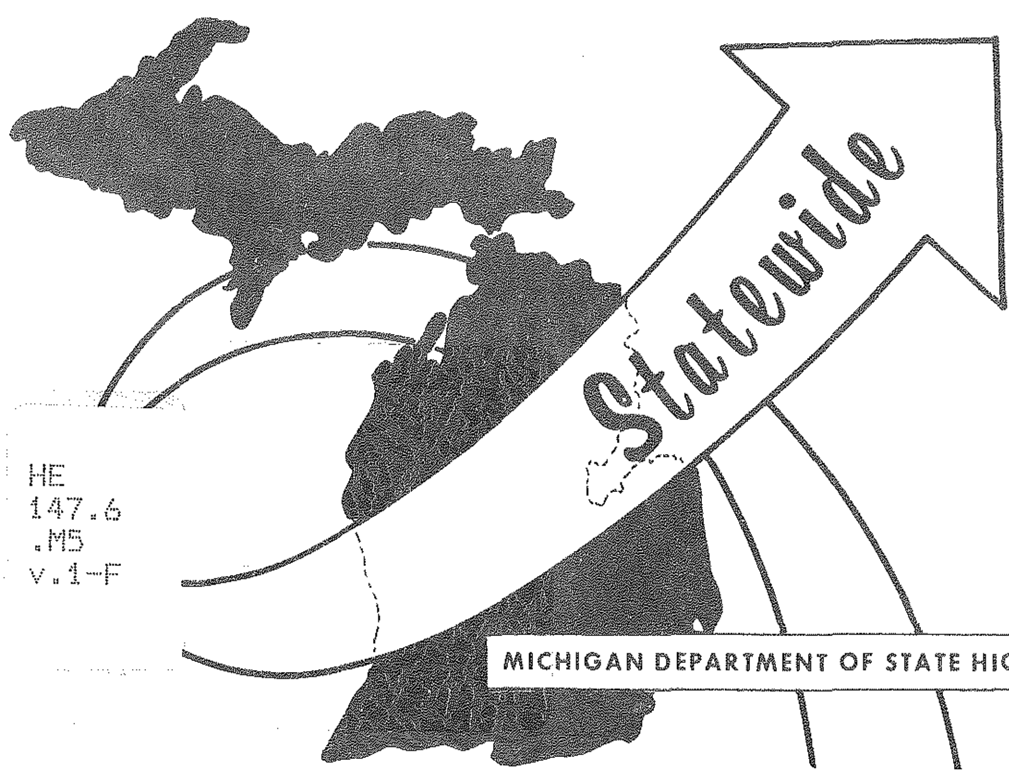
Statewide Transportation Analysis & Research

MICHIGAN'S STATEWIDE TRAFFIC FORECASTING MODEL

VOLUME I-F

AIR AND NOISE POLLUTION SYSTEM ANALYSIS MODEL

JULY, 1973



MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

MICHIGAN'S STATEWIDE TRAFFIC FORECASTING MODEL

VOLUME I-F

AIR AND NOISE POLLUTION SYSTEM ANALYSIS MODEL

JULY, 1973

With the Participation of:
U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF STATE HIGHWAYS

STATE HIGHWAYS BUILDING - POST OFFICE DRAWER K - LANSING, MICHIGAN 48904

JOHN P. WOODFORD, STATE HIGHWAY DIRECTOR

July 13, 1973

Mr. Sam F. Cryderman
Engineer of Transportation Planning
Transportation Planning Division

Dear Mr. Cryderman:

The Transportation Survey and Analysis Section is pleased to present a report entitled "Air and Noise Pollution System Analysis Model". The report documents the construction of a model which is able to compare the air and noise pollution of alternative transportation plans at the system level. Although it is well-known that any major change in the transportation system disrupts travel patterns throughout the state, it has not been feasible until now to monitor the impacts of pollution at any but a local level.

In addition, the model can aid in involving the public in the transportation planning process. A person who knows or cares nothing about Design Hour Volumes and Average Annual Daily Traffic might take notice if he were shown that his house would be quieter and freer of automobile exhaust fumes as a result of new highway construction two miles south of his home.

This report and the modeling process described herein were prepared by Jan M. Kneale of the Statewide Studies Unit under the supervision of Richard E. Esch.

Sincerely,

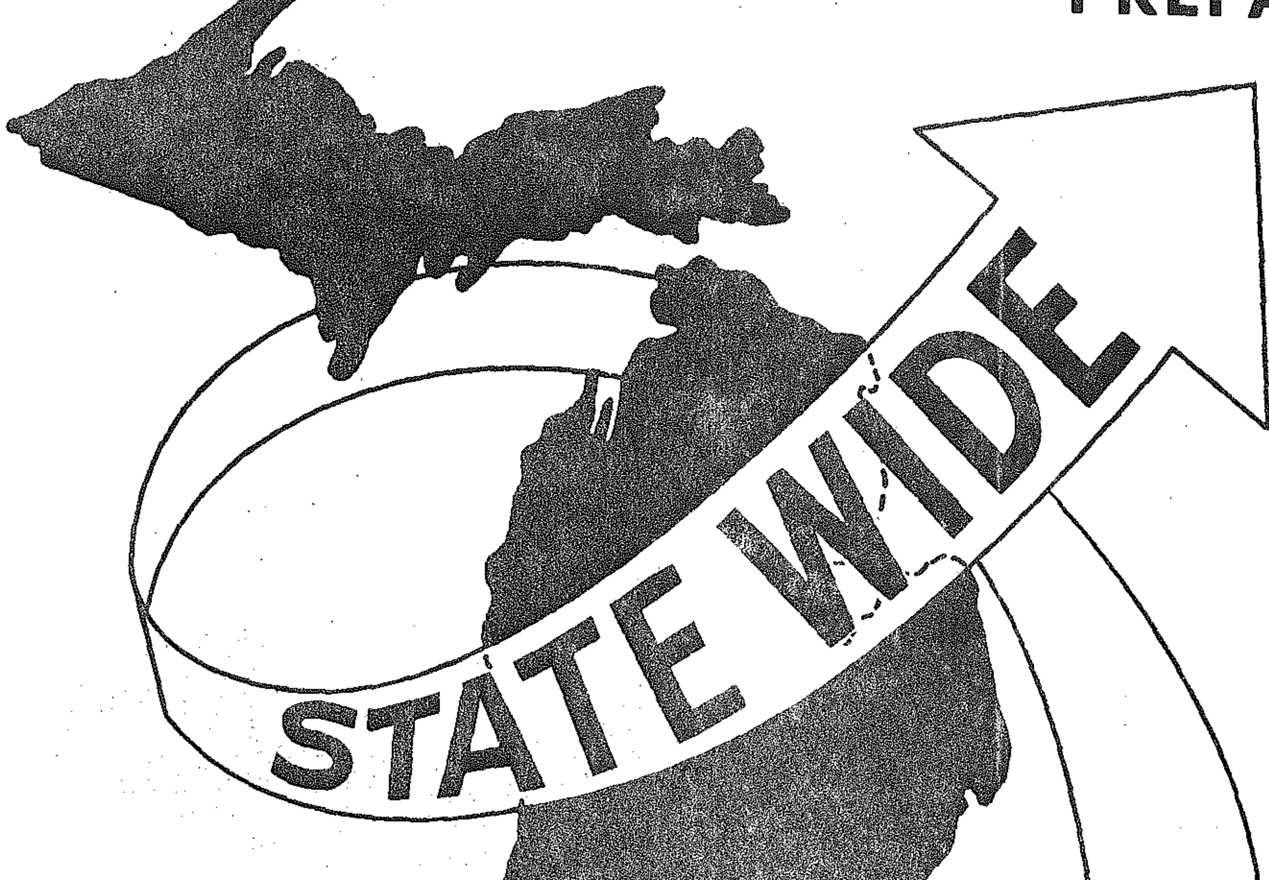
Keith E. Bushnell

Keith E. Bushnell
Engineer of Transportation
Survey and Analysis Section

MICHIGAN
THE GREAT LAKE STATE

TABLE OF CONTENTS

PREFACE



PREFACE

This is the sixth in a series of reports dealing with applications of Michigan's Statewide Traffic Forecasting Model. The preceding five are:

Volume I-A	Proceedings of the Statewide Traffic Forecasting Model Workshop
Volume I-B	Traffic Forecasting Applications, Single and Multiple Corridor Analysis
Volume I-C	Model Applications: Turnbacks
Volume I-D	Proximity Analysis: Social Applications of Alternate Highway Plans on Public Facilities
Volume I-E	Cost-Benefit Analysis

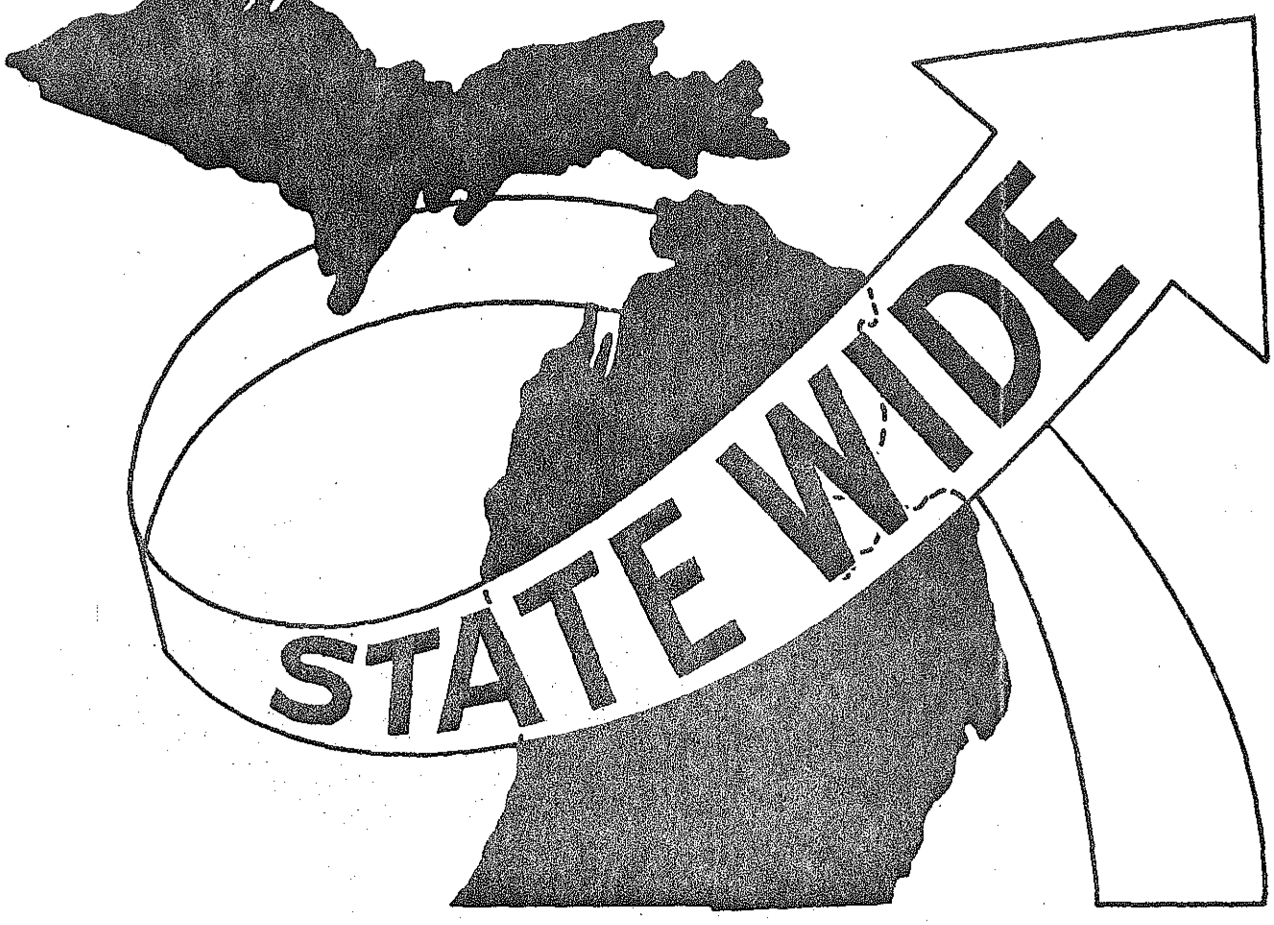
This report is Volume I-F. It deals with an automated routine which will quantitatively measure the amount of automobile noise and air pollution emissions at the system level. Using this technique, it is possible to receive one kind of estimate of the degree of air and noise pollution on alternative highway plans.

Section 109(h) Title 23, USC as contained in Section 136(h) of the Federal-Aid Highway Act of 1970 requires that final decisions on highway projects must be made in the best overall public interest. More specifically, this legislation, in Sections 109(i) and 109(j), requires that each highway project include an estimate of the amount of noise and air pollution which will be generated.

The problem of estimating automobile pollution does not appear to be a concern of the Highway Department alone. It is hoped that urban planners, public health administrators, and conservationists all might benefit from knowledge of the concentration of pollution.

This report presents a device for quickly and systematically measuring the effects of automobile pollution on the entire trunk line system. Such a technique may be beneficial to the Department in supplying the information required by the 1970 Federal-Aid Highway Act.

INTRODUCTION



INTRODUCTION

Environmental conservation and pollution control have become topics of considerable public interest in recent years. One goal of environmentalists has been to come to terms with the problem of air and noise pollution, particularly in urban and suburban areas, where medical studies indicate such pollution is becoming a health hazard.

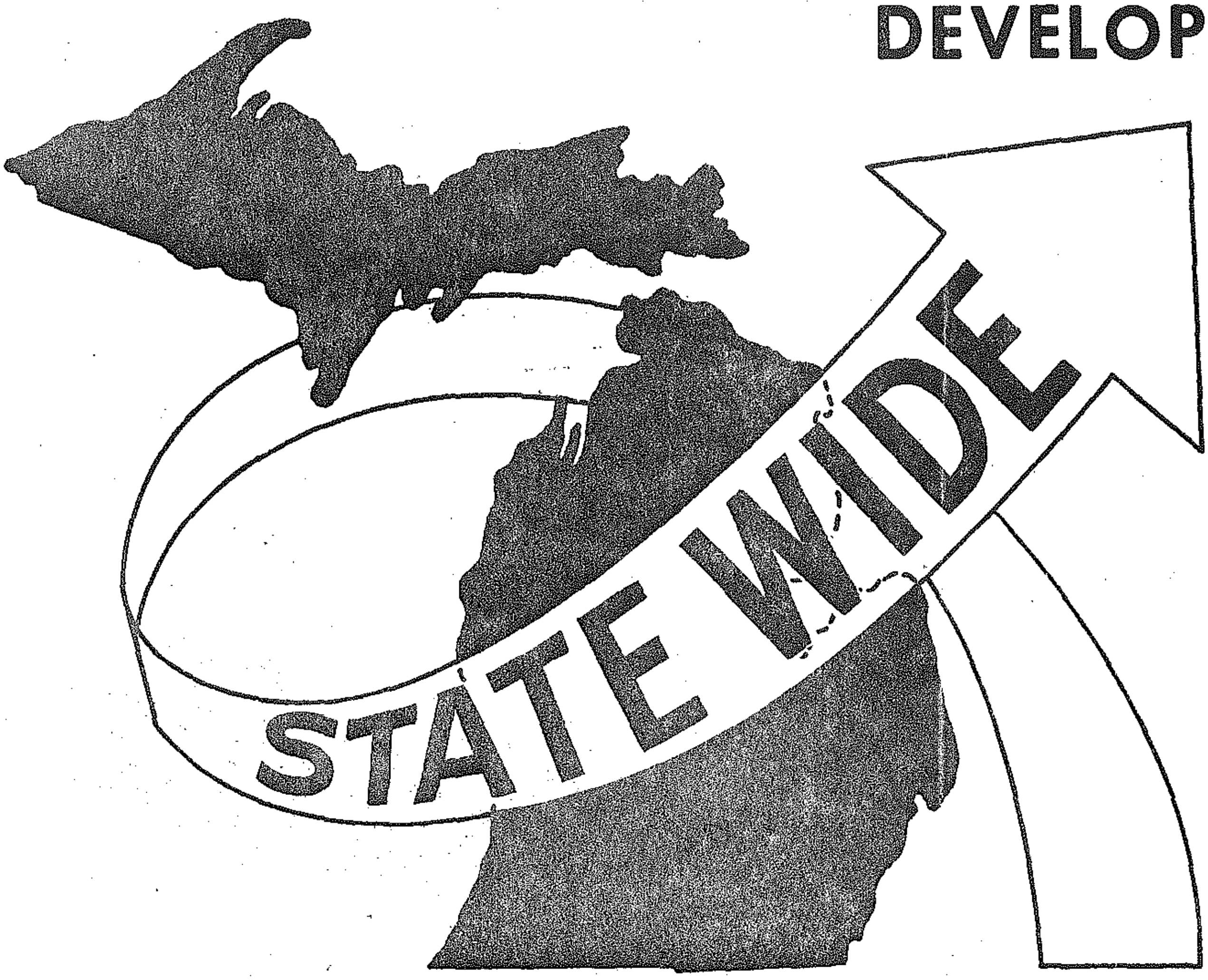
In all areas of Michigan, the automobile contributes its share to both air and noise pollution, which in some areas may have had a detrimental effect on the environment. Yet, little has been done to devise a system-level method to accurately and efficiently estimate the amount of pollution generated by automobile and truck traffic, although many project-oriented routines have been devised for this purpose.

In view of these medical warnings and widespread public concern, the Federal government has enacted into law several pieces of legislation which are designed to ensure that possible adverse effects of air and noise pollution be evaluated for any proposed project on a Federal-aid highway system. Among these new laws is the Federal-Aid Highway Act of 1970 (P.L. 91-605), which clearly states that all highway projects must be planned in the best overall public interest. Furthermore, Section 136(h) specifies that it is highly desirable to adopt a total highway plan which minimizes air and noise pollution.

The traditional approach to meeting these new Federal requirements is through the use of project-oriented impact analysis routines. The primary assumption of these models is that each highway or highway link is a separate and complete entity in itself. It is therefore concluded that the amount of automobile air and noise pollution can be estimated by considering only those traffic factors such as traffic volumes, average speed, and construction type, which pertain to the proposed highway. However, this approach can not provide an accurate estimate of the impact of the proposed highway on the pollution level of the state as a whole. It should be clear that when a new highway is constructed, or an old upgraded, traffic which previously used other roads will be diverted to the new or the upgraded highway, and therefore the pollution levels on the old, unchanged roads will be decreased. Consequently, the actual increase in the pollution level of an impacted community may be far different than the sum of the pollution generated on the new highway plus the pollution generated on the old roads.

The project-oriented routine is not a dynamic tool, and as such it may not provide as accurate an estimate of the impact of automobile pollution in <u>any</u> arbitrarily specified area as might be desired. Therefore, it may be beneficial to employ a system-level method which will satisfy Federal requirements and be sensitive to changing traffic patterns.

PROGRAM DEVELOPMENT



PROGRAM DEVELOPMENT

It was the purpose of the Statewide Studies Unit to develop a prediction model for levels of automobile air and noise pollution which could be integrated with its systems analysis approach to highway impact evaluation. Only two courses of action were feasible. Either the Unit could develop its own computer program depending upon the Statewide model, or an existing program could be adapted to Statewide's analysis system and interfaced with the Statewide Travel Model. Since Stanford Research Institute (SRI) and the Testing and Research Division (T&R) of Michigan's Highway Department had already done considerable work towards the development of system-oriented pollution models, the second plan of action was chosen.

Copies of the pollution models under consideration were easily obtained. It was found that the SRI pollution models are an integral part of the Stanford Network Analysis Package (SNAP), which was recently purchased by the State of Michigan. The T&R air and noise pollution models, on the other hand, were made available to the Statewide Unit through the cooperation of the T&R staff.

Upon comparing the air pollution models it was found that the one developed by T&R had two drawbacks. First, it was not, at that time, fully operational, and further research would be necessary before it could be incorporated into the Statewide system. Secondly, the T&R model required forecasts of weather conditions as input data. This information was not readily predictable. On the other hand, the SRI model was completely operational, and the information required for input data was either already on the Statewide data files or easily obtainable. Furthermore, the SRI model has an output format of pounds emissions per square mile of the summary region, which is a quantity that facilitates comparisons between alternative highway plans. For the purpose of this report, output has been generated at the county level. The output format of the SRI model is illustrated in figure 1.

Although all three of the available noise pollution models would provide adequate system-level measures of the adverse effects of noise, two considerations led the Statewide Studies Unit to implement the SRI noise pollution model before attempting to interface either of those models developed by T&R. First, both of the T&R models would have to be modified for use on the Statewide system. Since the Statewide Studies Unit wished to have a pollution model operational in a short period of time, the necessity for further developing T&R's models was a drawback. Secondly, the SRI model provides an estimate of the number of people affected by noise pollution at greater than 70dBA (refer to output format of SRI model, figure 1). The original version of the T&R model yields decibel levels at user-specified distances from highway links. T&R's second version, although producing estimates of the number of people affected by noise at a user-specified decibel level, was in the process of being modified.

FIGURE 1:
OUTPUT FORMAT FOR
SRI AIR AND NOISE POLLUTION MODEL

County	Pounds Emission Per Square Mile			Number of People Exposed to Noise Levels 70dBA
	CO	HC	OXN	
TOTALS				

KEY: CO = Carbon Monoxide

HC = Hydrocarbons

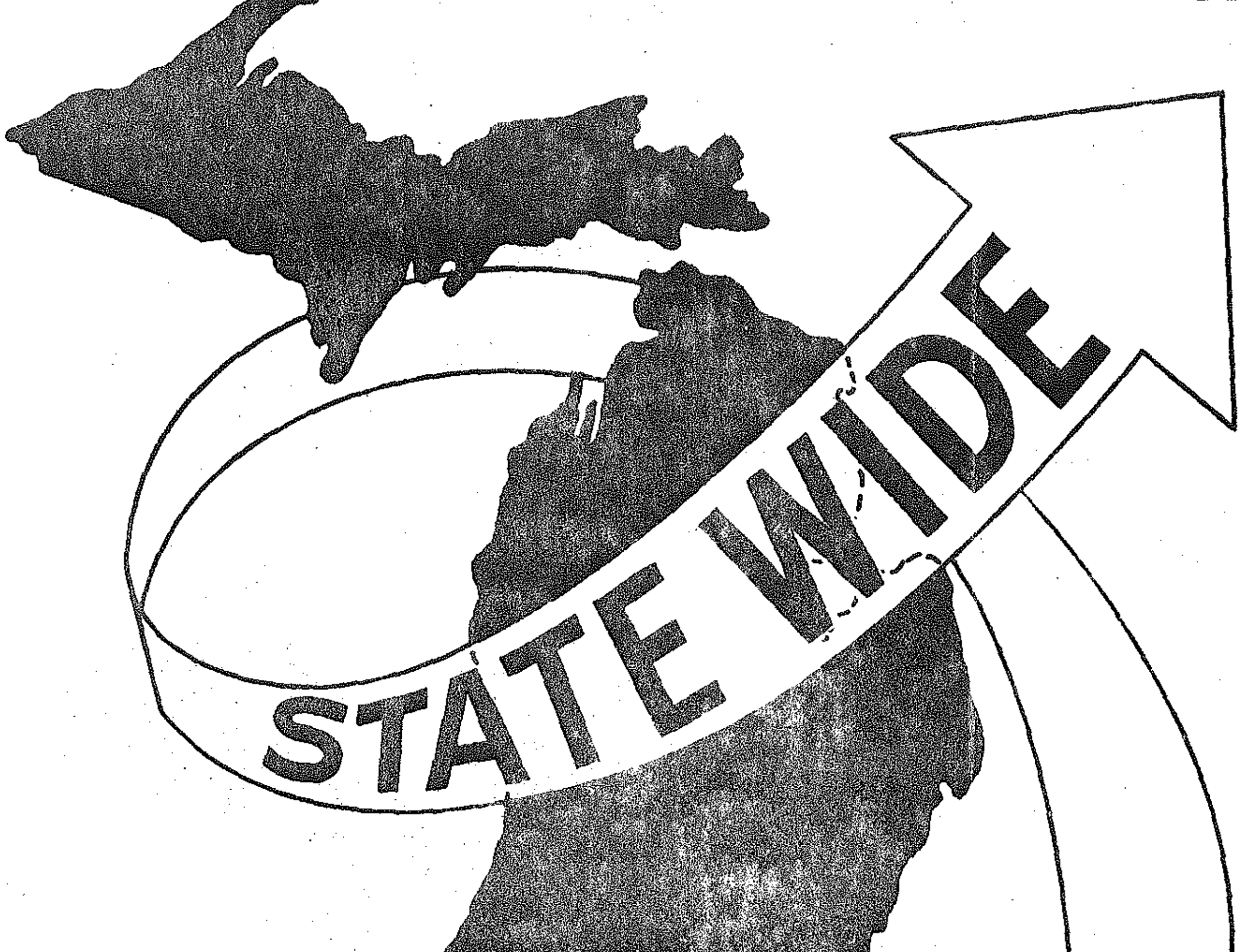
OXN = Nitric Oxides

It was decided that primary emphasis would be placed on estimates of people affected, and therefore the SRI noise pollution model was implemented; at a future date, the original T&R model would be used in conjunction with the Statewide facility file to offer a different perspective on the levels of noise pollution, and the modified version of the T&R model would eventually be implemented to offer comparative population estimates.

Once it had been decided to use the SRI pollution models, it was necessary to convert them from the Fortran IV language used on the CDC-6400 computer to that version of the language used on the Burroughs B-5500 system. It was also necessary to append those statements which would enable the pollution model to access the Statewide highway link data files.

Finally, to make the air and noise pollution models efficient to operate, they were meshed into one computer program, and a demographic file containing input data was created. It was found that the Statewide system already had the necessary data for the demographic file stored in either the socio-economic data bank or the land-use data file. Therefore, a routine was written to combine this data into one workfile which could be more easily accessed by the pollution model.

PROGRAM OPERATION



PROGRAM OPERATION

The following data must be input to the pollution model:

(A) For each highway link

(1) Zone number

(2) Traffic volume

(3) Width of the right of way (in feet)

(4) Length of the link (in miles)

(5) Average traffic speed (in miles per hour)

(6) Construction type (for example, expressway, construction at grade, depressed 20 feet or more, etc.

(B) For each instate zone

(1) County number

(2) Area (in square miles)

(3) Population estimates for the year of the traffic forecast

(C) For the study as a whole

(1) Year for which estimate is to be made

(2) Volume factor which converts input volume to hourly volume.

(3) Percent of cars in each of six age groups: pre-1968, 1968-69, 1970-72, 1973-75, 1975-79, 1980-on.

After preliminary computations, such as initializing arrays to zero, the calculation of the noise pollution indicator is begun. (See data flow chart and program operational chart, figures 2 and 3, respectively).

FIGURE 2

DATA FLOW

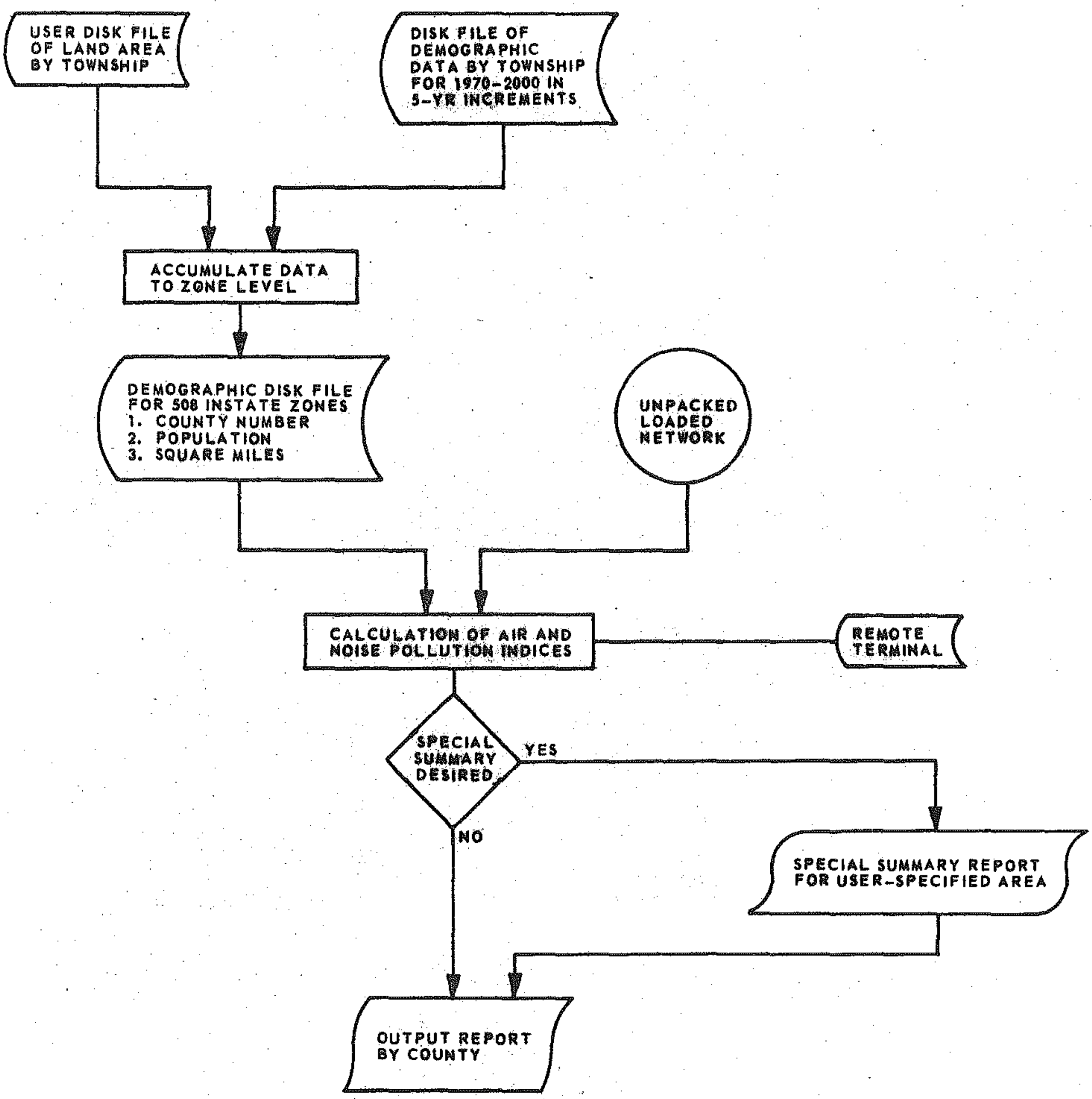
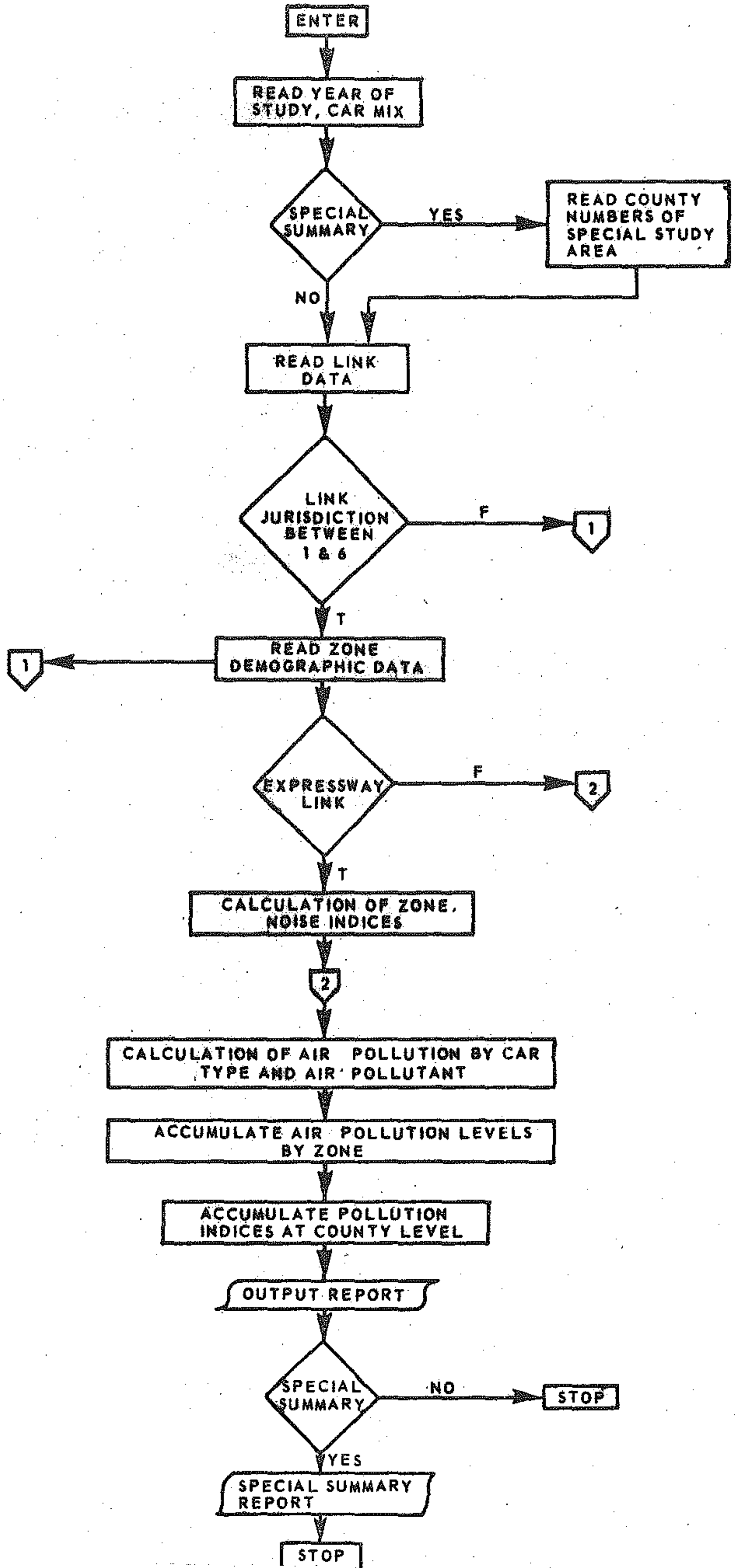
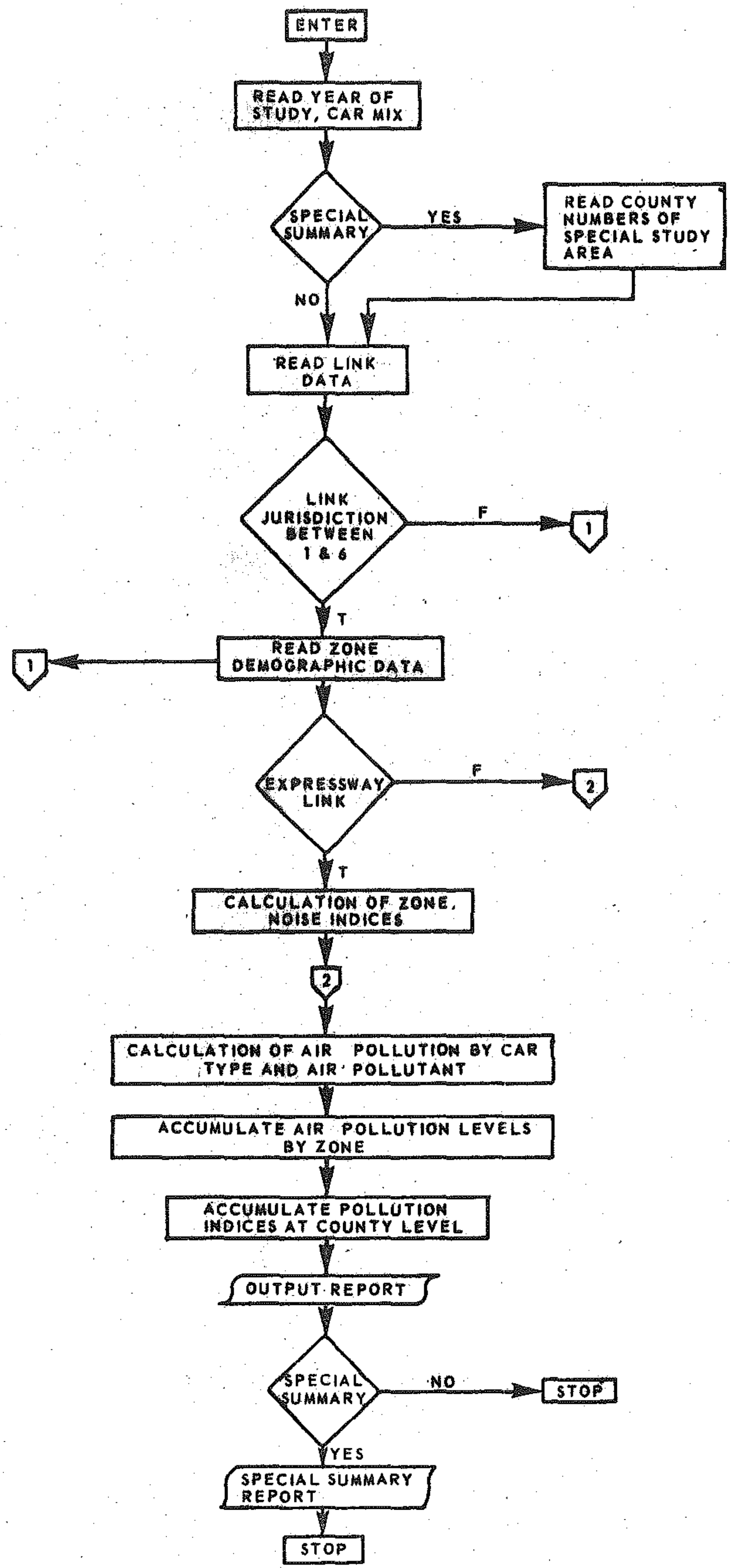


FIGURE 3

PROGRAM OPERATION



PROGRAM OPERATION



The initial task is to estimate the distance from the center of the highway link's right-of-way to the outer edge of the noise polluted area, which is defined to be that land area adjacent to the link which is exposed to noise levels in excess of 70dBA. The following equations calculate this distance.

(1) $A = [S^8(V^4+K)]^{1/2}$

(2) $B = \frac{S^4(V^2+A)}{C}$

(3) $D70 = (B^{1/2})$

Key: k and c denote constants

s is the average link speed

v is the average hourly volume.

One half the width of the link's right-of-way is then subtracted from the D70 value; the resulting distance is the width of the impacted area on one side of the highway link. This corrected distance is then multiplied by both the average population density of the zone through which the link passes and the length of the link to yield an estimate of the number of people impacted by noise pollution along one side of the link's right-of-way. Since population is assumed to be symmetrically distributed about the link, in order to get the final estimate of the total number of people affected by traffic noise (NPP), a factor of two must be introduced. The equation which performs these calculations is:

(4) $NPP = \frac{2\ (D70-1/2ROW)(L)}{M}(P)$

Where ROW is the width of the right-of-way, L is the length of the link, P is the average population density, and M is a constant.

This method has a couple of interesting aspects. First, the number of lanes and the lane width have only minimal effect on the distance to which the noise level is projected. The following example illustrates this fact.

> ... An observer 250 feet from the center of a 6 - lane facility with a 25 - foot median would be 246 feet from the effective center of the noise source. If the median were increased to 45 feet, he would be 244 feet from the effective center.[1] In light of this observation, no factor has been introduced to correct for these minor differences.

Secondly, the construction type of the link greatly influences the level of noise pollution. For example, a highway containing traffic signals would create significantly more noise then one with limited access and no traffic signals. Furthermore, figure 4 clearly shows that noise pollution of 70dBA or more is probably exceeded only on freeways and expressways; therefore the Statewide Studies model contains correction factors which modify the rate at which the model generates the noise pollution index, based on the link's construction type.

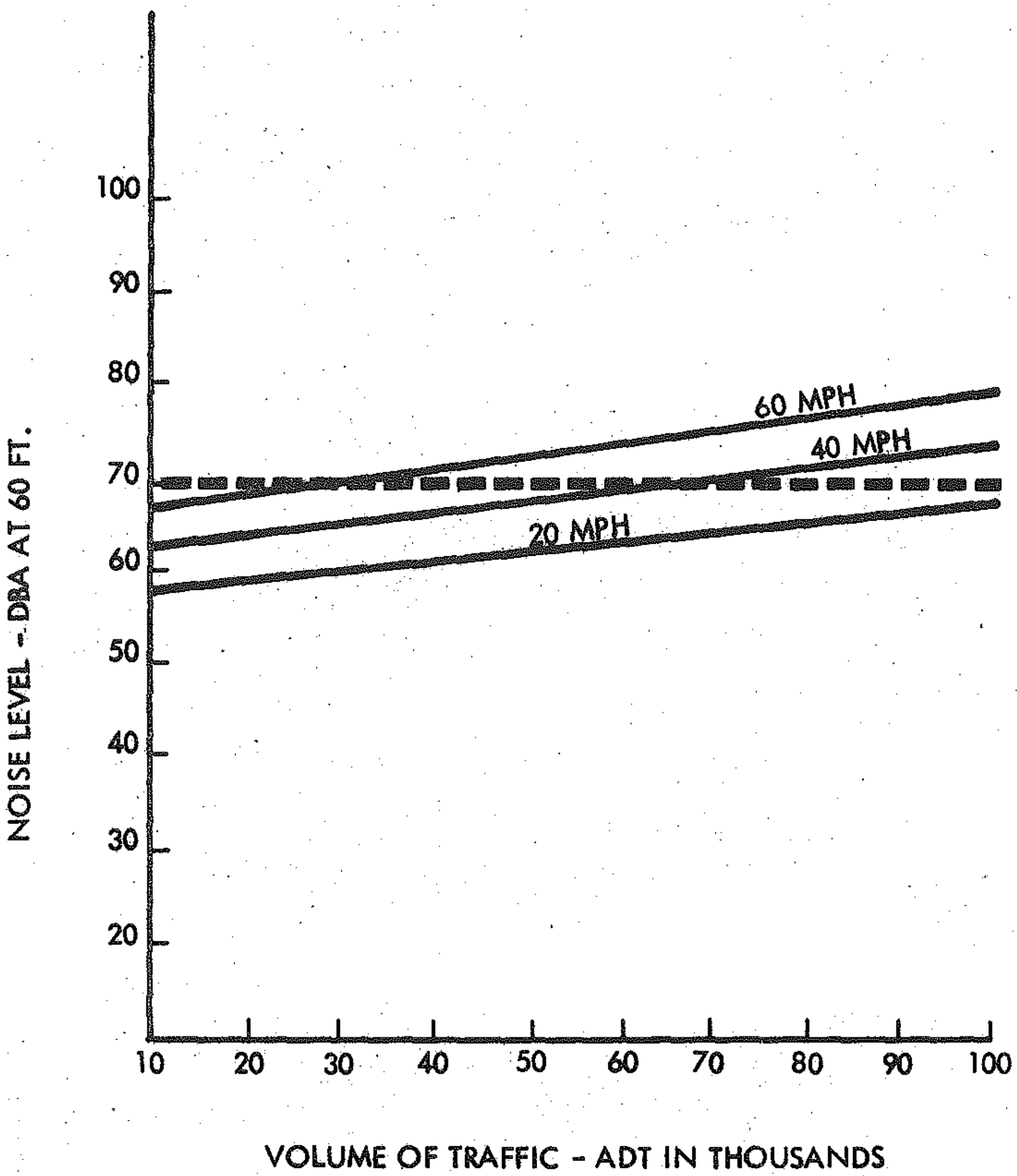
After the noise pollution index has been calculated the number of pounds or emissions per square mile of the three major air pollutants -- nitric oxide, carbon monoxide, and hydrocarbons -- are computed for all the counties as well as for any user-specified

---

1 G. E. Klein et al, Methods of Evaluation of the Effects of Transportation Systems on Community Values, pg. 212.

FIGURE 4

SOUND LEVELS NEAR TRAFFIC



REFERENCE: G.E. KLEIN Pg. 209

special summary region. SRI has developed a system of non-linear regression equations to estimate the output of these three pollutants. Estimates for different model years of automobiles are generated separately, taking into consideration the lower emissions produced by vehicles made after the passage of Federal emission control legislation. As an example of this procedure consider the following set of equations which was developed to estimate the air emissions by vehicles in the pre-1968 date-of-manufacture category.

(1) $CO = (2.46S^{-.85})(L)(VOL)(PCT)$

(2) $HC = (.104S^{-.66})(L)(VOL)(PCT)$

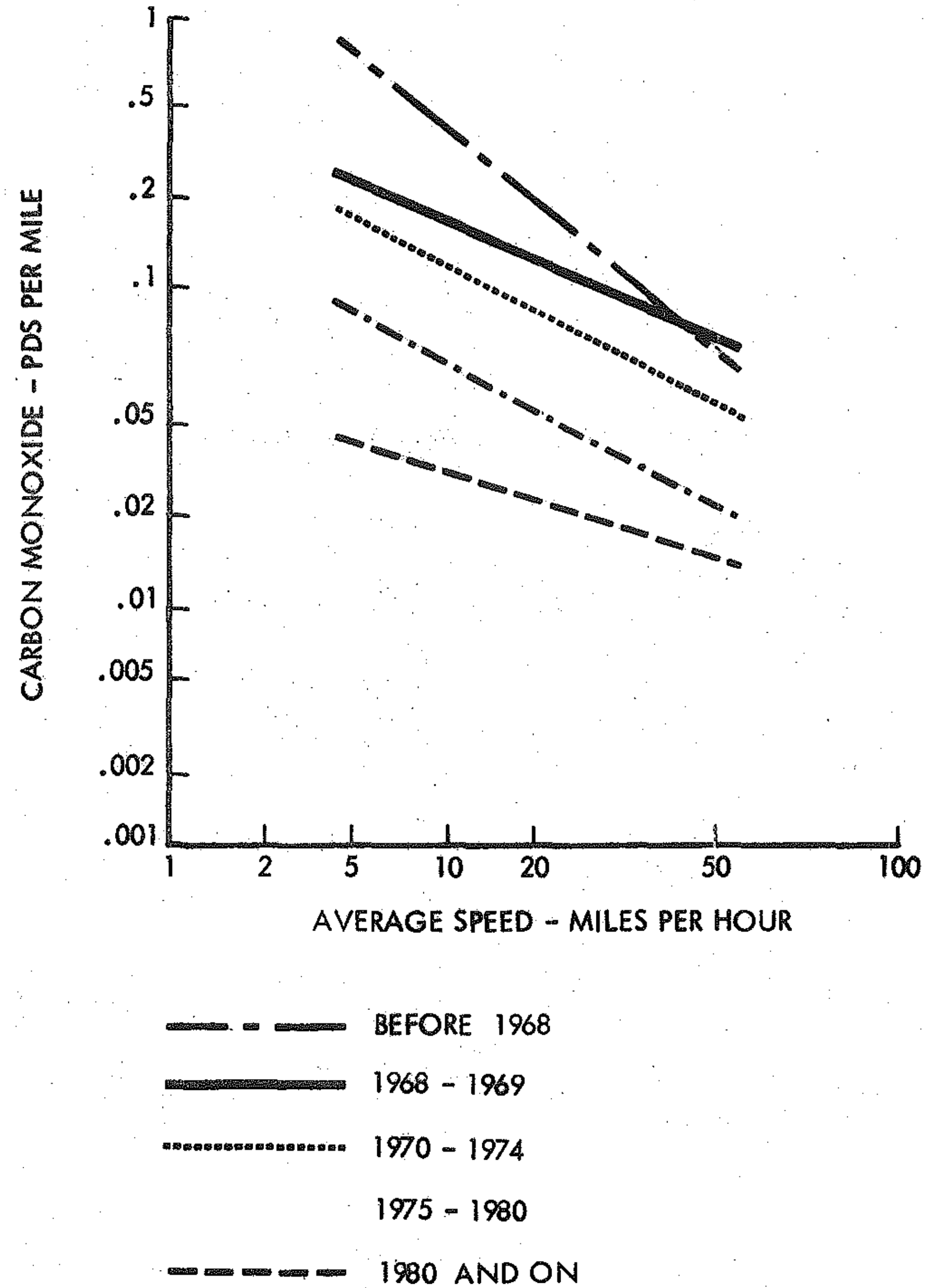
(3) $OXN = .0125\ L\ (VOL)(PCT)$

Key: S is average vehicle speed
L is link length
VOL is average traffic volume
PCT is percentage of cars using the link which fall into this age classification

It is interesting to note in the preceding equations that only carbon monoxide (CO) and hydrocarbons (HC) are dependent on the average link speed. Figures 5 and 6 clearly illustrate this relationship. For a complete chart of the regression equation functional relationships between emissions and speed -- for example, $2.46S^{-.85}$ in equation (1) -- refer to figure 7. A more precise explanation of the procedure which led to the derivation of these coefficients is offered by G. E. Klein (reference 1).

FIGURE 5

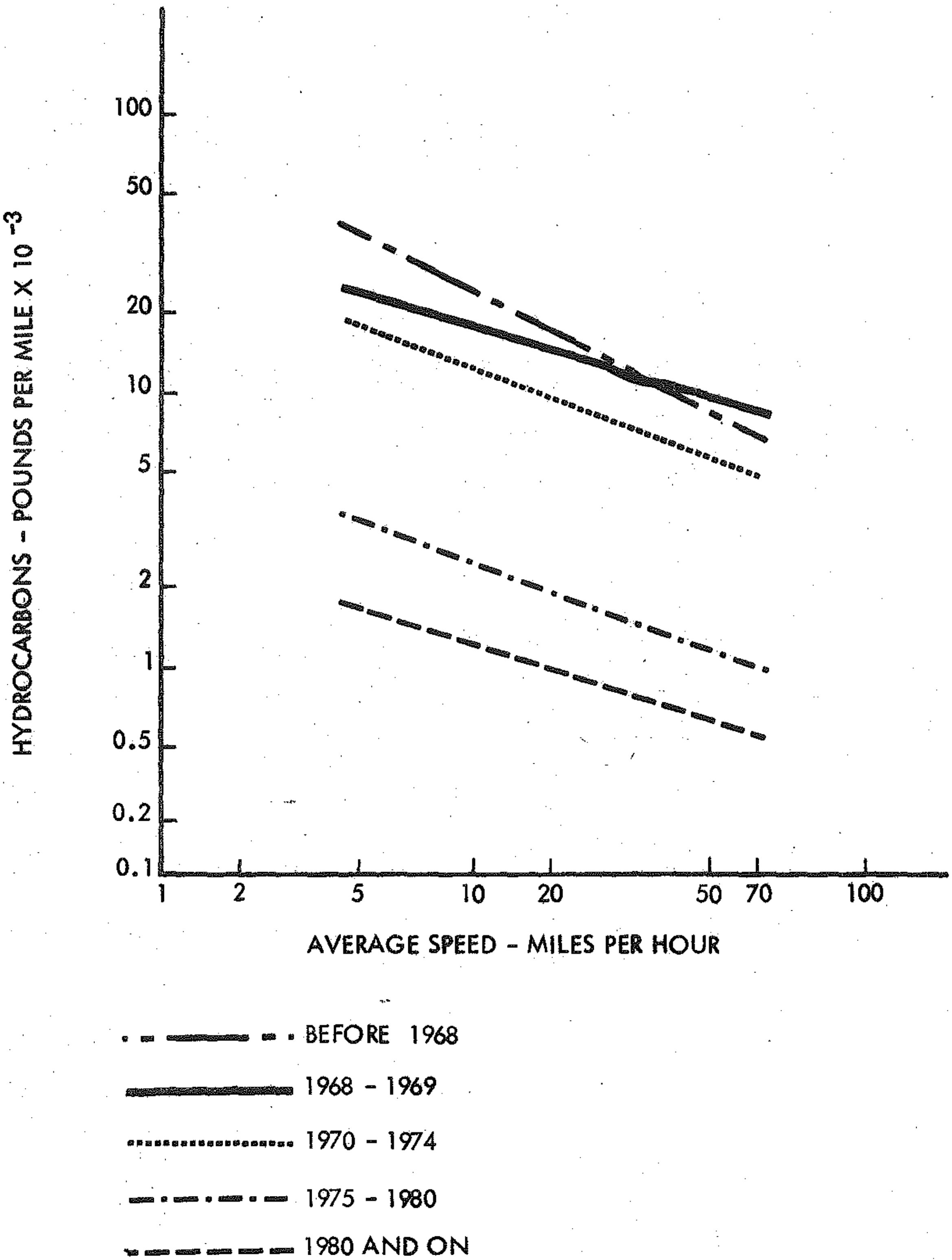
CARBON MONOXIDE EXHAUST EMISSIONS FROM AUTOMOBILES OF VARIOUS YEARS



REFERENCE: G.E. KLEIN - Pg. 193

FIGURE 6

HYDROCARBONS EXHAUST EMISSIONS FROM AUTOMOBILES OF VARIOUS MODEL YEARS



REFERENCE: G.E. KLIEN Pg. 183

FIGURE 7:
ESTIMATED EMISSION FACTORS FOR NETWORK ANALYSIS

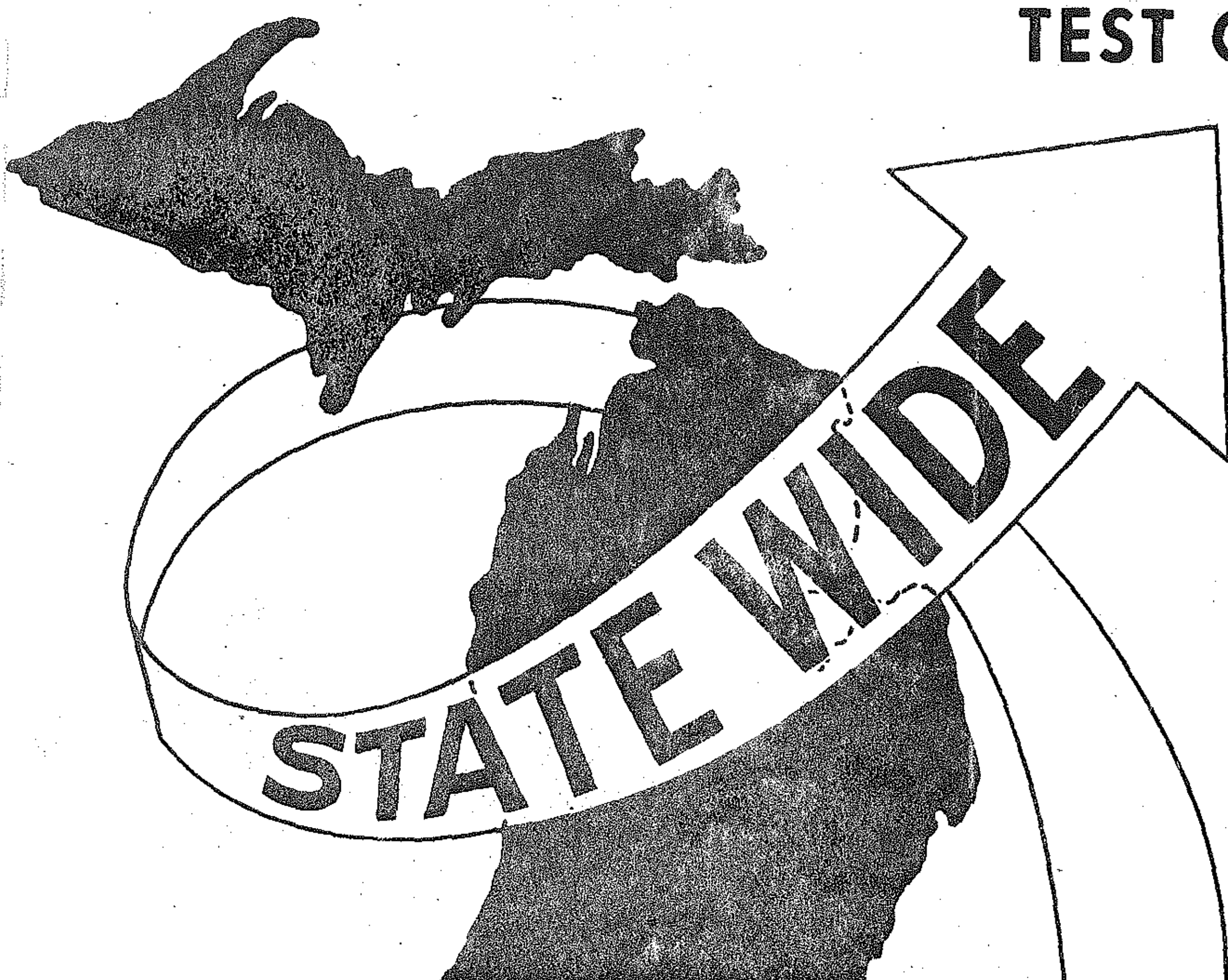
MODEL YEAR	CARBON MONOXIDE (lbs/mile)	HYDROCARBONS (lbs/mile)	OXIDES OF NITROGEN (lbs/mile)
Pre - 1968	$2.46S^{-.85}$	$.104S^{-.66}$	.0125
1968 - 1969	$.54S^{-.48}$	$.045S^{-.45}$	.0125
1970 - 1972	$.36S^{-.48}$	$.030S^{-.45}$	.0125
1973 - 1974	$.36S^{-.48}$	$.030S^{-.45}$	.0066
1975 - 1979	$.17S^{-.48}$	$.0067S^{-.45}$	.0022
1980 and on	$.074S^{-.48}$	$.0034S^{-.45}$	.0011

Where S is the average vehicle speed in miles per hour

Reference: G. E. Klein Pg. 182.

General information about the development of the original pollution model can be found in chapters 7 and 8 of Methods of Evaluation of the Effects of Transportation Systems on Community Values by G. E. Klein (et al) from SRI. The actual programs, and the technical information relating to their use, can be found in SNAP Volume II, program EVAL (Passenger Transportation Systems Evaluation), subroutine COMMUN.

TEST CASE



TEST CASE

The test case consists of comparing an alternative highway building plan with the "do-nothing" alternative, hereafter referred to as "alternate 0 (zero)". This technique of comparison with a do-nothing alternative follows the action plan guidelines established by the Federal Highway Administration. Alternate 0, depicted in figure 8, is the basic 1970 highway network currently in use.

It must be stressed that this is a test case. All inputs to the pollution model have not yet been edited for correctness. Therefore, the model results displayed here should be used only as an example of the types of output produced by the process; they cannot be construed as factual pollution estimates for the alternates involved.

The comparative alternate, which will be refered to as alternate 1, is formed by making the following changes in alternate 0.

1) US-31 is upgraded to freeway standards north of Montague.
2) US-131 is upgraded to freeway standards between M-57 and the M-72 interchange.
3) A new freeway parallels M-72 from Traverse City to I-75.

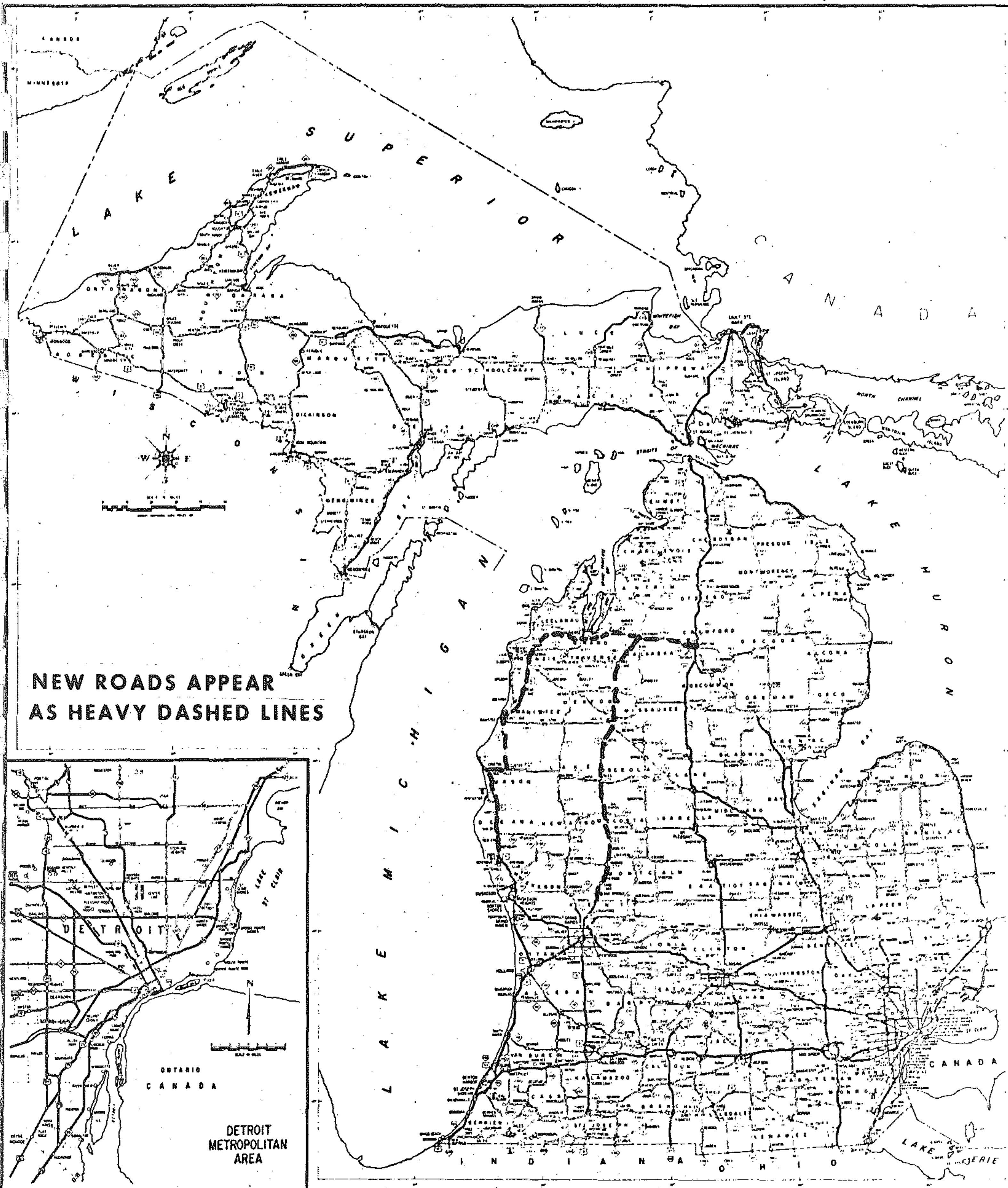
The new roads are depicted in figure 9 as heavy dashed lines.

For the purposes of the test runs, existing alternate assignments already completed by the Statewide Studies Unit were utilized. Consequently, the year 2000 was selected as

FIGURE 8:

DO-NOTHING ALTERNATE MAP

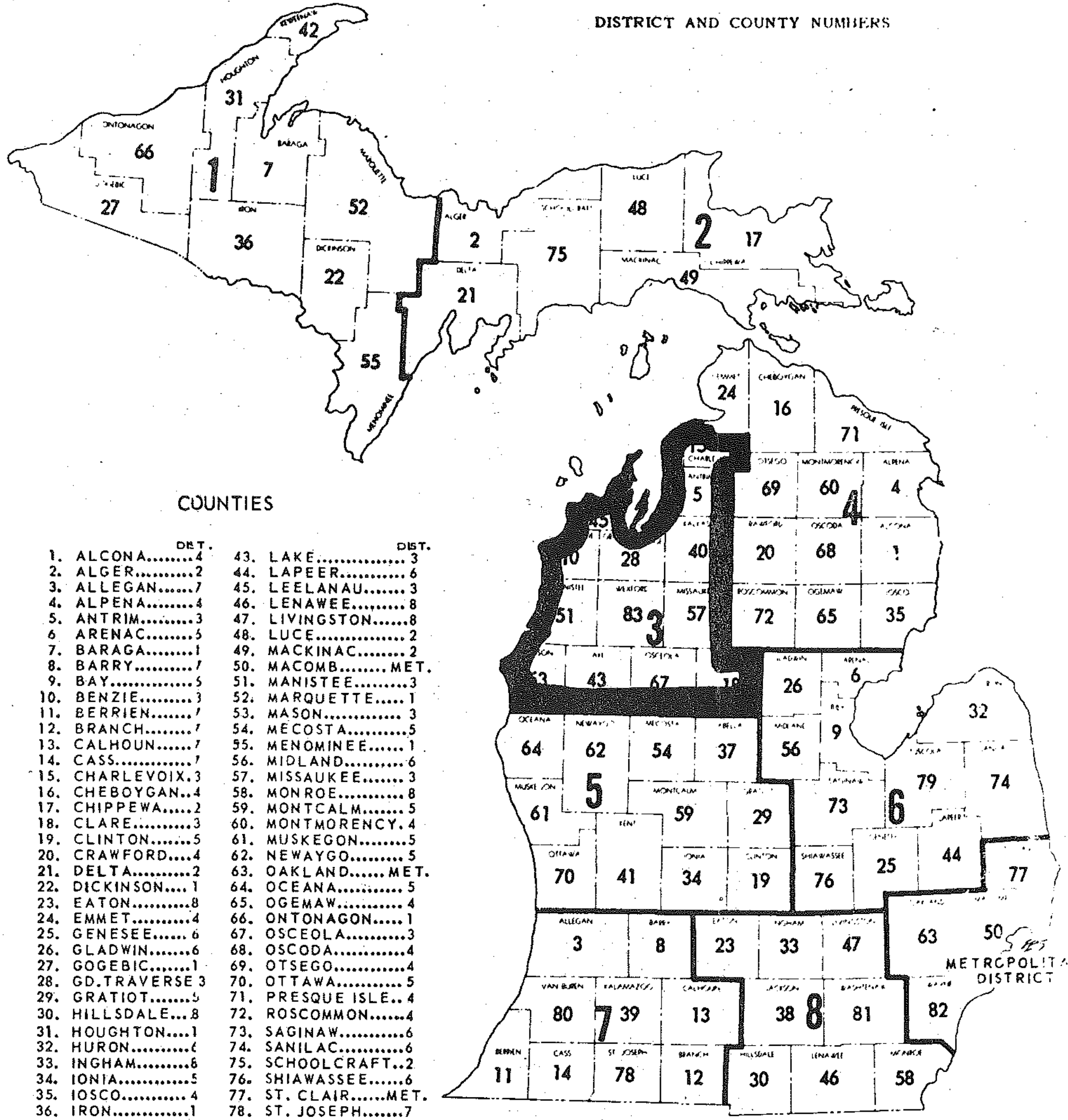
FIGURE 9: MAP OF ALTERNATE 1



the year of study, with all vehicles on the highway system necessarily assumed to be of post-1975 manufacture date. Furthermore, the option for a special summary report on a user-specified area has been exercised for state district 3, which is depicted in figure 10, since this district contains the largest portion of both US-31 and US-131. It seems reasonable to expect that the largest change in pollution levels will occur in this district, thereby providing a basis for analyzing the model's sensitivity. It is important to bear in mind that the routine provides only estimates of the pollution levels induced by traffic on the highway network, and therefore the output data should not be construed as exact measurements. However, in comparing alternate highway development plans it is hoped that some benefit may be derived from comparing the relative impact of different highway networks.

In order to establish a basis for comparison, the first test run was made using alternate 0. This highway system was loaded with the level of traffic expected for the year 2000, thereby producing estimates of the pollution levels which would result if Michigan chose to cancel future construction plans and concentrate effort on highway maintenance. It was felt that the output from this test run would provide a logical basis for comparing proposed construction plans in that the change in pollution levels, if any, under alternate 1 would be clearly indicated.

FIGURE 10: SAMPLE SUMMARY AREA



COUNTIES

	County	DIST.
1.	ALCONA	4
2.	ALGER	2
3.	ALLEGAN	7
4.	ALPENA	4
5.	ANTRIM	3
6.	ARENAC	6
7.	BARAGA	1
8.	BARRY	7
9.	BAY	6
10.	BENZIE	3
11.	BERRIEN	7
12.	BRANCH	7
13.	CALHOUN	7
14.	CASS	7
15.	CHARLEVOIX	3
16.	CHEBOYGAN	4
17.	CHIPPEWA	2
18.	CLARE	3
19.	CLINTON	5
20.	CRAWFORD	4
21.	DELTA	2
22.	DICKINSON	1
23.	EATON	8
24.	EMMET	4
25.	GENESEE	6
26.	GLADWIN	6
27.	GOGEBIC	1
28.	GD. TRAVERSE	3
29.	GRATIOT	5
30.	HILLSDALE	8
31.	HOUGHTON	1
32.	HURON	6
33.	INGHAM	8
34.	IONIA	5
35.	IOSCO	4
36.	IRON	1
37.	ISABELLA	5
38.	JACKSON	8
39.	KALAMAZOO	7
40.	KALKASKA	3
41.	KENT	5
42.	KEWEENAW	1
43.	LAKE	3
44.	LAPEER	6
45.	LEELANAU	3
46.	LENAWEE	8
47.	LIVINGSTON	8
48.	LUCE	2
49.	MACKINAC	2
50.	MACOMB	MET.
51.	MANISTEE	3
52.	MARQUETTE	1
53.	MASON	3
54.	MECOSTA	5
55.	MENOMINEE	1
56.	MIDLAND	6
57.	MISSAUKEE	3
58.	MONROE	8
59.	MONTCALM	5
60.	MONTMORENCY	4
61.	MUSKEGON	5
62.	NEWAYGO	5
63.	OAKLAND	MET.
64.	OCEANA	5
65.	OGEMAW	4
66.	ONTONAGON	1
67.	OSCEOLA	3
68.	OSCODA	4
69.	OTSEGO	4
70.	OTTAWA	5
71.	PRESQUE ISLE	4
72.	ROSCOMMON	4
73.	SAGINAW	6
74.	SANILAC	6
75.	SCHOOLCRAFT	2
76.	SHIAWASSEE	6
77.	ST. CLAIR	MET.
78.	ST. JOSEPH	7
79.	TUSCOLA	6
80.	VAN BUREN	7
81.	WASHTENAW	8
82.	WAYNE	MET.
83.	WEXFORD	3

The output from the test run made on alternate 0 is displayed in figure 11. The major portion of the output information is contained in a chart which lists, by county, the calculated pollution indices for the three air emissions -- carbon monoxide, hydrocarbons, and nitric oxides -- which are measured in pounds per square mile, and the estimate of the number of people in each county impacted by traffic noise in excess of 70dBA. The final line of the primary output chart presents the pollution indices summarized at the state level. Note that the levels of carbon monoxide, hydrocarbons and nitric oxides are, respectively, 627.66, 32.34, and 58.58 pounds per square mile. Furthermore, 82,356 people throughout the state are impacted by excessive noise.

Appended to the regular output table is the special summary report for district 3, which was requested in the option statement early in the program's operation. This report indicates that 1535 people in this district are affected by noise levels exceeding 70dBA under alternate 0. Moreover, there are approximately 29.3 pounds of carbon monoxide, 1.5 pounds of hydrocarbons and 2.7 pounds of nitric oxides per square mile of district 3.

Figure 12 is the output information from the test runs on alternate 1. Of particular interest are the total statewide pollution levels, which are found in the last line of the main output chart. It is these quantities which facilitate the comparison of alternate 1 with alternate 0. Note that the air pollution indices under alternate 1 are 611.49, 31.50 and

FIGURE 11: ALTERNATE (ZERO) OUTPUT

COUNTY	EMISSIONS (POUNDS) PER SQ. MILE CO	HC	NOX	NO. PEOPLE EXPOSED TO NOISE LEVELS > 70DBA
1	0.89005	0.04598	0.08655	33
2	0.83965	0.04318	0.07606	22
3	5.59199	0.28898	0.54683	737
4	2.25800	0.11661	0.21815	146
5	1.52615	0.07859	0.14102	117
6	4.25164	0.21980	0.41788	140
7	0.82010	0.04219	0.08459	26
8	2.74083	0.14108	0.25106	318
9	14.75462	0.76067	1.39433	1182
10	1.95369	0.10062	0.18048	125
11	17.00697	0.87729	1.61993	2767
12	4.41070	0.22743	0.41730	263
13	11.46951	0.59242	1.11421	1613
14	5.19398	0.26779	0.48870	663
15	1.71699	0.08838	0.15724	94
16	2.54168	0.13149	0.25239	106
17	0.92746	0.04779	0.08673	140
18	4.71808	0.24353	0.45368	154
19	7.15959	0.36968	0.68976	415
20	2.62223	0.13562	0.25975	37
21	1.57631	0.08125	0.14744	97
22	1.65734	0.08481	0.13911	40
23	10.69491	0.55016	0.97514	1545
24	3.47846	0.17893	0.31566	109
25	25.59498	1.31592	2.31887	16123
26	1.72492	0.08880	0.15840	99
27	0.92124	0.04728	0.08076	23
28	3.65776	0.18825	0.33427	217
29	5.41568	0.27890	0.50322	203
30	3.03378	0.15621	0.27930	316
31	1.67725	0.08605	0.14610	202
32	2.11480	0.10891	0.19516	333
33	21.17254	1.08708	1.87734	843
34	5.38058	0.27792	0.52219	500
35	2.38090	0.12283	0.22639	340
36	0.67088	0.03452	0.06118	57
37	4.29044	0.22116	0.40467	187
38	11.29883	0.58283	1.07810	1737
39	13.89121	0.71615	1.31462	3191
40	1.20488	0.06210	0.11276	36
41	19.46514	1.00383	1.84471	3340
42	0.18281	0.00942	0.01689	4
43	1.30828	0.06738	0.12086	28
44	4.80367	0.24730	0.44089	465
45	1.66853	0.08592	0.15383	156
46	5.65013	0.29094	0.52059	939
47	11.10655	0.57538	1.12811	1018
48	0.58909	0.03034	0.05443	36
49	2.09327	0.10784	0.19449	119
50	40.14061	2.06803	3.73801	7140
51	1.75535	0.09042	0.16267	214
52	1.43771	0.07373	0.12453	247
53	2.75182	0.14133	0.24427	82

ALTERNATE O
FIGURE 11 (continued)

COUNTY	EMISSIONS (POUNDS) PER SQ. MILE CO	HC	NOX	NO. PEOPLE EXPOSED TO NOISE LEVELS > 70DBA
54	2.89292	0.14901	0.26804	120
55	1.73347	0.08879	0.14790	82
56	5.73948	0.29544	0.53118	1213
57	0.91826	0.04723	0.08308	37
58	16.26689	0.84123	1.60874	1879
59	3.96817	0.20400	0.35638	325
60	0.90099	0.04640	0.08323	28
61	11.55503	0.59420	1.05086	783
62	1.90073	0.09778	0.17274	173
63	37.33054	1.92613	3.56650	8908
64	2.60654	0.13417	0.23901	84
65	1.92521	0.09913	0.17733	85
66	0.73447	0.03783	0.06794	59
67	2.87678	0.14823	0.26764	156
68	0.98183	0.05060	0.09157	23
69	2.20686	0.11416	0.21928	51
70	9.42452	0.48646	0.90487	1479
71	1.09699	0.05650	0.10184	108
72	3.59761	0.18598	0.35357	120
73	13.71742	0.70424	1.21423	2358
74	2.28844	0.11790	0.21255	359
75	0.85576	0.04413	0.08063	17
76	6.28091	0.32372	0.58877	508
77	8.05085	0.41364	0.72054	1719
78	5.61603	0.28917	0.51810	846
79	3.21273	0.16499	0.28395	421
80.	6.79077	0.35096	0.66530	1067
81	19.73148	1.01863	1.90447	5056
82	141.06542	7.26013	12.94511	5089
83	3.21301	0.16531	0.29270	119
TOTALS	627.66465	32.33712	58.57966	82356

KEY: CO = CARBON MONOXIDE
HC = HYDROCARBONS
NOX= OXIDES OF NITROGEN

THE SPECIAL STUDY ZONES ARE 5
10
15
18
28
40
43
45
51
53
57
67
83

CO = 29.26958 LBS PER SQ MILE
HC = 1.50728 LBS PER SQ MILE
NOX= 2.70449 LBSPER SQ MILE
NUMBER OF PEOPLE AFFECTED BY NOISE 1535

KEY: CO = CARBON MONOXIDE
HC = HYDROCARBONS
NOX= OXIDES OF NITROGEN.

FIGURE 12: ALTERNATE 1 OUTPUT

COUNTY	EMISSIONS (POUNDS) PER SQ. MILE CO	HC	NOX	NO. PEOPLE EXPOSED TO NOISE LEVELS > 70DBA
1	0.89052	0.04601	0.08659	52
2	0.83965	0.04318	0.07606	22
3	5.59208	0.28899	0.54684	765
4	2.25819	0.11662	0.21819	242
5	1.52615	0.07859	0.14102	117
6	4.25238	0.21984	0.41796	208
7	0.82010	0.04219	0.07459	26
8	2.74083	0.14108	0.25106	318
9	14.75462	0.76067	1.39433	1182
10	1.76737	0.09102	0.16329	145
11	17.00696	0.87729	1.61999	3424
12	4.41070	0.22743	0.41730	263
13	11.46951	0.59242	1.11421	1613
14	5.19398	0.26779	0.48870	663
15	1.71699	0.08838	0.15724	94
16	2.54168	0.13149	0.25239	106
17	0.92746	0.04779	0.08673	140
18	4.71884	0.24357	0.45370	190
19	6.73825	0.34785	0.64689	1084
20	2.62290	0.13565	0.25976	41
21	1.41702	0.07302	0.13196	174
22	1.65780	0.08483	0.13913	92
23	10.69491	0.55016	0.97514	1545
24	3.47846	0.17893	0.31566	109
25	25.59527	1.31593	2.31889	16479
26	1.72492	0.08880	0.15840	99
27	0.92124	0.04728	0.08076	23
28	3.53240	0.18179	0.32265	414
29	4.12023	0.21177	0.37141	203
30	3.13724	0.16154	0.28887	346
31	1.67725	0.08605	0.14610	202
32	2.11480	0.10891	0.19516	333
33	21.17257	1.08708	1.87735	1544
34	5.38058	0.27792	0.52219	500
35	2.38132	0.12285	0.22644	524
36	0.67115	0.03453	0.06120	62
37	4.29044	0.22116	0.40467	187
38	11.04965	0.56996	1.05388	1722
39	13.89121	0.71615	1.31462	3191
40	0.61880	0.03184	0.05645	35
41	19.46422	1.00378	1.84475	4276
42	0.18281	0.00942	0.01689	4
43	1.30828	0.06738	0.12086	28
44	4.27410	0.22003	0.39201	734
45	1.66853	0.08592	0.15383	156
46	5.65086	0.29098	0.52064	1161
47	10.93183	0.56635	1.11112	1018
48	0.58909	0.03034	0.05443	36
49	2.40863	0.12420	0.22711	132
50	38.88357	2.00319	3.61894	8018
51	1.34726	0.06940	0.12501	273
52	1.43771	0.07372	0.12453	247
53	1.53754	0.07880	0.13212	86

ALTERNATE 1
FIGURE 12 (continued)

COUNTY	EMISSIONS (POUNDS) PER SQ. MILE CO	HC	NOX	NO. PEOPLE EXPOSED TO NOISE LEVELS > 70DBA
54	1.13630	0.05842	0.10204	135
55	1.73347	0.08879	0.14790	82
56	5.73948	0.29544	0.53118	1213
57	0.91826	0.04723	0.08308	37
58	16.26645	0.84121	1.60877	2176
59	3.39551	0.17446	0.30213	341
60	0.90099	0.04640	0.08323	28
61	11.50692	0.59172	1.04641	785
62	1.90073	0.09778	0.17274	173
63	34.21116	1.76548	3.27783	11791
64	0.20282	0.01048	0.01972	66
65	1.92521	0.09913	0.17733	85
66	0.73447	0.03783	0.06794	59
67	1.83991	0.09483	0.17216	159
68	0.98183	0.05060	0.09157	23
69	2.20686	0.11416	0.21928	51
70	9.42483	0.48648	0.90491	1805
71	1.09699	0.05650	0.10184	108
72	3.59761	0.18598	0.35357	120
73	13.71742	0.70424	1.21423	2358
74	2.28844	0.11790	0.21255	359
75	0.82263	0.04242	0.07757	22
76	6.28105	0.32373	0.58879	563
77	8.05099	0.41365	0.72057	1767
78	5.61628	0.28919	0.51812	900
79	3.21273	0.16499	0.28395	421
80	6.79077	0.35096	0.66530	1067
81	19.73155	1.01863	1.90448	5157
82	141.06899	7.26030	12.94520	8307
83	2.19294	0.11273	0.19734	224
TOTALS	611.49444	31.50353	57.06171	95030

KEY: CO = CARBON MONOXIDE
HC = HYDROCARBONS
NOX= OXIDES OF NITROGEN.

THE SPECIAL STUDY ZONES ARE 5
10
15
18
28
40
43
45
51
53
57
67
83

CO = 24.69327 LBS PER SQ MILE
HC = 1.27148 LBS PER SQ MILE
NOX= 2.27873 LBSPER SQ MILE
NUMBER OF PEOPLE AFFECTED BY NOISE 1958

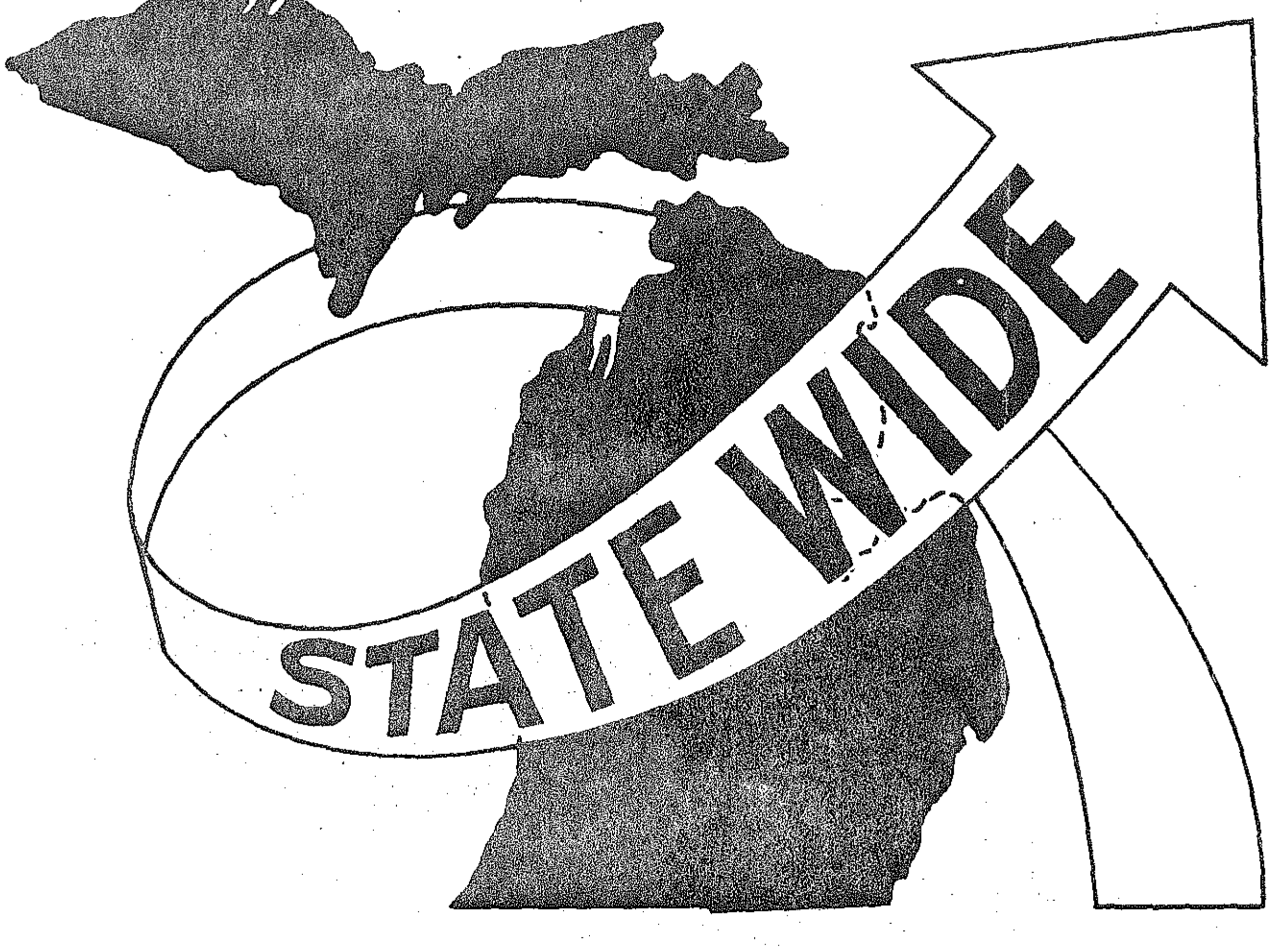
KEY: CO = CARBON MONOXIDE
HC = HYDROCARBONS
NOX= OXIDES OF NITROGEN.

57.06 pounds per square mile for carbon monoxide, hydrocarbons, and nitric oxides, respectively. Moreover, 95,030 people in the state are impacted by noise in excess of 70dBA.

Comparing these results with those obtained on alternate 0, it is clear that alternate 1 is not totally advantagous. Although the air emission levels decrease significantly for all three of the air pollutants, the number of people affected by excessive noise sharply increases. However, these results are totally consistent with the program's method of calculating the pollution indicators. Recall that the equations which generate the air pollution indices are of the general form $f(\frac{1}{S_k}, L, V, PCT)$, while $g(S_n, V_n)$ is the general form of the equations which calculates the estimate of the number of people impacted by excessive traffic noise. In these equations S is the average speed on the link, V is the average hourly volume, L is the length of the link, and PCT is the percentage of cars in the specified age group; k, m, and n are constants. It is important to note that in these equations the increase in traffic volume and traffic speed, which result when US-31 and US-131 are upgraded to freeway standards, affect the "f" and "g" functions in completely different ways. Since the "f-function" depends on V/S^k, the increase in volume is counterbalanced by the increase in average vehicle speed. Therefore, it is entirely consistent with these equations to have a decrease in the air emission levels under alternate 1. Following a similar link of reasoning, and noting that the "g-function" depends on V S, the increase in both of these factors logically leads to an increase in the noise pollution indicator.

The special summary reports on district 3 conform to the same pattern as described above. Specifically, the number of people affected by noise in excess of 70dBA increases from 1535 under alternate 0, to 1958 under alternate 1. However, the air pollution levels decrease significantly. For example, the level of carbon monoxide decreases approximately 16%, since on alternate 0 there are 29.3 pounds per square mile, while alternate 1 "produces" only 24.7 pounds.

FUTURE MODIFICATIONS



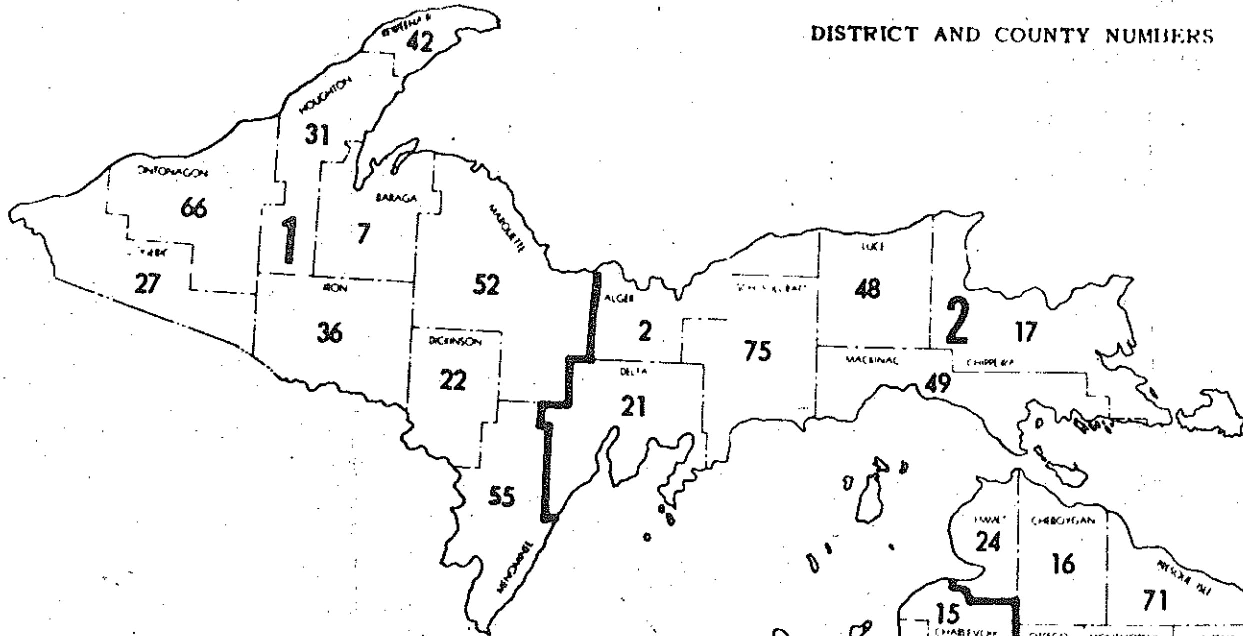
FUTURE MODIFICATIONS

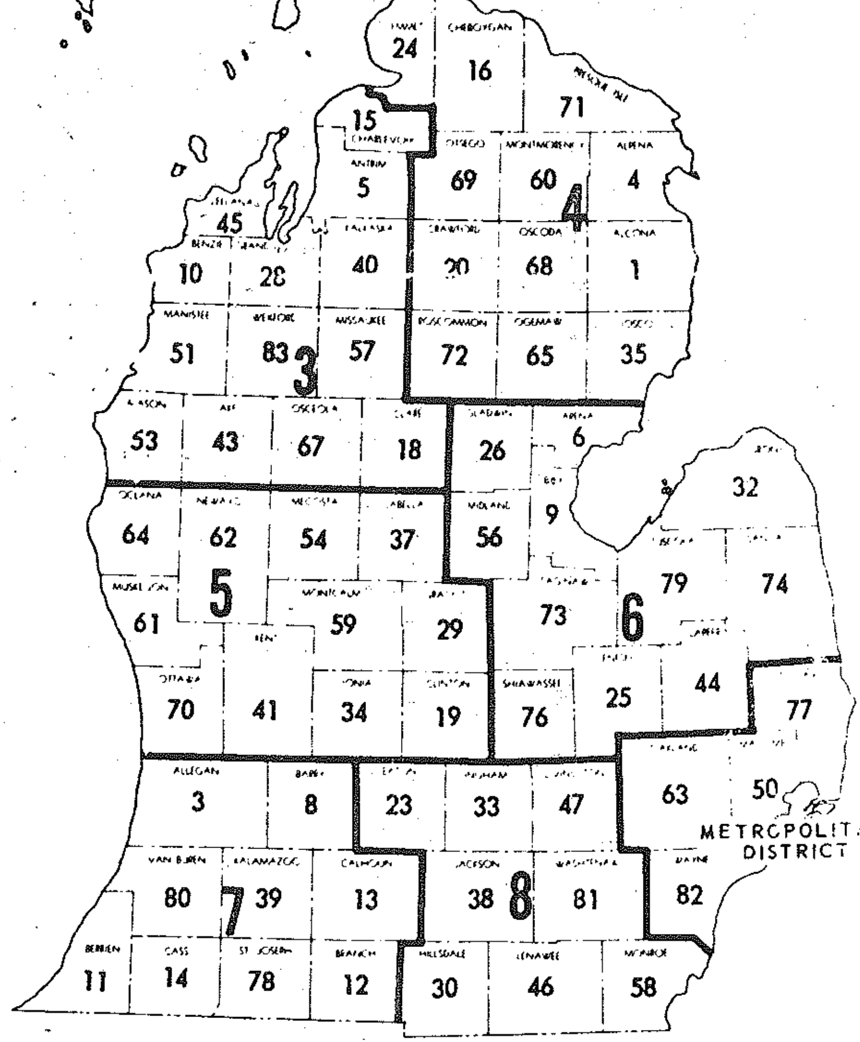
The air and noise pollution model, as implemented by the Statewide Studies Unit, is a systematic routine which can be used to provide an estimate of the pollution levels in all of Michigan's counties and for any user-specified special county summary. Furthermore, the program can be modified to make it more responsive to the needs of the individual user and to provide a more accurate measurement of pollution levels.

In comparing the benefits of alternative highway projects, an output format which furnishes information summarized to any user-specified level may be desirable. The modifications required to provide this kind of information can be accomplished with minimal time and effort, since it is only necessary to revise the program's method of generating summaries. In fact, with the present structure of Statewide's pollution model it is possible to provide information at various levels, for example by individual zone or by any combination of zones or counties, or by the state planning regions shown in figure 13. In this sense the program is extremely flexible and responsive to the needs of the individual user.

In the discussion of the program's operation it has been stated that the construction type of the highway link is an important factor in determining the level of noise pollution. The SRI model proposes dividing highway construction types into five basic groups:

FIGURE 13: MAP OF STATE PLANNING ZONES





COUNTIES

	DIST.		DIST.
1. ALCONA	4	43. LAKE	3
2. ALGER	2	44. LAPEER	6
3. ALLEGAN	7	45. LEELANAU	3
4. ALPENA	4	46. LENAWEE	8
5. ANTRIM	3	47. LIVINGSTON	8
6. ARENAC	6	48. LUCE	2
7. BARAGA	1	49. MACKINAC	2
8. BARRY	7	50. MACOMB	MET.
9. BAY	6	51. MANISTEE	3
10. BENZIE	3	52. MARQUETTE	1
11. BERRIEN	7	53. MASON	3
12. BRANCH	7	54. MECOSTA	5
13. CALHOUN	7	55. MENOMINEE	1
14. CASS	7	56. MIDLAND	6
15. CHARLEVOIX	3	57. MISSAUKEE	3
16. CHEBOYGAN	4	58. MONROE	8
17. CHIPPEWA	2	59. MONTCALM	5
18. CLARE	3	60. MONTMORENCY	4
19. CLINTON	5	61. MUSKEGON	5
20. CRAWFORD	4	62. NEWAYGO	5
21. DELTA	2	63. OAKLAND	MET.
22. DICKINSON	1	64. OCEANA	5
23. EATON	8	65. OGEMAW	4
24. EMMET	4	66. ONTONAGON	1
25. GENESEE	6	67. OSCEOLA	3
26. GLADWIN	6	68. OSCODA	4
27. GOGEBIC	1	69. OTSEGO	4
28. GD.TRAVERSE	3	70. OTTAWA	5
29. GRATIOT	5	71. PRESQUE ISLE	4
30. HILLSDALE	8	72. ROSCOMMON	4
31. HOUGHTON	1	73. SAGINAW	6
32. HURON	6	74. SANILAC	6
33. INGHAM	8	75. SCHOOLCRAFT	2
34. IONIA	5	76. SHIAWASSEE	6
35. IOSCO	4	77. ST. CLAIR	MET.
36. IRON	1	78. ST. JOSEPH	7
37. ISABELLA	5	79. TUSCOLA	6
38. JACKSON	8	80. VAN BUREN	7
39. KALAMAZOO	7	81. WASHTENAW	8
40. KALKASKA	3	82. WAYNE	MET.
41. KENT	5	83. WEXFORD	3
42. KEWEENAW	1		

(1) expressway

(2) construction at grade

(3) elevated on narrow fill

(4) elevated on broad fill

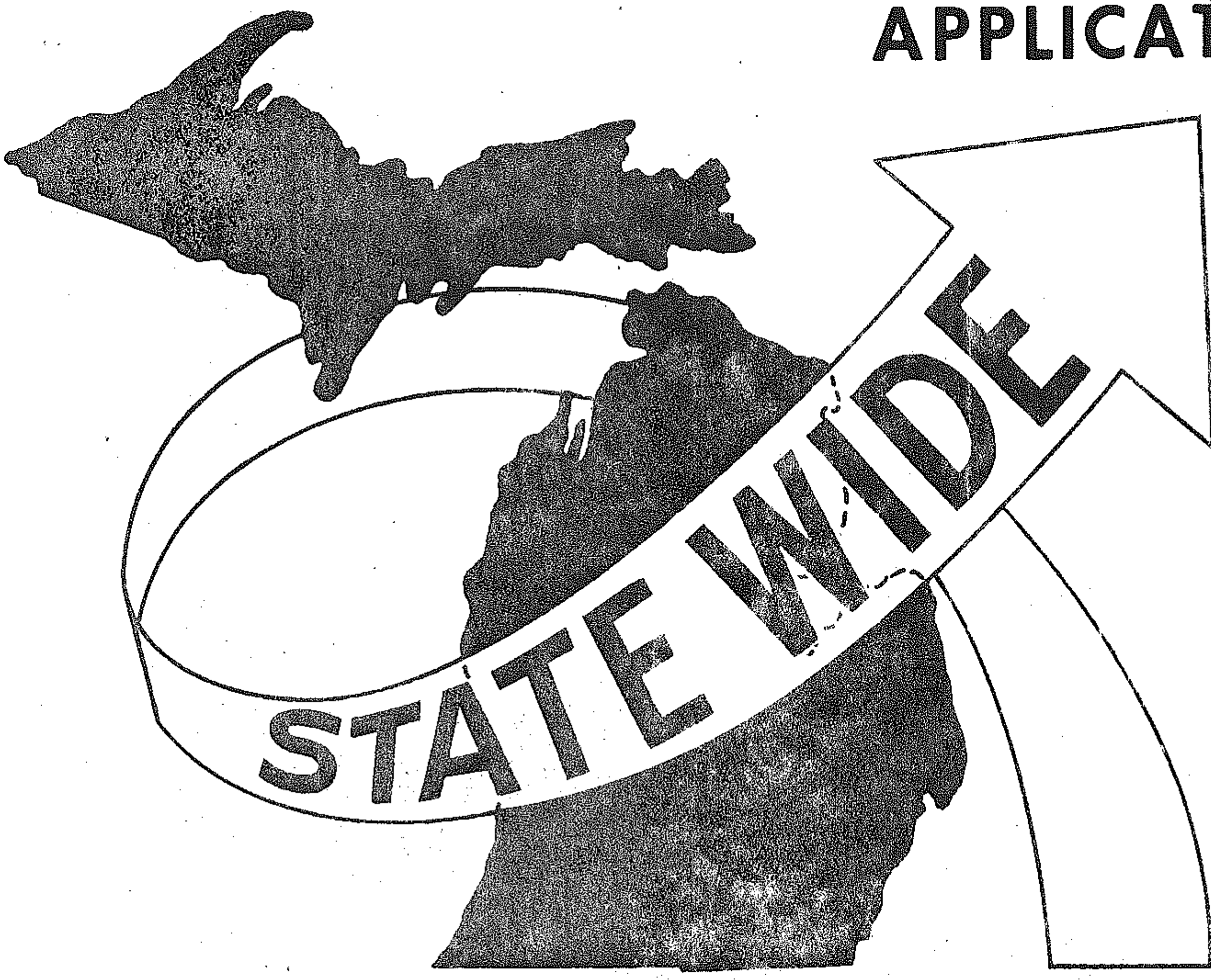
(5) depressed twenty feet or more.

However, at present the model developed by the Statewide Unit discriminates between links on the basis of the general classifications such as expressways, primary and secondary trunk line, and centroid link. This method is basically satisfactory, since noise pollution in excess of 70dBA occurs only on freeways and expressways, and the level of air pollution is independent of link construction types. Yet, using this procedure it is not possible to account for the decrease in the noise pollution index due for example, to the twenty foot high embankments adjoining depressed facilities, although such embankments reduce the distance traffic noise is projected by as much as a factor of ten. Therefore it will ultimately be necessary to accumulate the required data on link construction types as specified by SRI and enter this data into the Statewide highway link files.

At present the pollution model assumes a standard truck mix on all highways of ten percent of the/total traffic volume. This is an averaged value, and therefore the pollution indices do not reflect the exact level of pollution since, for example, no allowance has been made for calculating the extra pollution which exists along heavily traveled truck routes. To deal with this situation the modified version of the T&R noise pollution model will be introduced as soon as possible as an alternative to the SRI method, since this T&R model allows the user to enter the level of commercial traffic on each link as input data, thereby offering a more precise estimate of additional pollution due to trucks. The data necessary to implement the T&R model is already part of the Statewide highway link file.

The Statewide Studies Unit will be pleased to discuss any other modifications which would make the pollution model more responsive to the needs of highway agencies. As always, the objective is to develop an efficient, accurate, and completely accessible tool. Any suggestions to that end will be greatly appreciated.

APPLICATIONS



APPLICATIONS

The automobile air and noise pollution model was developed by the Statewide Studies Unit primarily to offer the Highway Department a system-level method of estimating the pollution levels on Michigan's highway network. It is hoped that this routine may be of some use in satisfying the requirements of the 1970 Federal-Aid Highway Act, which makes it mandatory for the State of Michigan to conduct an environmental-impact analysis for each proposed Federal-Aid highway project. Furthermore, due to the system-level procedure employed by this routine, it is anticipated that management will find it helpful when comparing the statewide impact of alternative highway plans.

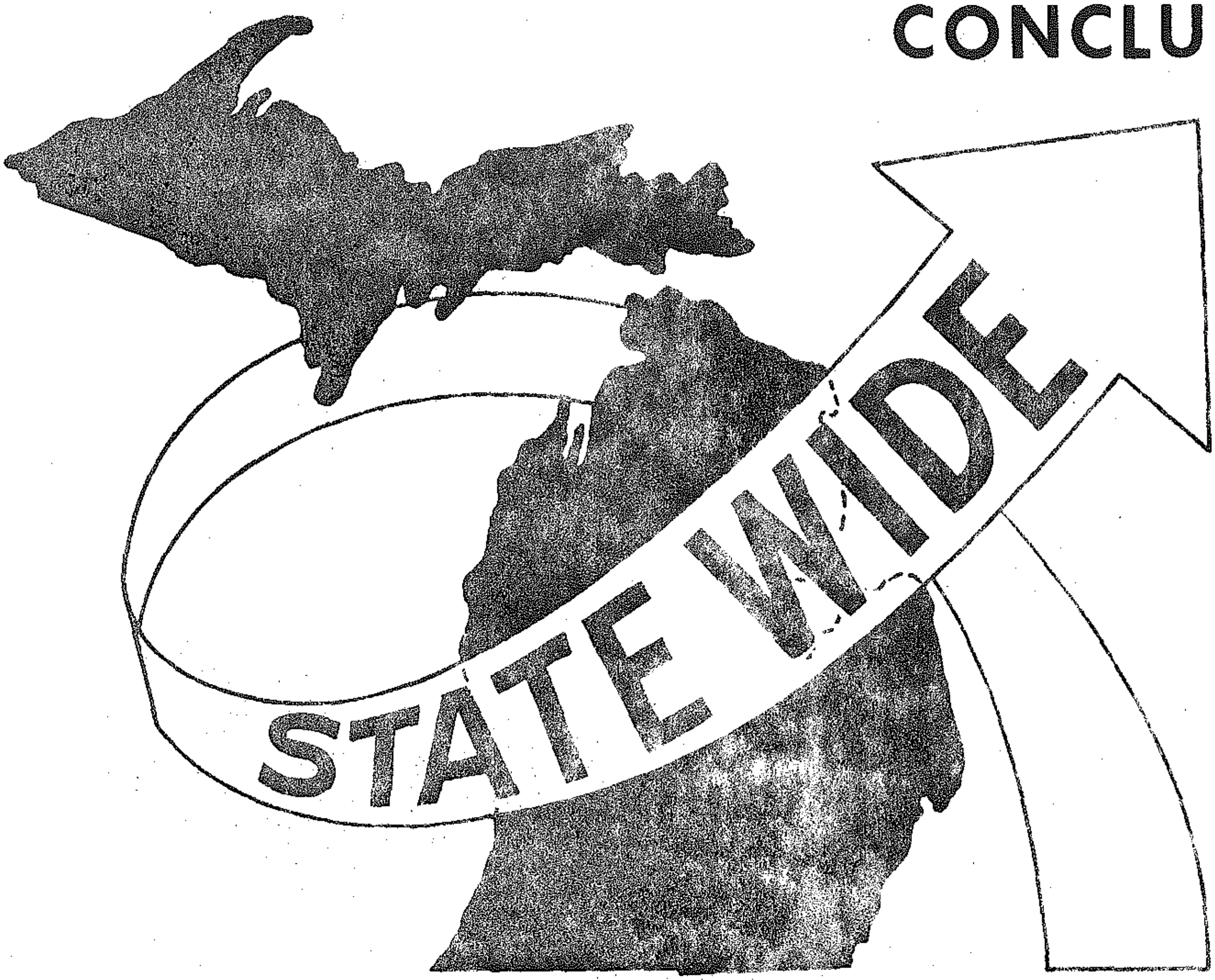
The pollution model is user-oriented. As developed by the Statewide Studies Unit, the pollution indices are generated at the county level, with an optional special summary report appended for any combination of counties as specified by the user. However, reports can be produced for virtually <u>any</u> summary region by performing minor modifications in the summary routine, thereby offering both general over-views of the system-wide pollution levels and detailed analyses of the areas of special interest.

This versatility suggests several possibilities for the model's application outside the area of transportation planning, such as measuring the impact of automobile pollution on both public and private facilities.

More specifically, in conjunction with the facility file, Statewide's pollution model can be used by governmental agencies to measure the impact of automobile pollution -- especially noise pollution -- on the public facilities under their supervision. As presented in the discussion of program operation, the SRI noise pollution model computes a "pollution band", which is the land area adjacent to the highway's right-of-way that is exposed to noise levels greater than 70dBA. The facility file then provides the coordinates of the building or building complex under consideration, and a check can subsequently be made to determine if those coordinates are within the impacted area. Using this routine, it may also be possible for the Highway Department to advise public administrators about the impact of new highways on their facilities by comparing the relative sizes of the pollution bands. This is possible because pollution is measured on the system-level; therefore changes in traffic flow patterns, which alter pollution levels, can be taken into account.

It should be noted that the generality of this process makes it applicable to the commercial and industrial sectors of the economy as well. Once the coordinates of an industrial plant or commercial center are incorporated into the facility file it is possible to perform an analysis of pollution levels as described above.

CONCLUSION



CONCLUSION

The goal of the Statewide Studies Unit was to develop a systematic routine to provide estimates of the air and noise pollution generated by traffic on the state's highway network. The need for developing a model of this type is clear. System 109(h) Title 23, USC as contained in Section 136(h) of the Federal-Aid Highway Act of 1970 requires that all future Federal-aid highway projects consider the environmental impact of the proposed construction. It is hoped that the routine presented in this report may assist the management of the Highway Department in meeting these new regulations.

In its present form, the output information is summarized to county-level, with a special summary area report appended as specified by the user. However, the present method of generating summaries can be easily modified to produce output information at virtually any user-specified level. It is felt that this versatility will greatly expand the scope of possibilities for the model's application. For example, it may be possible for the Highway Department to advise the DNR about the anticipated impact new highway construction will have on their facilities.

It should again be made clear that the output tables and charts displayed in this report were made for demonstration purposes only, using the most up-to-date networks of the Statewide Studies Unit. As more complete files are created, it will be possible to measure pollution levels on all of the proposed changes to the state's highway system.