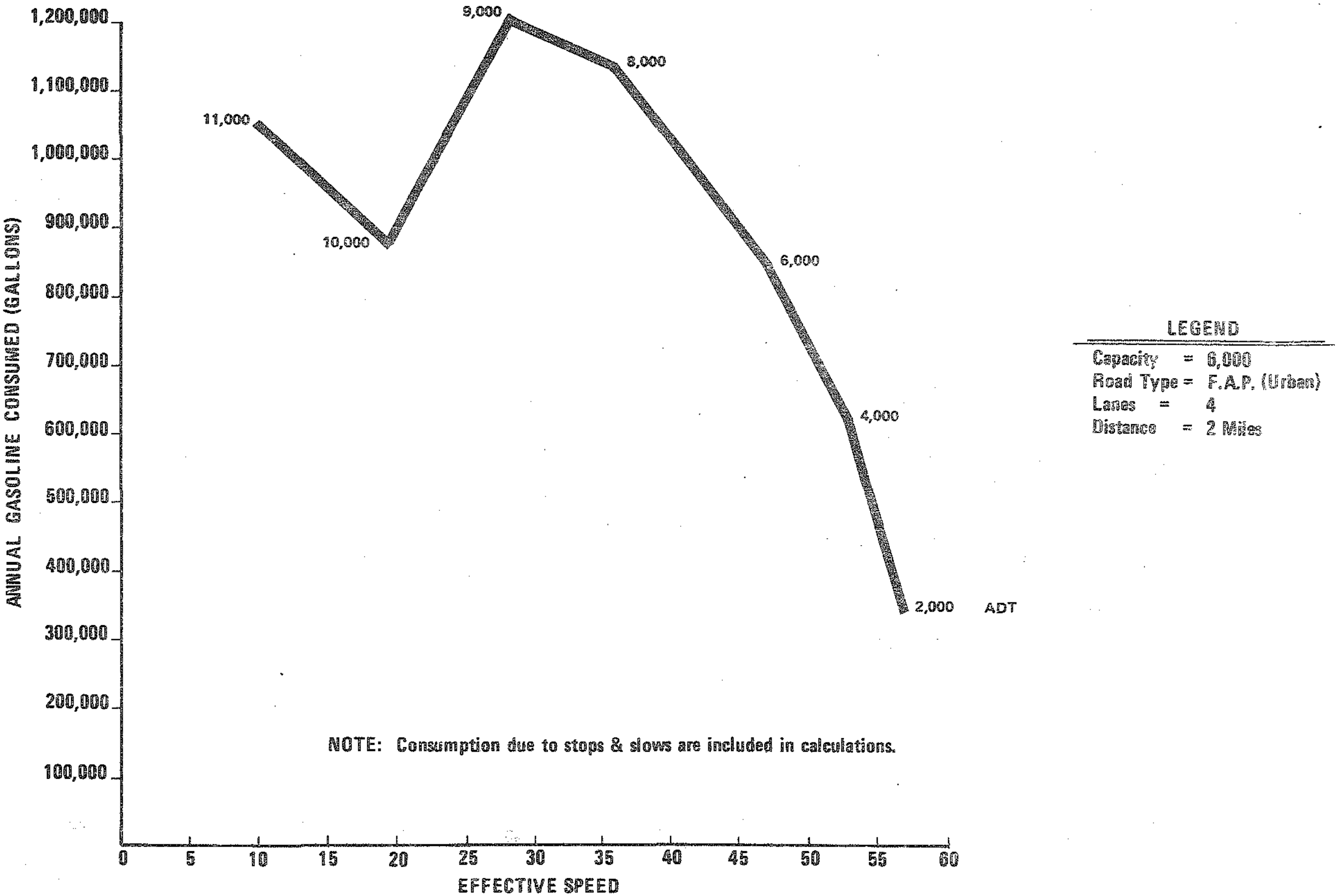


FIGURE 2C

GAS CONSUMPTION AS A FUNCTION OF CONGESTION & SPEED

(EQUATIONS ARE TAKEN FROM HIGHWAY INVESTMENT ANALYSIS PACKAGE, APPENDIX B)

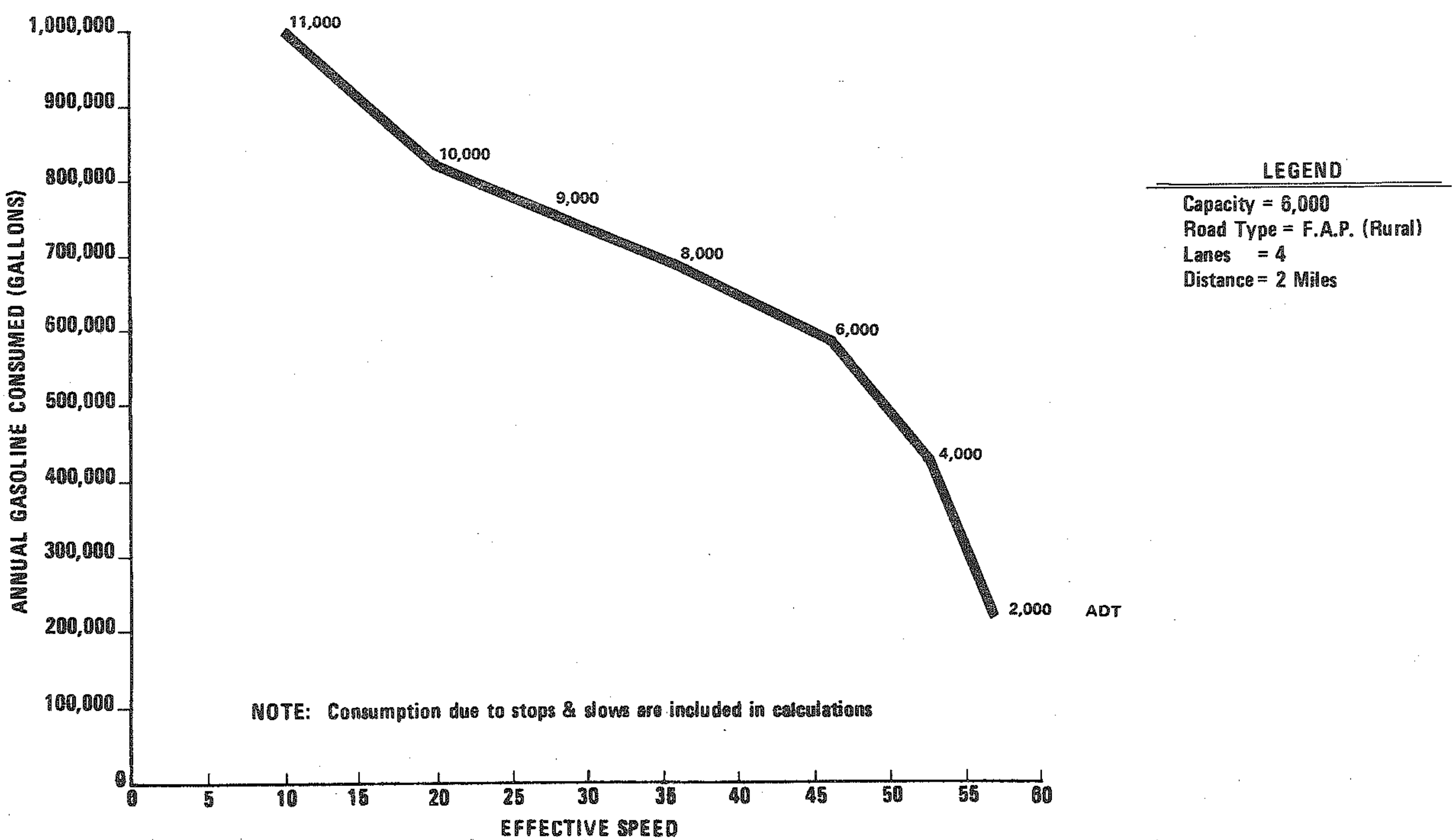


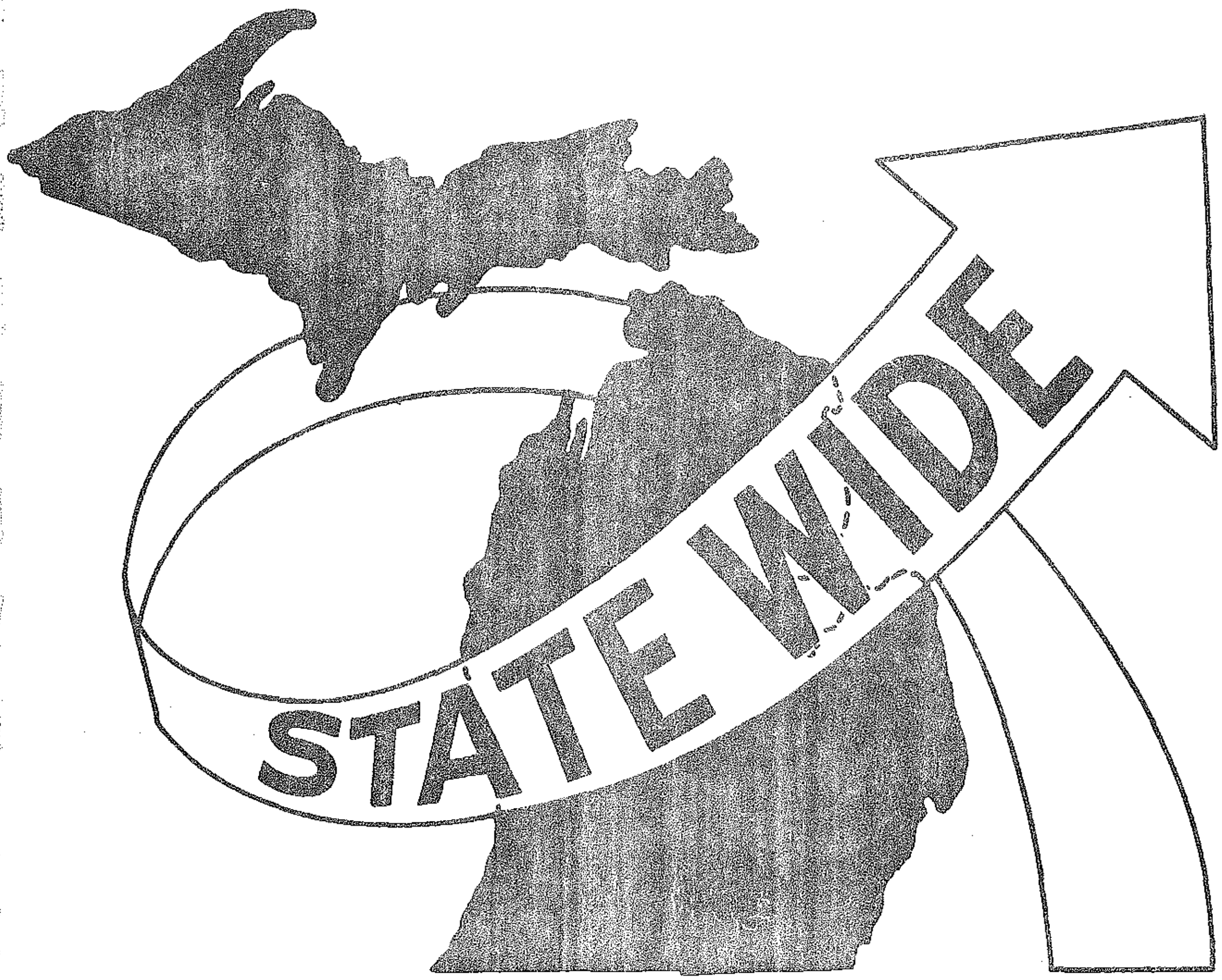
FIGURE 2D

Gals./1000 Veh.Miles	Miles Per Gallon	Speed MPH
102.4	9.8	5
76.1	13.1	7½
63.3	15.8	10
55.8	17.9	12½
51.1	19.6	15
48.0	21.0	17½
45.9	21.8	20
44.4	22.5	22½
43.5	23.0	25
43.0	23.3	27½
42.8	23.4	30
43.0	23.3	32½
43.3	23.1	35
43.9	22.8	37½
44.7	22.4	40
45.6	21.9	42½
46.8	21.4	45
48.1	20.8	47½
49.6	20.2	50
51.3	19.5	52½
53.2	18.8	55
55.3	18.2	57½
57.6	17.4	60
60.2	16.6	62½
63.1	15.9	65
66.3	15.1	67½
70.0	14.3	70
74.1	13.5	72½
78.1	12.7	75
84.1	11.9	77½
90.4	11.1	80

FIGURE 3: MODELING GASOLINE CONSUMPTION

tables, allowing quick analysis of an alternate proposal. A graphic comparison of several alternates is also available (see examples in next section).

SYSTEM APPLICATION



SYSTEM APPLICATION

The gasoline consumption analysis model can be applied initially in two types of comparisons.

First, a given alternate may be compared for different speeds on the same network. The special Statewide report, Impact of 50, 55, or 60 M.P.H. Statewide Speed Limit, provides a special example on the existing highway network. The user should be aware that the analysis can be made using either planned speed or effective speed. Figure 7 illustrates the difference between calculating gasoline consumption with effective speed model versus using planned speed for three statewide alternate network proposals.

The second gasoline consumption comparison that can be made is between several alternate highway systems. Figures 4A, 4B, and 4C are examples of system impact summary tables for three regional alternate highway proposals in central Michigan, shown in Figure 5. Figures 6A, 6B, 6C, 6D, and 6E are graphic comparisons of the relative gasoline consumption of the alternates studied in this region.

These alternates should not be interpreted as justifying or not justifying the construction of I-69. These examples are solely for illustrating the operation of the gasoline consumption analysis model.

FIGURE 4A

S Y S T E M   I M P A C T   S U M M A R Y
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM
OPTIONAL SYSTEM IMPACTS
JURISDICTIONS: 1 2 3 4 5 6 7 8
00000 HIGHWAYS   ALTERNATE A0605   STATEWIDE

GAS CONSUMPTION - RURAL - URBAN TOTALS

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	877966	343945	1523335	411642	3156889

S Y S T E M   I M P A C T   S U M M A R Y
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM
OPTIONAL SYSTEM IMPACTS
JURISDICTIONS: 1 2 3 4 5 6 7 8
00000 HIGHWAYS   ALTERNATE A0605   REGION
REGION CONSISTS OF COUNTIES NOS. 12, 13, 19, 23, 33, 38, 76,

GAS CONSUMPTION - RURAL - URBAN TOTALS

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	129677	27392	141372	44979	343421

S Y S T E M   I M P A C T   S U M M A R Y
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM
OPTIONAL SYSTEM IMPACTS
JURISDICTIONS: 1 2 3 4 5 6 7 8
00000 HIGHWAYS   ALTERNATE A0601   STATEWIDE

GAS CONSUMPTION - RURAL - URBAN TOTALS

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	867727	325608	1531245	411558	3136139

S Y S T E M   I M P A C T   S U M M A R Y
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM
OPTIONAL SYSTEM IMPACTS
JURISDICTIONS: 1 2 3 4 5 6 7 8
00000 HIGHWAYS   ALTERNATE A0601   REGION
REGION CONSISTS OF COUNTIES NOS. 12, 13, 19, 23, 33, 38, 76,

GAS CONSUMPTION - RURAL - URBAN TOTALS

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	119636	26562	148059	45198	339456

S Y S T E M   I M P A C T   S U M M A R Y
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM
OPTIONAL SYSTEM IMPACTS
JURISDICTIONS: 1 2 3 4 5 6 7 8
00000 HIGHWAYS   ALTERNATE A0604   STATEWIDE

GAS CONSUMPTION - RURAL - URBAN TOTALS

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	878914	324878	1523245	411536	3138575

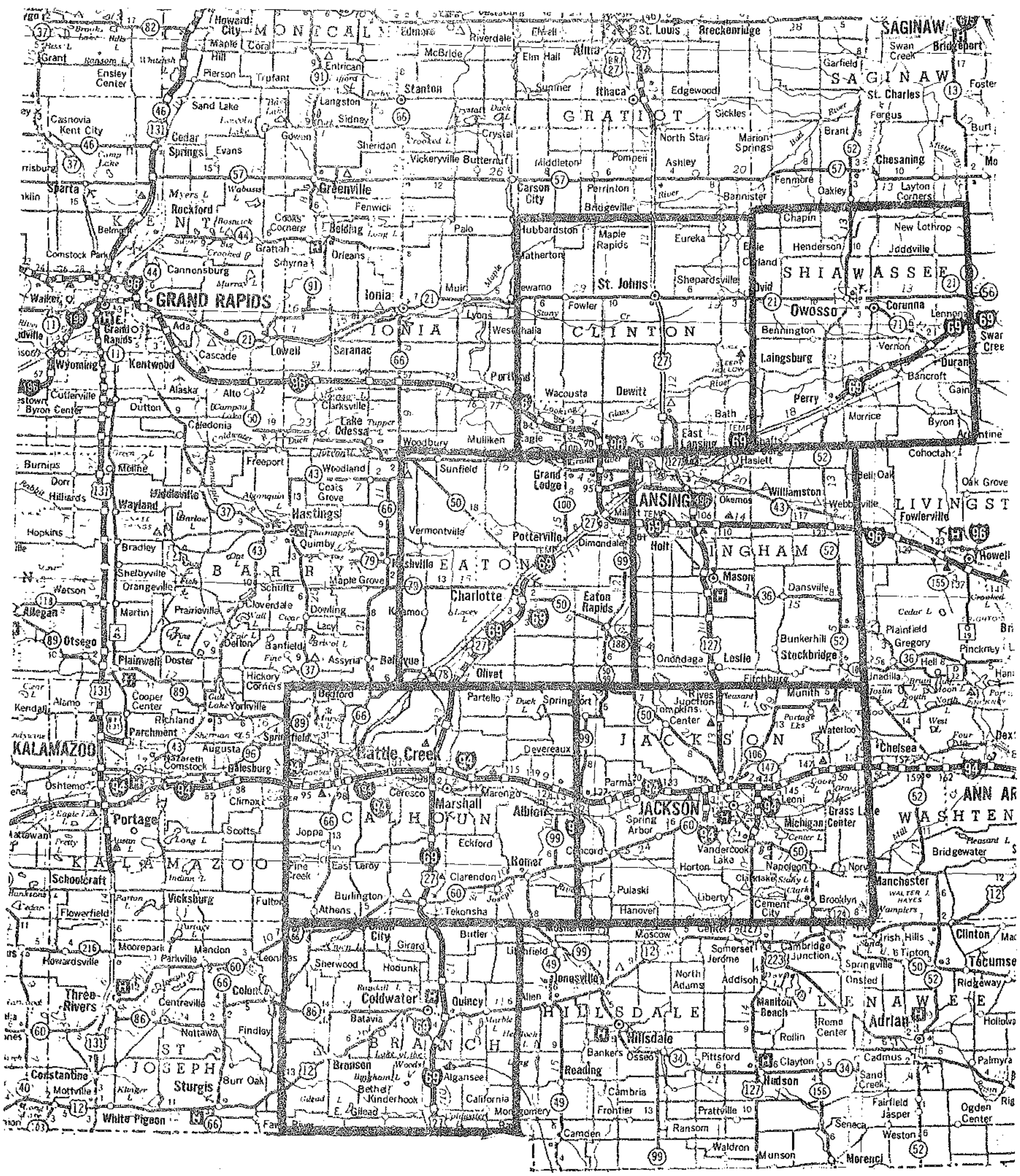
S Y S T E M   I M P A C T   S U M M A R Y
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM
OPTIONAL SYSTEM IMPACTS
JURISDICTIONS: 1 2 3 4 5 6 7 8
00000 HIGHWAYS   ALTERNATE A0604   REGION
REGION CONSISTS OF COUNTIES NOS. 12, 13, 19, 23, 33, 38, 76,

GAS CONSUMPTION - RURAL - URBAN TOTALS

	INTER STATE	FAP FWY	FAP NON-FWY	FAS	TOTAL
ANNUAL GASOLINE CONSUMPTION (THOUSAND GALS.)	130296	26942	140215	44811	342265

FIGURE 5

STUDY REGION



S Y S T E M   I M P A C T   C O M P A R I S O N   **FIGURE 6A**

MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM

PROJECT A0 GAS CONSUMPTION IN THOUSANDS OF GALLONS (URBAN - RURAL)
STATEWIDE SUMMARY FOR INTERSTATE HIGHWAYS

```
      I-----------------I
878914I         ***     I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
862914+---------***--***-+
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
      I         ***  ***I
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846915+---------***--***-+
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830915+---------***--***-+
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      I         ***  ***I
814916I         ***  ***I
      I  ***    ***  ***I
      I-----------------I
         601  604  605
         ALTERNATES
```
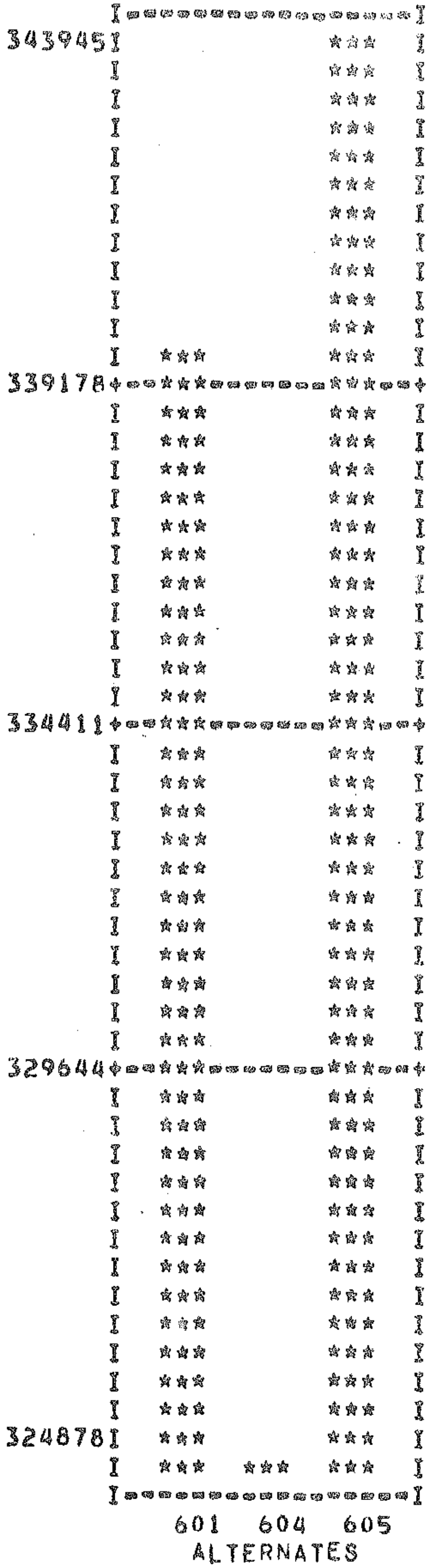

ANNUAL GASOLINE CONSUMPTION (THOUSANDS OF GALLONS)

S Y S T E M   I M P A C T   C O M P A R I S O N
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM **FIGURE 6B**

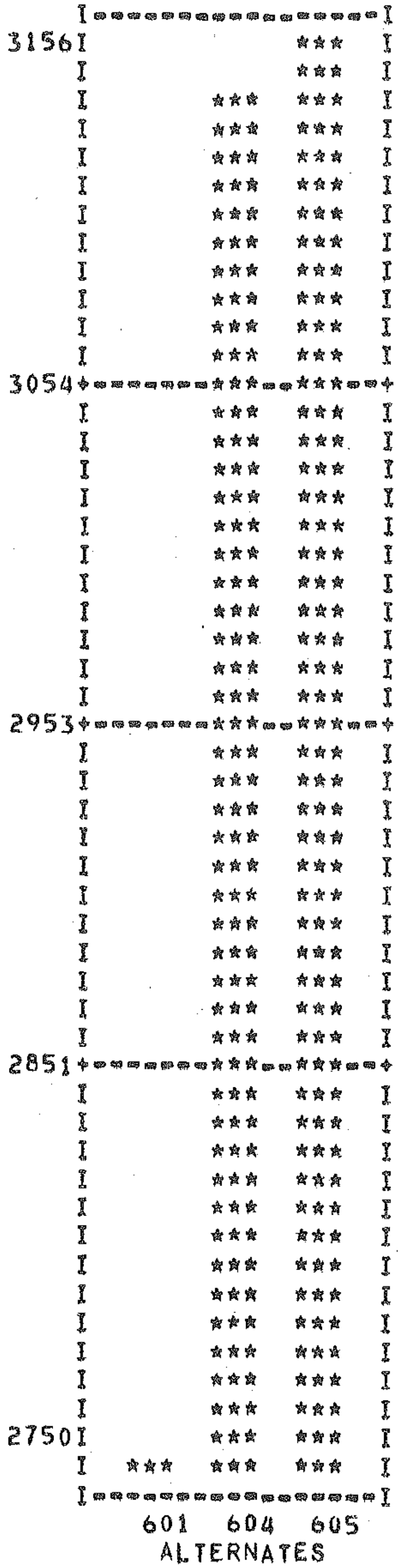
PROJECT A0 GAS CONSUMPTION IN THOUSANDS OF GALLONS (URBAN - RURAL)
STATEWIDE SUMMARY FOR FAP FWY HIGHWAYS



ANNUAL GASOLINE CONSUMPTION (THOUSANDS OF GALLONS)

S Y S T E M   I M P A C T   C O M P A R I S O N
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM   **FIGURE 6C**

PROJECT A0 GAS CONSUMPTION IN THOUSANDS OF GALLONS (URBAN - RURAL) .
STATEWIDE SUMMARY FOR INTERSTATE, FAP, AND FAS HIGHWAYS

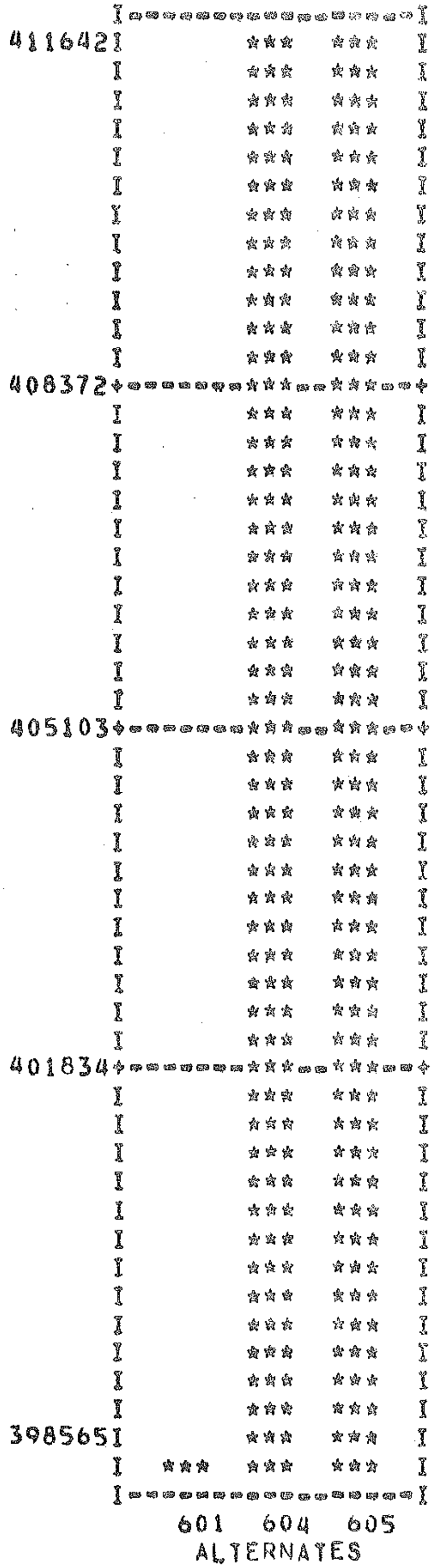


ANNUAL GASOLINE CONSUMPTION (MILLIONS OF GALLONS)

S Y S T E M   I M P A C T   C O M P A R I S O N
MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM

FIGURE 6D

PROJECT A0 GAS CONSUMPTION IN THOUSANDS OF GALLONS (URBAN = RURAL)
STATEWIDE SUMMARY FOR FAS HIGHWAYS

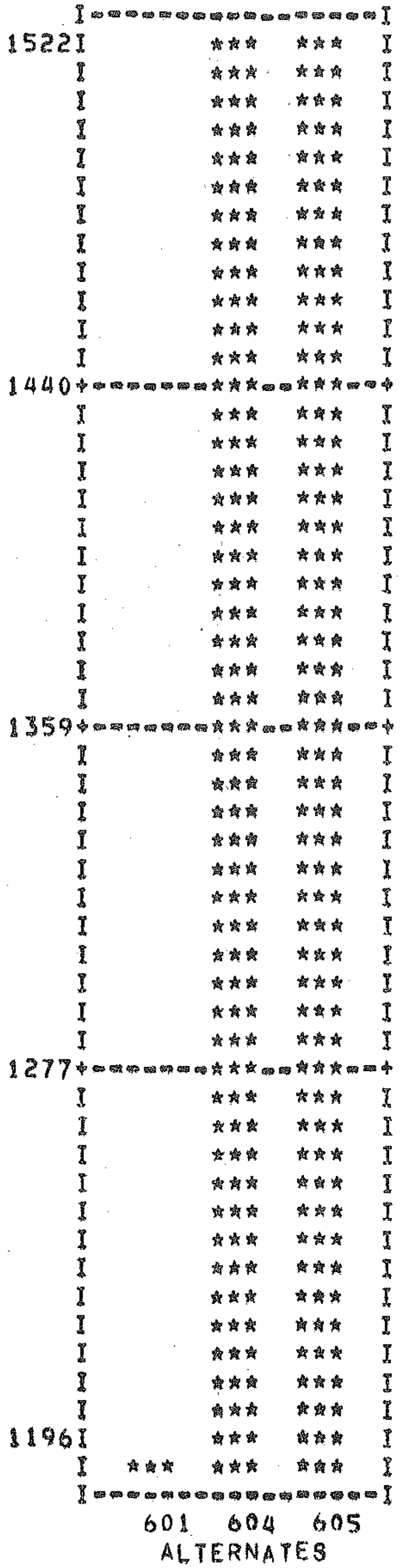


ANNUAL GASOLINE CONSUMPTION (THOUSANDS OF GALLONS)

S Y S T E M   I M P A C T   C O M P A R I S O N

MICHIGAN STATEWIDE TRANSPORTATION MODELING SYSTEM **FIGURE 6E**

PROJECT A0 GAS CONSUMPTION IN THOUSANDS OF GALLONS (URBAN - RURAL)
STATEWIDE SUMMARY FOR FAP NON-FWY HIGHWAYS



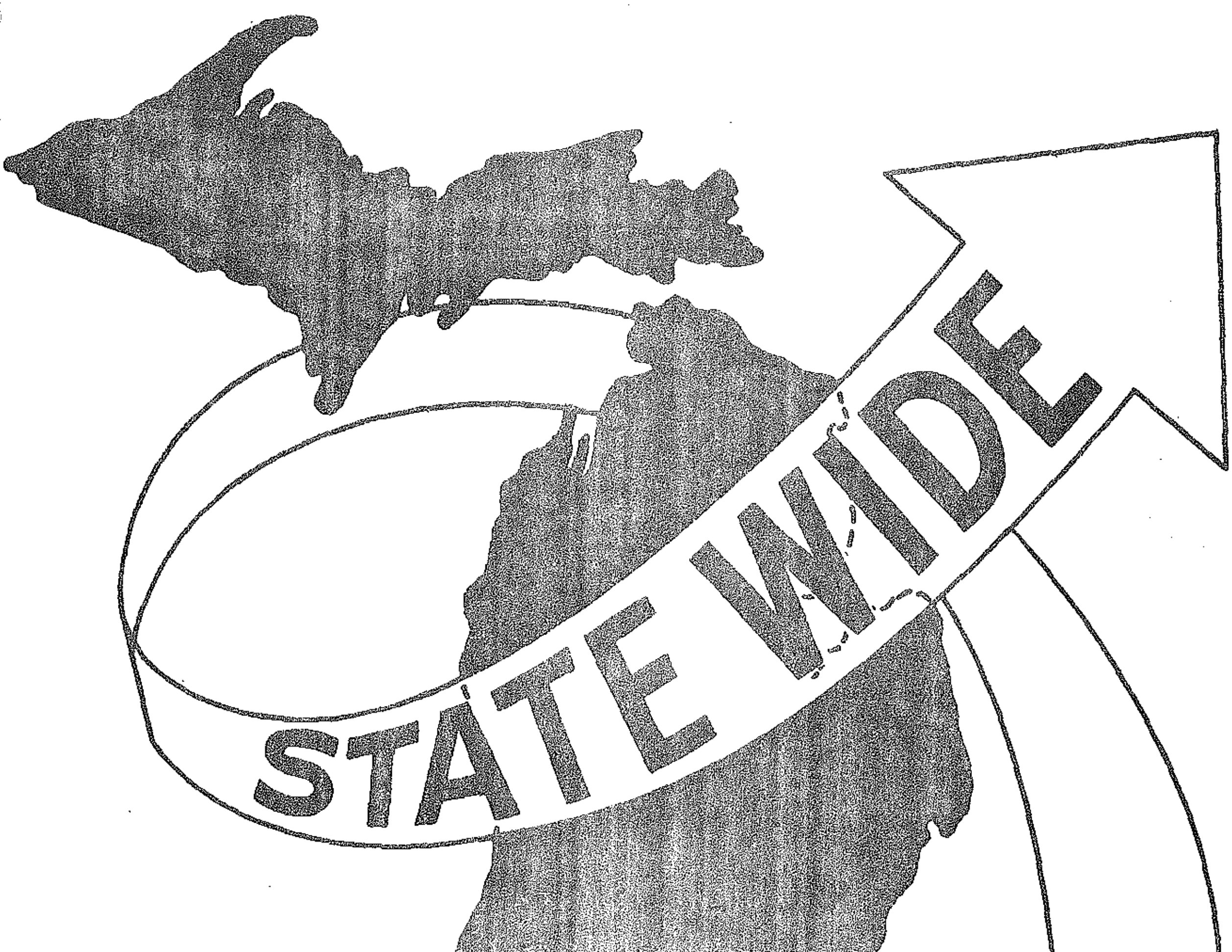
ANNUAL GASOLINE CONSUMPTION (MILLIONS OF GALLONS)

REGION TOTALS (THOUSAND GALLONS)

	ALT. A0601		ALT. A0604		ALT. A0605	
HWY TYPE	EFFECTIVE SPEED	PLANNED SPEED	EFFECTIVE SPEED	PLANNED SPEED	EFFECTIVE SPEED	PLANNED SPEED
Interstate	119636	133391	130296	141774	129677	141475
F.A.P. (FWY)	26562	51756	26942	57823	27392	58602
F.A.P. (NON FWY)	148059	109411	140215	116925	141372	117605
F.A.S.	45198	39349	44811	43768	44979	43894
TOTAL	339456	333908	342265	360291	343421	361577

FIGURE 7

SYSTEM EXTENSIONS



SYSTEM EXTENSIONS

It is anticipated that the simple gasoline consumption measure described herein is only the beginning of a significant battery of energy impact analyses within the Statewide Transportation Modeling System. As the validity and usefulness of modeling energy demand are substantiated, as the basic Modeling System is further refined, and as energy consciousness grows in society and government, the gasoline consumption measure will be extended and refined appreciably. Some of the more likely extensions are discussed below.

A recalibration of the current network model (which as of this writing is in progress) will differentiate between auto and truck travel. Winfrey has tables for trucks as well as autos in Economic Analysis for Highways. Thus, after recalibration it will be possible to calculate gasoline consumption based on travel figures for autos and trucks, whichw ill reflect demand more accurately than current auto-only figures.

As detailed in Statewide Volume XIII, Michigan Goes Multi-Modal, the Statewide Transportation Modeling System is rapidly expanding capabilities to include air, rail, and bus modes as well as highway travel. The energy consumption component of the system will also expand to allow comparison of energy demands of all four modes, permitting a comprehensive measure of energy demand from the transportation sector and comparisons of alternative future modalconfigurations.

The energy measure currently is expressed in gallons consumed (or demanded) and assumes adequate supplies. As the energy situation changes, the impact of varying costs and supply may assume greater importance. Thus a cost factor and/or a supply factor (to allow for free market or rationed supply) may be incorporated into the system.

The above list of probable extensions to the gasoline consumption model demonstrates that the potential exists for vastly improving the knowledge with which government agencies plan for future energy needs. The Statewide Transportation Modeling System is the beginning framework for realizing that potential, if state government elects to follow the conclusions of the Governor's Special Commission on Energy.

CONCLUSIONS

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As energy becomes scarcer or more expensive, the citizens of the state will demand that state government help them conserve fuel. The tool described herein allows the Department of State Highways and Transportation to obtain that end in three important ways:

(1) The Department can assess the energy use of its transportation system while still in the design phase, thereby insuring that the systems which are actually built create the most energy-efficient network.

(2) By measuring impact in concrete layman's terms, rather than mystical acronyms like AADT and DHV, public input can be utilized in the initial design phases of transportation proposals.

(3) The State Energy Office and the Department can cooperate in perfecting a model of the demand for gasoline and other fuels in the transportation sector.

This simple measure, if expanded and used effectively, can help the Department improve its final product, its relations with the public it serves, and its interaction with other agencies in state government.