ANNUAL TRAVEL ON THE COUNTY HIGHWAY SYSTEM OF INDIANA

HIGHWAY EXTENSION AND RESEARCH PROJECT FOR INDIANA COUNTIES

PURDUE UNIVERSITY
LAFAYETTE INDIANA

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Final Report

ANNUAL TRAVEL ON THE COUNTY HIGHWAY SYSTEM OF INDIANA

December 15, 1966

File: 19-2-5

To: K. B. Woods, Director
Highway Extension and Research Project
for Indiana Counties

From: J. F. McLaughlin, Assistant Director

Attached is the Final Report for the research project, "Annual Travel on the County Highway System of Indiana." The report has been authored by Messrs. Walter Vodrazka and Harold L. Michael of our staff.

This project was approved on December 16, 1965, as the result of action of the HERPIC Advisory Board at its September 16, 1965 meeting.

The Report is submitted for the record and for possible publication.

Respectfully submitted,

J. F. McLaughlin /jgs

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Assistant Director
HERPIC

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cc: HERPIC Advisory Board Members
G. A. Hawkins
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FINAL REPORT

ANNUAL TRAVEL ON THE COUNTY HIGHWAY SYSTEM OF INDIANA

by

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Highway Extension and Research Project for
Indiana Counties

File No: 19-2-5

Purdue University
Lafayette, Indiana

December, 1966

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The Indiana Association of County Commissioners, which recommended the study, and its Executive Secretary, Claude Hodson, also contributed to the success of the study.

The study could never have been started, let alone completed, without the complete cooperation of the county representatives. These men and their counties are listed here:

Lawrence Noll, Adams County
Road Supervisor

Walter Gilliom, Adams County
Engineer

James Wilkerson, Brown County
Road Supervisor

Sherril Page, Clay County Engineer

Theodore Cook, Dearborn County
Road Supervisor

Alfred Schmitt, Dubois County
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Carl Heim, Dubois County Engineer

Ia Mar Snyder, Elkhart County
Road Supervisor

Homer Vance, Fayette County
Road Supervisor

Carl Records, Franklin County
Road Supervisor

Elmer Douglass, Fulton County
Road Supervisor

Delmar Milliner, Hancock County
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Earl Hemmeger, Howard County
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Robert Florence, Jasper County
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Carl Underwood, Jefferson County
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Worley Spitler, Kosciusko County
Clerk

Harold Turner, Lawrence
County Road Supervisor

Robert Fulwider, Montgomery
County Road Supervisor

Raymond Richardson, Monroe
County Road Supervisor

Charles Meunier, Perry County
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John Baner, Posey County
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Ralph Kennedy, Wayne County
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Stanton Gedvillas, City-County
Director of Planning, Wayne County

William Altherr, White County
Engineer

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INTRODUCTION

BACKGROUND AND PURPOSE

The study of some traffic characteristics on Indiana's County Highway System described in this paper was the result of a proposal submitted to the Highway Extension and Research Project for Indiana Counties (HERPIC) Advisory Board by the Indiana Association of County Commissioners (IACC) in September, 1965. A copy of this proposal is included in Appendix I of this paper. The purpose of the study was to provide factual information on the use of county highways.

Information concerning the vehicle miles of travel on the state highway system and in many urban areas is generally available but there was virtually no data of a similar nature available for county highways. Such information, however, was considered desirable inasmuch as it is useful in the equitable allocation of funds from the State's Motor Vehicle Highway Account to the various units of government responsible for highways.

The study was designed and conducted to provide a realistic measure of the vehicle miles of travel on county highways and some auxiliary information, such as vehicle classification and a frequency distribution of road miles as a function of traffic volume.

The Problem

In general, when the available funds and time are limited, the

scope of a study of this type is confined to a sampling of study sites rather than to the entire county road network. The IACC proposal suggested that the study be confined to six or eight counties and the results expanded to provide an estimate for Indiana's entire 92 counties. This procedure was open to question since known relationships by which a reasonably accurate expansion could be made were not available. Extensive initial research, time, and money would have been required to establish the necessary relationships. Thus an alternative sampling procedure was developed.

The daily vehicle miles of travel on a particular road is the product of the length of the road in miles and the annual average daily traffic (AADT) on the road. This may be placed on an annual basis by multiplying by 365 days. When such an operation is carried out for all segments of all roads in the system, the sum of all products is the annual vehicle miles of travel on the system.

The desired estimate, i.e. the vehicle miles of travel, is the product of two variables; namely the roadway or section length which is known or can be measured, and the AADT which must be estimated. An estimate of AADT for each road section in an area is often based on a short count of traffic, such as for eight (8) hours duration at a site on each road section in the area and a 24 hour count taken at one site on a road within the area. Each short count is then expanded to an estimate of AADT by appropriate expansion factors which are easily calculated from the 24-hour count data.

The approach used in this study was to obtain an estimate of the average AADT for all miles of road in the county highway system. This average when multiplied by the total length of the system, provided

the estimate of the vehicle miles of travel. Thus, if the average AADT is given as $\bar{A}$, the desired estimate is $N\bar{A}$, where N is the size of the population which, in this case, is the length of the system in miles.

Since the section length of road for which the AADT applies is a continuous variable, it was decided to measure all lengths to the nearest tenth of a mile. Each mile was considered as one sample. Thus, if a 2.5 mile road section had an AADT of 500, it was considered as 2.5 samples, each with an AADT of 500.

Since information on vehicle classification was desired and since many counts would have to be made on aggregate surfaced roads, the use of automatic traffic counters was precluded. All short counts, consequently, were taken manually. In all counties in which such counts were made, either personnel of the county highway department or persons especially recruited for the study by the individual counties were used.

Study Method

If a sample of roadway sections is selected and the AADT on each section is measured, an estimate of vehicle miles of travel can be obtained. The validity of such an estimate depends on the validity of the assumption that the average AADT of those sections included in the sample is a good approximation of the average AADT for the entire system. The validity of this assumption, in fact, is dependent upon the variability of the AADT's and on the number of samples selected. For example, if all road sections carried the same volume, there would be no variability and one traffic count would be adequate. Obviously there is considerable variation in the AADT's of roads.

On the other hand, if the AADT of all roads were measured, variability would be no problem since then the true average AADT could be calculated and no estimate necessary. Obviously, this procedure would be prohibitively expensive. Thus, a sampling of road sections must be used. The size of the sample required in order to measure the average AADT with a prescribed precision, such as plus or minus 5%, is a function of the magnitude of the variation.

Fortunately, traffic volume data for the primary and secondary county road systems of Allen County, Indiana, collected in 1955, were available for study (1). These data showed that a better job of estimating vehicle miles of travel could be done if the road sections were classified into several volume strata rather than considered as one large stratum.

The data available were in the form of section lengths and AADT's for 57 sections (146.6 miles total length) covering the primary county road system and for 54 sections (138.4 miles total length) covering the secondary county road system. No data were available for the remaining miles of county roads.

For the purpose of this study, a road section was defined as a length of road having similar volume characteristics throughout its length. Thus one traffic count was representative of the traffic volume throughout its length.

The problem was one of establishing the number of miles of road for which the AADT must be measured in order to obtain an acceptable measure of the average AADT for the entire system. When considering the entire 285 miles of Allen County's arterial road systems, the following parameters were calculated:

Average AADT, $\bar{A}$ = 485.6 VPD

Variance, S^2 = 174,071.2

The expression for sample size, n, is given by:

$$n_o = t^2 S^2/d^2$$

and: $$n = n_o/(1 + n_o/N)$$

where: n is the required number of miles in the sample,

n_o is the sample size uncorrected for finite population,

t is the appropriate t-statistic (taken as 1.96)

d is the maximum desired deviation of the estimate of average AADT ($\bar{a}$) from the true value ($\bar{A}$) and,

N is the total number of miles of road in the system under discussion.

In order to estimate $\bar{A}$ within plus or minus 5%, the required value of n was 229.6 miles of road or 80.6% of the system length. This sample size was considered excessively large for economy reasons.

However, it was also found that the number of samples required could be reduced if road sections could be classified into groups which had traffic volumes falling within a relatively narrow range. This technique is known as stratification and often has the advantage of providing a lower standard error of the estimate in addition to decreasing the sample size, thus yielding a more precise estimate at lower cost.

The stratification plan adopted for this study placed all road sections into one of four volume strata: stratum 1, AADT over 1,000; stratum 2, AADT between 400 and 1,000; stratum 3, AADT between 100 and 400; stratum 4, AADT less than 100. The sample size required for this plan was 159.4 miles of road while the standard error of the estimate was reduced from 12.14 to 7.06.

Implementation of this technique, however, for the 92 county highway systems of Indiana presented several problems. Individual roadway sections for which traffic information was representative had to be selected. Each section then had to be assigned to its appropriate volume stratum. It was recognized that the AADT's of the road sections were unknown and that their placement would have to be estimated. It was believed, however, that qualified county personnel could assign road sections to their proper volume stratum reasonably well.

Upon completion of the study, the accuracy of the actual estimated stratification was measured. Table 1 shows the percentage of miles which actually fell into each volume range for each of the estimated strata. The overall percentage of miles placed in their proper stratum was 60.5%. The general tendency was that volumes were slightly underestimated.

It was anticipated that the necessary estimation for volume stratum would result in a larger variance for each stratum than that computed for the Allen County data. Table 2 shows the variances estimated for each stratum and the variances as actually determined from the collected data. The variances were grossly underestimated.

In an effort to reduce the cost of the study and to make its conduct practical (i.e. to complete the data collection phase during the summer months of 1966), it was decided to restrict sampling operations to approximately 25% of Indiana's 92 counties. Rather than select the sample of counties at random from the State at large, the counties were grouped so that widely differing population and size ranges would be represented.

The grouping of counties was done in the following manner. The population and registered motor vehicles in each county were summed, and this

TABLE 1

Effectiveness of Stratification

Estimated Volume Stratum	Percent Distribution of Estimated Stratum Miles Falling Into Each Volume Class			
	1	2	3	4
1	78.4	17.1	4.5	0.0
2	11.1	34.7	49.6	4.6
3	1.8	6.5	63.3	28.4
4	0.0	2.4	31.2	66.4

Overall Effectiveness: 60.5%

TABLE 2

Estimated and Computed Within Stratum Variances

Stratum	Variance	
	Estimated	Computed
1	200,000	3,912,000
2	25,000	187,750
3	15,000	48,780
4	1,500	8,720

sum then divided by the county's square mile area. The resulting densities were numerically ranked and seven arbitrary groups formed from each of which a 25% sample was selected at random. This resulted in the sample of 25 counties shown in Figure 1.

In summary, the method employed was to place each road section in 25 counties selected randomly from seven county size strata into its appropriate volume stratum and select a random sample of these sections from each stratum. One short volume count was then made on each sample selected to obtain an estimate of the system AADT. The AADT was then multiplied by the system length to obtain the vehicle miles of travel in the system.

Data Collection Procedure

The data collection procedure is described in detail in Appendix II of this paper and is outlined briefly here. The procedure consisted generally of the following steps:

1. Each of the 25 selected counties were notified of the study and its purpose and the County Commissioners were asked to name a qualified county representative to act as liaison with the HERPIC staff.

2. Those roads which were State primary and secondary and Federal-Aid-Secondary county roads were delineated on a county map. The county representative checked the map to insure its accuracy and that all unmarked roads were county roads.

3. The county representative then sectioned all county roads on a traffic volume basis and placed each section in one of the four volume strata.

4. Each county stratification map was then checked by the study staff for reasonableness. Three were rejected as inconsistent and were handled in the data analysis as special cases. All road sections were

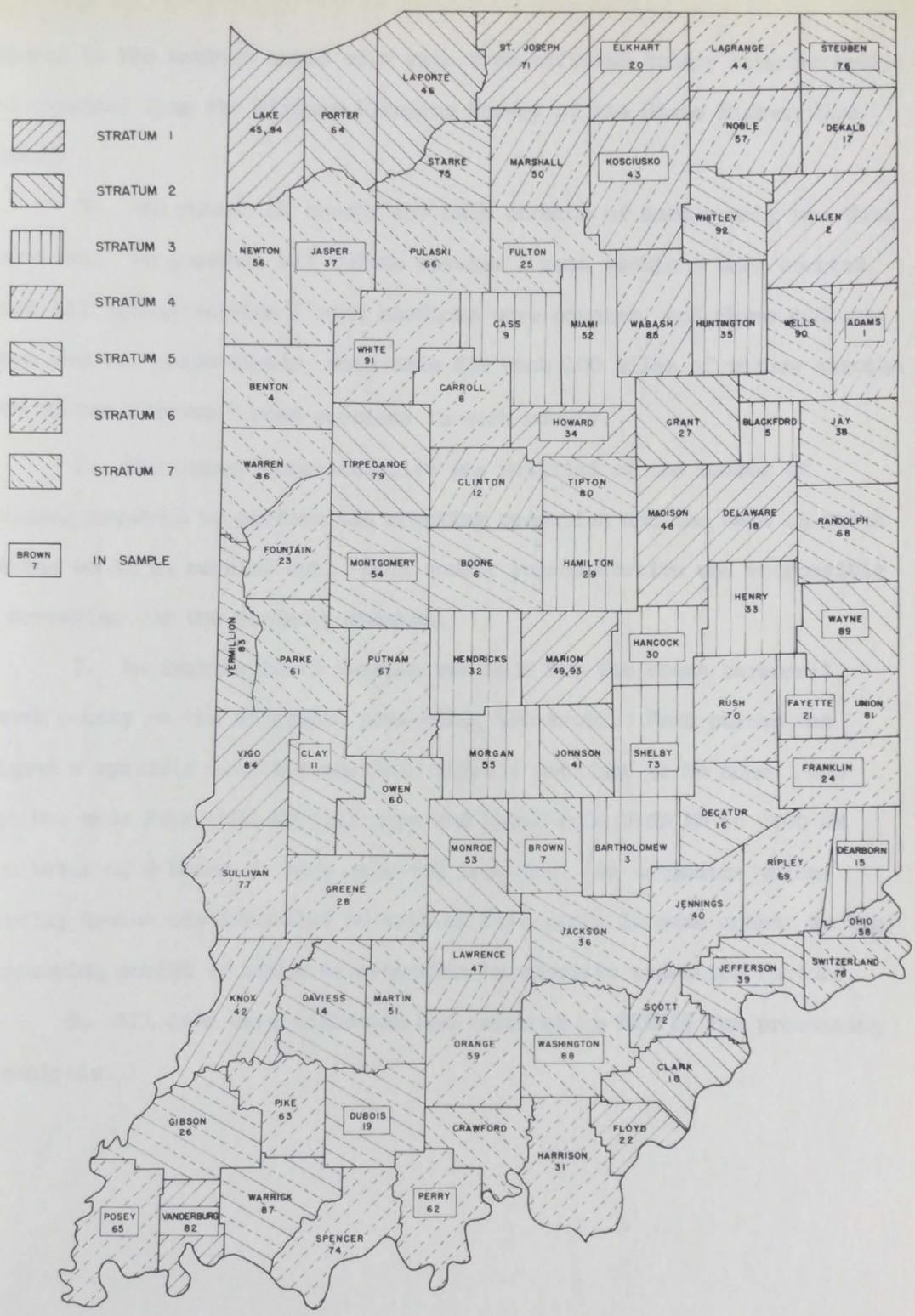

FIGURE 1. INDIANA - SHOWS LOCATION OF EACH COUNTY IN SAMPLE AND THE VEHICLE-PERSON DENSITY GROUP OF EACH COUNTY

measured to the nearest tenth of a mile from official county transportation maps obtained from the Highway Planning Survey of the State Highway Commission.

5. The number of counts for each stratum of each county was then determined. In general, all volume stratum I road sections were counted, almost all volume stratum 2 road sections were counted, and three and one volume counts, respectively, were made for each 100 miles of volume stratum 3 and volume stratum 4 road sections in each county.

6. The county representative was notified of the number of personnel required to perform the counting operation and the date on which counting would be carried out. Each county representative was responsible for arranging for the needed personnel.

7. An instructional session was held for the count personnel in each county on the afternoon preceeding the count. Each person was assigned a specific location and told exactly what had to be done. The count was made from 8:00 AM till noon and again from 2:00 PM to 6:00 PM for a total of 8 hours at each selected location. An automatic volume recording device was installed on each of five roads in each county during the counting period in order to determine appropriate expansion factors.

8. All data were collected and returned to HERPIC for processing and analysis.

RESULTS OF THE STUDY

GENERAL

The County Highway System of Indiana consists of two distinct subsystems, each under county supervision. The first subsystem consists of 12,948.3 miles of Federal-Aid-Secondary county roads while the second consists of 55,079.0 miles of non-FAS county roads. The County Highway System thus totals 68,027.3 miles of road. These figures are based on the recently completed inventory of all county roads as performed under the direction of the Indiana State Highway Commission (ISHC).

As the Division of Planning of the ISHC conducts a continuing program of volume counts on all State and Federal-Aid roads, the FAS county road system was not included in the sampling operations. Traffic volumes for these roads were obtained from the Division of Planning for the sampled 25 Indiana counties.

Thus, two road populations were sampled. However, since three counties submitted an unreasonable volume stratification, these three were considered as a third population as distinguished from the remaining 89 counties.

FAS COUNTY ROAD SYSTEM

Traffic volume data were available from the Division of Planning for almost all miles of FAS county roads in each of the 25 counties. These were raw data in the form of a 24-hour volume count for each road section.

Two expansion factors, growth and seasonal, were required to convert these volumes to 1966 AADT's. An average growth of 4% per year was used

in order to update those counts not made in 1966.

The seasonal expansion factor, to account for the time of year when the count was taken, was estimated from Figure 2 which is a plot of the expansion factors used by the Division of Planning to convert 24-hour weekday volumes to AADT's for local roads in rural areas. The application of these two factors to each volume produced an AADT for each road section. The factors used for each county are shown in Table 3.

Volume measurements for 3229.4 miles of FAS county roads in the 25 counties were used in providing an estimate of vehicle miles of travel for the 12,948.3 miles of this system. The data were analyzed as a simple random sample. This could be considered as a double sampling or sub-sampling of m_i miles from the total miles, M_i, of each of the n counties selected from the N total counties. Since in each county, virtually all the miles of road were sampled, the double sampling reverts to a cluster sample. However, each cluster (county) has a largely varying size (number of miles) and since the counties were selected at random, the normal analyses of cluster sampling revert to those for simple random sampling.

The average AADT ($\bar{a}$) of this system was 412.4 vehicles per day. The variance, s^2, was calculated by:

$$s^2 = \frac{1}{m-1} \left(\sum m_i (a_i)^2 - \left(\sum m_i a_i \right)^2 / \sum m_i \right)$$

where m is the sample size,

m_i is the length of the i^{th} road section,

and a_i is the ADT of the i^{th} road section.

The variance of $\bar{a}$, $s_{\bar{a}}^2$, was estimated by:

$$s_{\bar{a}}^2 = \frac{s^2}{m} \left((M - m) / M \right)$$

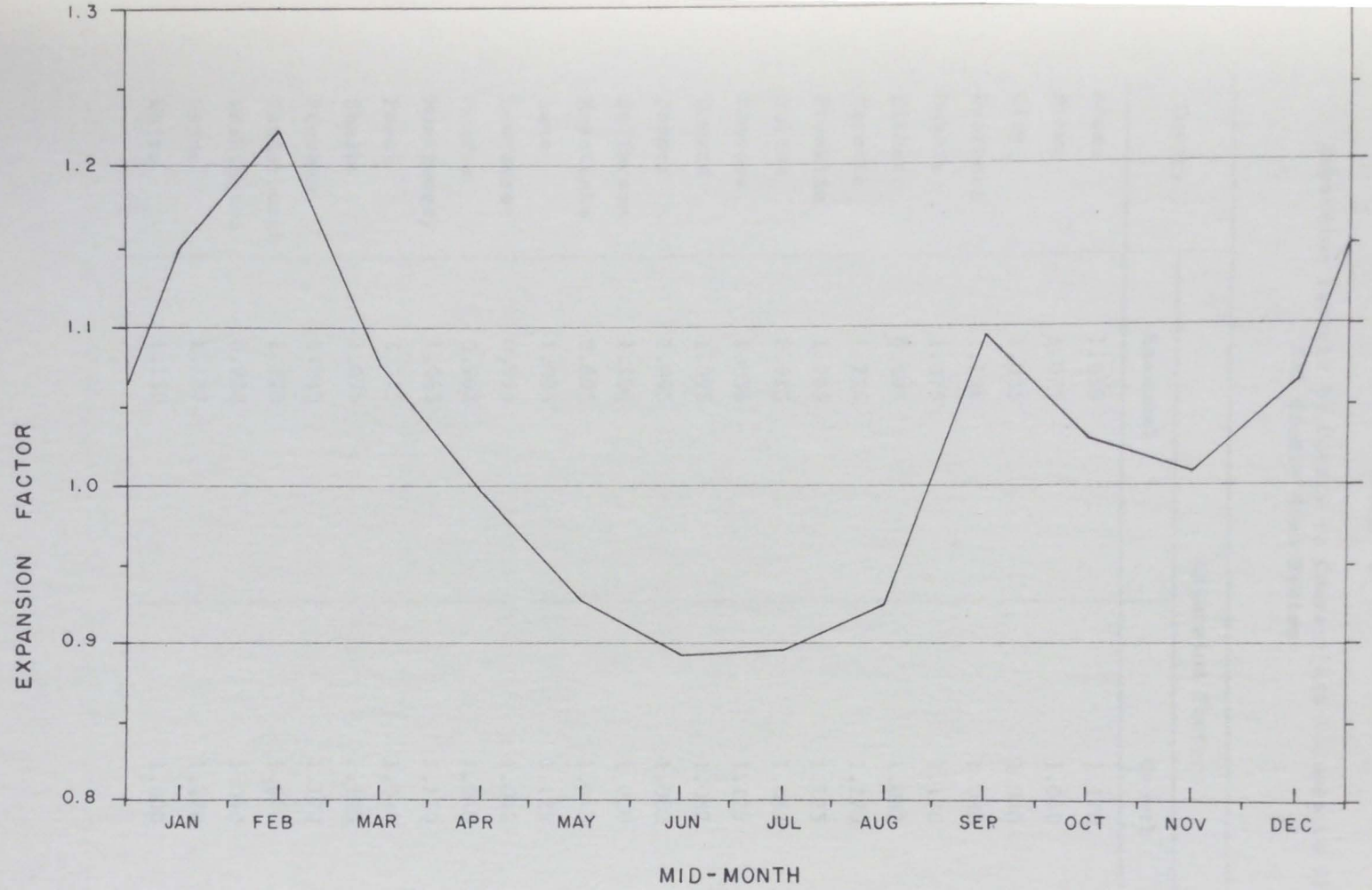

FIGURE 2. FACTORS TO EXPAND 24 HOUR WEEKDAY (MONDAY THROUGH THURSDAY) VOLUMES TO AADT - LOCAL ROADS IN RURAL AREAS

TABLE 3

Expansion Factors by County to Convert Raw Volumes to ADT
FAS County Road System

County	Expansion Factors	
	Seasonal	Growth
Adams	1.018	1.170
Brown	1.075	1.040
Clay	1.035	1.040
Dearborn	1.106	1.082
Dubois	1.075	1.170
Elkhart	0.895	1.082
Fayette	1.224	1.170
Franklin	1.065	1.125
Fulton	0.915	1.082
Hancock	1.036	1.125
Howard	1.095	1.082
Jasper	1.095	1.082
Jefferson	1.180	1.000
Kosciusko	0.895	1.040
Lake	1.035	1.125
Lawrence	0.995	1.040
Monroe	0.962	1.040
Montgomery	1.065	1.170
Posey	1.225	1.040
Shelby	1.075	1.125
Steuben	0.915	1.170
Vanderburgh	1.225	1.040
Washington	0.928	1.040
Wayne	1.107	1.170
White	1.150	1.000

where M is the total length of the system.

The estimate of vehicle miles, $\hat{A}$, was given by $M\bar{a}$, the population total, and equaled 5.34 million per day or 1.949 billion vehicle miles per year. The estimate of annual vehicle miles of travel was computed to be within plus or minus 4.86% the true value at the 95% confidence level. The estimates computed for the FAS county road system are summarized in Table 4.

Figure 3 shows the complementary cumulative distribution of road miles and vehicle miles as a function of AADT. About 50% of the vehicle miles of travel occurs on the 88% of the road miles with an AADT of 750 vehicles per day or less.

Non-FAS County Roads - 89 Counties

Since the volume stratification of three counties was judged inadequate, the analysis described here was performed on the data collected in 22 counties and expanded to 89 of Indiana's 92 counties.

The data were collected in the form of eight hourly counts of the four vehicle classifications: namely automobiles, pickup and panel trucks, other trucks, and other vehicles. The 8-hour totals of each vehicle classification as well as the total number of vehicles were determined for each road section counted. The hourly breakdown on the data sheets (see Appendix I) served no purpose other than to insure some order in data collection.

In all, there were 748 data sets covering 1676.5 miles of road included in this portion of the analysis.

An expansion factor to convert the 8-hour counts to AADT's was determined separately for each county and applied to all counts made in

TABLE 4

Summary of Estimates - FAS County Roads

Total Length -	12,948.3 Miles
Sampled Length -	3,229.4 Miles

Average Daily Traffic

Average ADT	412.4 Vehicles Per Day
Variance	104.75
Standard Deviation	10.24
95% Confidence Interval	392.3 to 432.5

Vehicle Miles of Travel

Vehicle Miles	5,339,797 Per Day
Variance	17.562 Billion
Standard Deviation	132,523
95% Confidence Interval	5,080,000 to 5,600,000

Annual Vehicle Miles of Travel

Vehicle Miles	1.949 Billion Per Year
95% Confidence Interval	1.854 Billion to 2.044 Billion

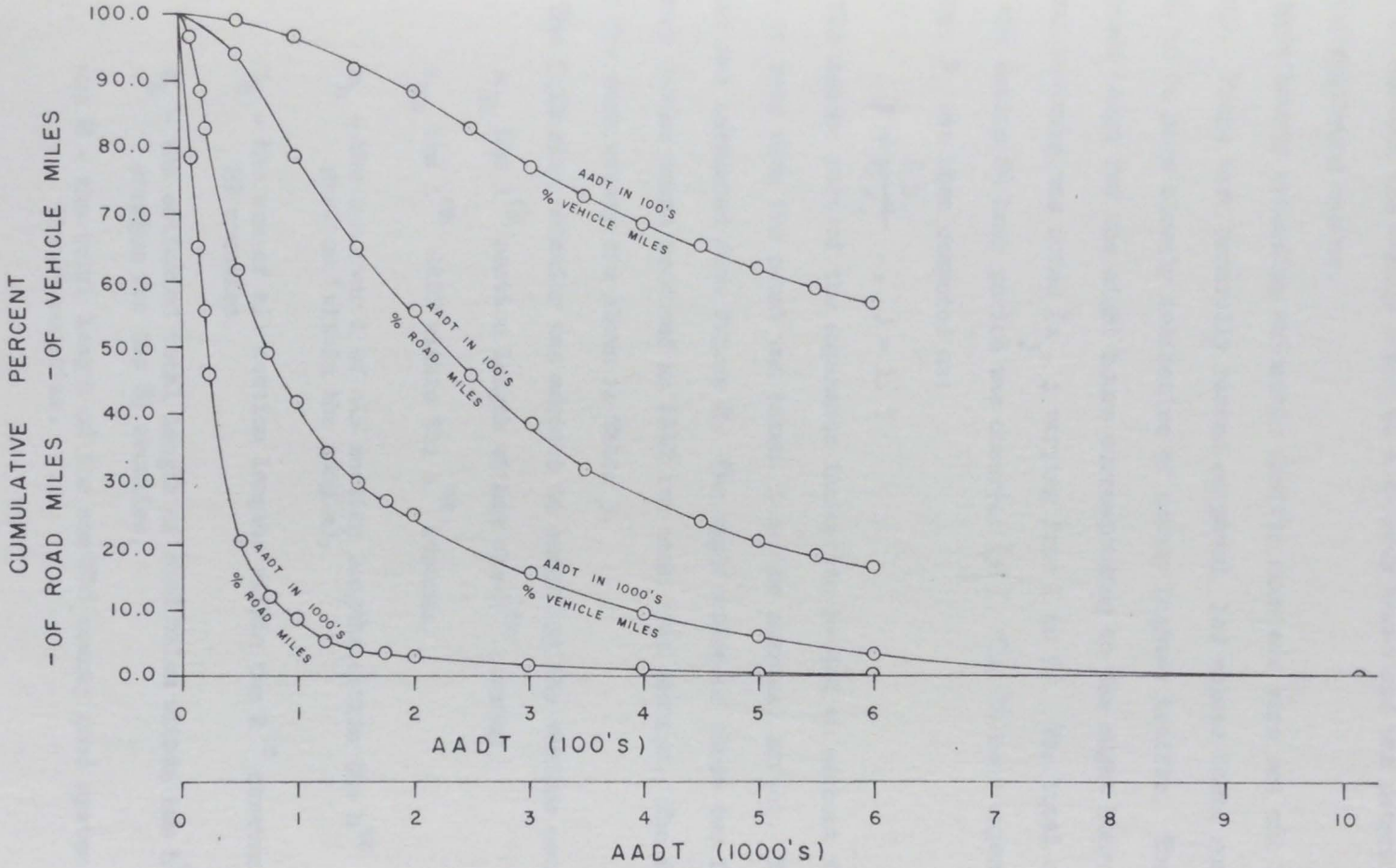

FIGURE 3. ROAD MILES AND VEHICLE MILES AS A FUNCTION OF AADT
(FAS COUNTY ROAD SYSTEM)

the county. Each expansion factor consisted of two parts. The first was used to convert the 8-hour count to a 24-hour count and was determined in the following manner.

Five hourly recording automatic traffic counters were set out in each county. These were generally placed on paved, low volume State routes in order to be more closely indicative of county highway traffic. The total recorded count for the eight hours corresponding to the eight hours of manual counting was noted (x_j, j varying from 1 to 5). The total count for the entire 24 hour period was observed (y_j). The 24 hour expansion factor, F, was then computed as:

$$F = \frac{\Sigma y_j}{\Sigma x_j} \quad , \quad j = 1, 5$$

The second part of the expansion factor was needed to account for the time of year when the count was taken, i.e. the seasonal effect. This factor was estimated from Figure 2. The application of these two factors to each 8-hour count produced an AADT for each road section. The factors used for each county are shown in Table 5.

The following notation was adopted in computing the various estimates:

m_{ih} the i^{th} section length within the h^{th} stratum,

a_{ih} the i^{th} AADT within the h^{th} stratum,

m_h - the sum over i of all section lengths within the h^{th} stratum (within the sample),

L_h - the sum of all section lengths within the h^{th} stratum for 22 counties,

M_L - the estimated total length of road miles within the h^{th} stratum for the 89 counties,

and M - the total length of the non-FAS county road system in the 89 counties.

TABLE 5

County Data Summary

County	Expansion Factors		County Road Miles						Number of Counts by Stratum				
	24 Hour	Seasonal	All Roads	FAS Roads	Totals by Stratum 1	2	3	4	1	2	3	4	All
Adams	2.04	0.895	692.4	194.0	0.0	3.8	38.6	456.0	0	3	14	5	22
Brown	1.95	0.904	565.3	88.6	0.0	0.0	39.7	437.0	0	0	15	5	20
Clay	2.02	0.894	719.9	145.9	3.0	5.4	88.9	476.7	4	7	18	6	35
Dearborn	2.04	0.918	529.9	77.9	0.0	11.6	74.9	365.5	0	4	13	5	22
Dubois	2.09	0.895	720.2	121.7	0.0	7.8	47.8	542.9	0	6	18	6	30
Elkhart	1.96	1.060	1011.4	134.8	26.7	114.4	162.9	572.6	15	18	22	7	62
Fayette	2.09	0.920	374.4	92.0	0.0	4.2	66.3	211.9	0	3	9	3	15
Franklin	1.98	0.920	717.7	129.1	0.0	0.0	68.6	520.1	0	0	18	6	24
Fulton	1.97	0.948	774.9	153.4	1.1	80.6	241.1	298.7	1	20	17	5	43
Howard	2.06	0.977	642.9	171.1	2.7	19.2	67.7	382.2	4	13	15	4	36
Jefferson	2.00	0.918	605.9	84.7	0.0	8.6	262.9	249.7	0	11	15	5	31
Kosciusko	1.96	0.910	1160.7	166.2	0.0	9.0	363.8	621.7	0	6	30	10	46
Lawrence	2.15	0.901	708.7	130.4	0.0	34.5	122.4	421.4	0	16	15	4	35
Monroe	2.18	0.903	739.0	171.9	10.1	37.3	103.7	416.0	6	16	16	5	43
Montgomery	2.03	0.910	869.3	201.8	0.0	18.9	183.8	464.8	0	14	20	6	40
Perry	2.12	0.895	589.9	60.5	0.0	1.7	20.4	507.3	0	1	11	10	22
Posey	2.01	0.895	801.9	113.7	0.0	8.5	118.2	561.5	0	2	21	7	30
Steuben	1.90	0.937	644.4	70.7	0.0	22.1	257.4	294.2	0	19	16	5	40
Vanderburgh	2.13	0.895	509.9	151.2	9.7	40.0	59.6	249.4	8	17	11	2	38
Washington	1.98	0.901	842.5	116.4	0.0	31.6	199.0	495.5	0	15	21	7	43
Wayne	2.14	0.925	715.5	204.1	0.0	40.3	279.8	191.3	0	16	11	4	31
White	1.95	0.910	881.3	211.3	0.0	15.2	122.3	532.5	0	13	20	7	40

The sum of squares, SS_h, and the variance, s_h^2, were then computed for each stratum as follows:

$$= \Sigma\, m_{ih}\,(a_{ih})^2 - \frac{(\Sigma\, m_{ih}\, a_{ih})^2}{\Sigma\, m_{ih}}$$

$$s_h^2 = SS_h / (m_h - 1)$$

The average AADT of each stratum, $\bar{a}_h$, was computed by:

$$\bar{a}_h = \Sigma\, m_{ih}\, a_{ih}/m_h$$

The estimated size of each stratum for the 89 counties was computed by:

$$M_h = (L_h/\Sigma\, L_h)\, M$$

The individual stratum totals for each of the 22 counties from which these estimates were made are given in Table 5.

The overall AADT of this road system, $\bar{a}_{st}$, was given by:

$$\bar{a}_{st} = (\Sigma\, \bar{a}_h\, M_h)/M$$

and the variance of this estimate, $s^2(\bar{a}_{st})$, by:

$$s^2(\bar{a}_{st}) = \frac{1}{M^2}\,\Sigma\, M_h(M_h - m_h)\left(\frac{s_h^2}{m_h}\right)$$

The population total (vehicle miles), $\hat{A}_{st}$, was estimated by:

$$\hat{A}_{st} = \bar{a}_{st}\, M$$

and the variance of this estimate, $s^2(\hat{A}_{st})$, by:

$$s^2(\hat{A}_{st}) = \Sigma\, M_h(M_h - m_h)\left(\frac{s_h^2}{m_h}\right)$$

The standard deviation of each estimate was obtained by taking the square root of the respective variances. Thus, the estimate of the overall AADT, $\bar{a}_{st}$, was 151.6 vehicles per day with a standard deviation of

4.195, and a 95% confidence interval of plus or minus 8.22. The estimate of vehicle miles, $\hat{A}_{st}$, was 8,052,000 per day with a standard deviation of 222,775, and a 95% confidence interval of plus or minus 436,640.

The estimate of vehicle miles and its confidence interval were placed on an annual basis by multiplying each respective estimate by 365 days. This yielded an estimate of 2.939 billion vehicle miles per year with a 95% confidence interval of plus or minus 159.4 million. This estimate was calculated to be within plus or minus 5.4% of the true value at the 95% confidence level.

The quantities calculated for each stratum and for the population estimates are summarized in Table 6.

Figure 4 shows the complementary cumulative distribution of road miles and vehicle miles as a function of AADT. About 50% of the vehicle miles of travel are driven on the 85% of the road miles with an AADT of about 220 vehicles per day or less.

Non-FAS County Roads - 3 Counties

The analysis of the data for these three counties was similar to that described in the last section. There were 121 data sets covering 288.2 miles of road included in this portion of the analysis.

The overall AADT of this road subsystem, $\bar{a}_{st}$, was estimated as 166.7 vehicles per day with a standard deviation of 16.734, and a 95% confidence interval of plus or minus 32.80. The estimate of vehicle miles, $\hat{A}_{st}$, was 328,630 with a standard deviation of 32,984, and a 95% confidence interval of plus or minus 64,650.

Converting these estimates to an annual basis resulted in an estimate of 119,949,000 vehicle miles per year with a 95% confidence interval of

TABLE 6

Summary of Estimates - Non-FAS County Roads - 89 Counties

	Within Stratum Quantities					
Stratum	m_h	L_h	M_h	s_h^2	$\bar{a}_h$	$M_h(M_h - m_h)(s_h^2/m_h)$
1	53.3	53.3	220.7	3911776	2515.4	2,711,033,046
2	358.0	514.7	2131.1	187746	499.9	1,981,593,609
3	925.5	2989.8	12379.0	48781	214.2	7,473,081,887
4	339.7	9268.9	38377.2	8718	98.5	37,463,197,110
all	1676.5	12826.7	53108.0			49,628,905,060

Stratified Estimates

Average Daily Traffic

Average ADT	151.6 Vehicles Per Day
Variance	17.6
Standard Deviation	4.195
95% Confidence Interval	143.4 to 159.8

Vehicle Miles of Travel

Vehicle Miles	8052013 Per Day
Variance	49.629 Billion
Standard Deviation	222775
95% Confidence Interval	7615373 to 8488653

Annual Vehicle Miles of Travel

Vehicle Miles	2.939 Billion Per Year
95% Confidence Interval	2.780 to 3.098 Billion

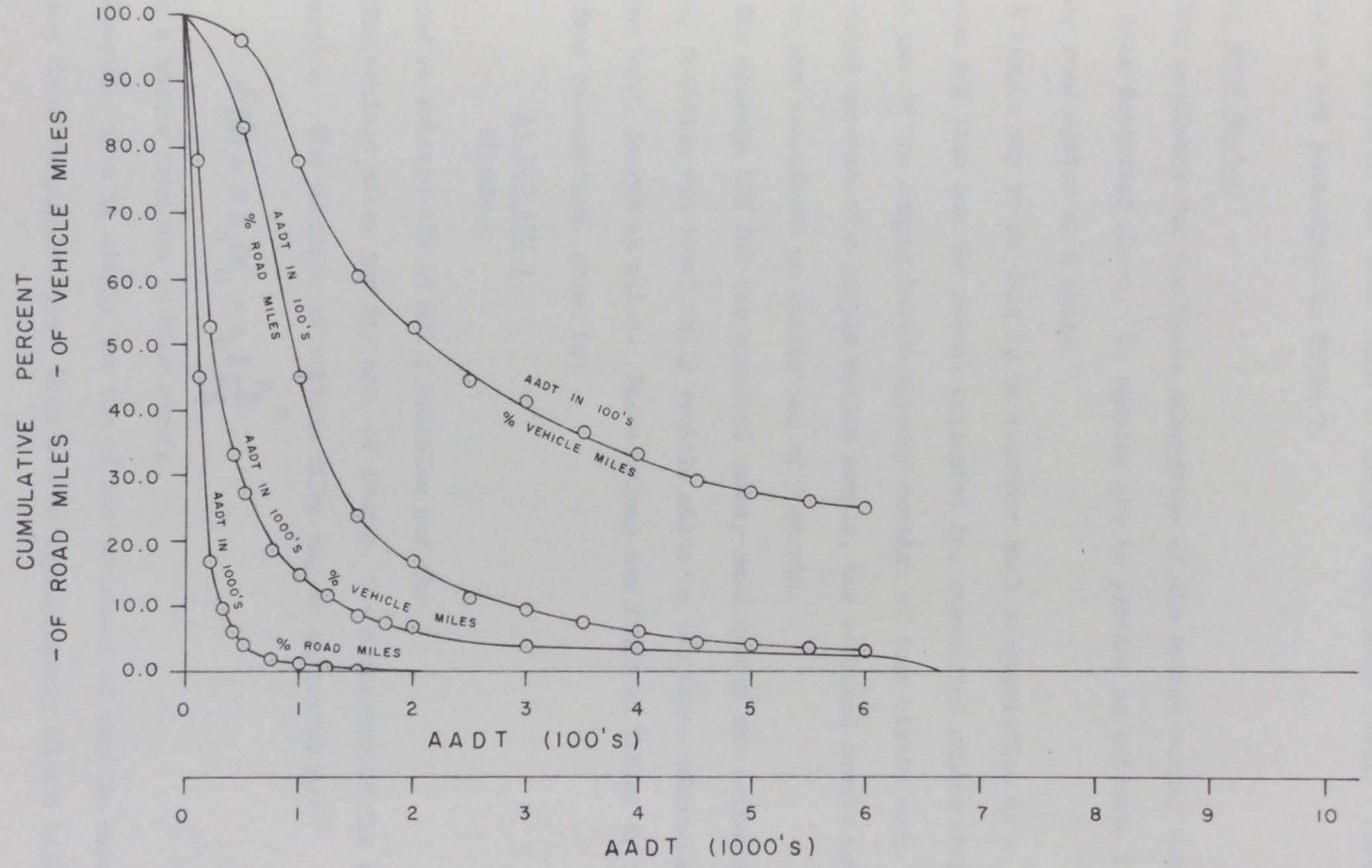

FIGURE 4. ROAD MILES AND VEHICLE MILES AS A FUNCTION OF AADT
(NON-FAS COUNTY ROAD SYSTEM)

plus or minus 23,596,000. This estimate was calculated to be within plus or minus 19.7% of the true value at the 95% confidence level. These estimates are summarized in Table 7.

County Road System

The estimates for the three subsystems of the entire county road system have been described above. It remains now to provide an estimate for the county road system as a whole.

A simple way to do this is to consider each subpopulation as a stratum and then use the normal estimates for stratified random sampling. Since two of the subpopulation already consist of four strata each, while the third consist of a simple random sample, the combined county road system was considered as consisting of 9 strata.

The average ADT for the combined county road system was estimated by simply dividing the total daily vehicle miles on the three subpopulations by the total length in miles. These values are found in Tables 4, 6, and 7. This calculation, given by:

$$\frac{13,720,437.7}{68,027.3}$$

yielded an average ADT of 201.7 vehicles per day.

The vehicle miles per day are, of course, the numerator of the above expression. The variance of vehicle miles may be estimated by:

$$s^2(\hat{X}) = \Sigma M_h(M_h - m_h)\frac{s_h^2}{m_h}$$

where h varies from one to nine strata.

However, this is simply the sum of the variances of vehicle miles for the three subpopulations. This sum is approximately 68.279 billions,

TABLE 7

Summary of Estimates - Non-FAS County Roads - 3 Counties

Within Stratum Quantities						
Stratum	m_h	L_h	M_h	s_h^2	$\bar{a}_h$	$M_h(M_h - m_h)(s_h^2/m_h)$
1	56.6	307.7	307.7	508557	445.5	694,220,948
2	141.8	513.8	513.8	25419	151.3	34,263,118
3	71.1	484.6	484.6	8443	95.6	23,793,792
4	18.7	664.9	664.9	14608	101.5	335,635,823
all	288.2	1971.0	1971.0			1,087,913,677

Stratified Estimates

Average Daily Traffic

Average ADT	166.7 Vehicles Per Day
Variance	280.0
Standard Deviation	16.73
95% Confidence Interval	133.9 to 199.5

Vehicle Miles of Travel

Vehicle Miles	328627 Per Day
Variance	1.088 Billion
Standard Deviation	32984
95% Confidence Interval	263979 to 393275

Annual Vehicle Miles of Travel

Vehicle Miles	119.9 Million Per Year
95% Confidence Interval	96.4 to 143.5 Million

so that the standard deviation of vehicle miles is about 261,300.

The variance of the average AADT is obtained by dividing the variance of vehicle miles by the square of the total length in miles. This calculation produced a variance of 14.8 and a standard deviation of 3.84.

The estimate of annual vehicle miles of travel was 5.008 billion. The 95% confidence interval was plus or minus 186.9 million. This estimate was calculated to be within plus or minus 3.7% of the true value at the 95% confidence level.

The estimates for the combined county road system are summarized in Table 8.

Figure 5 shows the complementary cumulative distribution of road miles and vehicle miles as a function of AADT for the combined county road system. About 50% of the vehicle miles are driven on the 88.5% of the road miles with an AADT of about 370 vehicles per day or less.

The concentration of vehicle traffic is illustrated in Figure 6. Here the complementary cumulative distribution of vehicle miles of travel is plotted versus that of road miles. The curves for FAS roads, non-FAS roads, and the complete county road system are virtually identical in shape and placement. However, it must be noted that at points where the three curves are identical, the AADT's relative to each curve are quite different.

Vehicle Classification

The analysis of vehicle classification was restricted to the data collected for 22 counties.

The 8 hour total of each vehicle classification type for each data set was first multiplied by the appropriate expansion factors for the

TABLE 8

Summary of Estimates - All County Roads

Total Length	68,027.3	Miles
FAS Roads	12,948.3	Miles
Non-FAS Roads	55,079.0	Miles
Sampled Length	5,194.1	Miles
FAS Roads	3,229.4	Miles
Non-FAS Roads	1,964.7	Miles
Average Daily Traffic		
FAS Roads	412.4	
Non-FAS Roads	151.6	
All County Roads	201.7	
Variance	14.8	
Standard Deviation	3.84	
95% Confidence Interval	194.2 to 209.2	
Vehicle Miles of Travel		
FAS Roads	5.340	Million Per Day
Non-FAS Roads	8.381	Million Per Day
All County Roads	13.720	Million Per Day
Variance	68.279	Billion
Standard Deviation	261,300	
95% Confidence Interval	13.208 to 14.233	Million
Annual Vehicle Miles of Travel		
FAS Roads	1.949	Billion Per Year
Non-FAS Roads	3.059	Billion Per Year
All County Roads	5.008	Billion Per Year
95% Confidence Interval	4.821 to 5.195	Billion Per Year

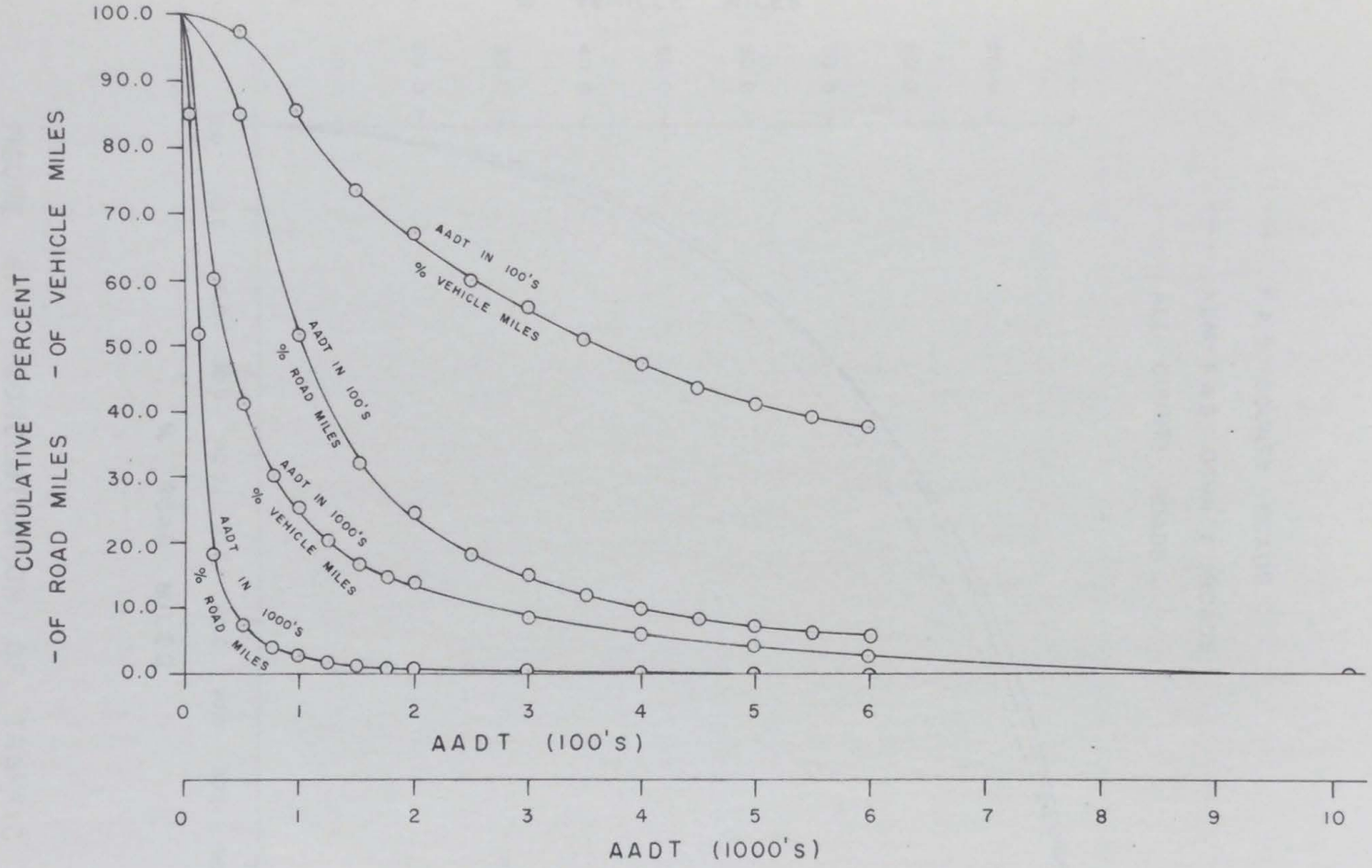

FIGURE 5. ROAD MILES AND VEHICLE MILES AS A FUNCTION OF AADT (COMPLETE COUNTY ROAD SYSTEM)

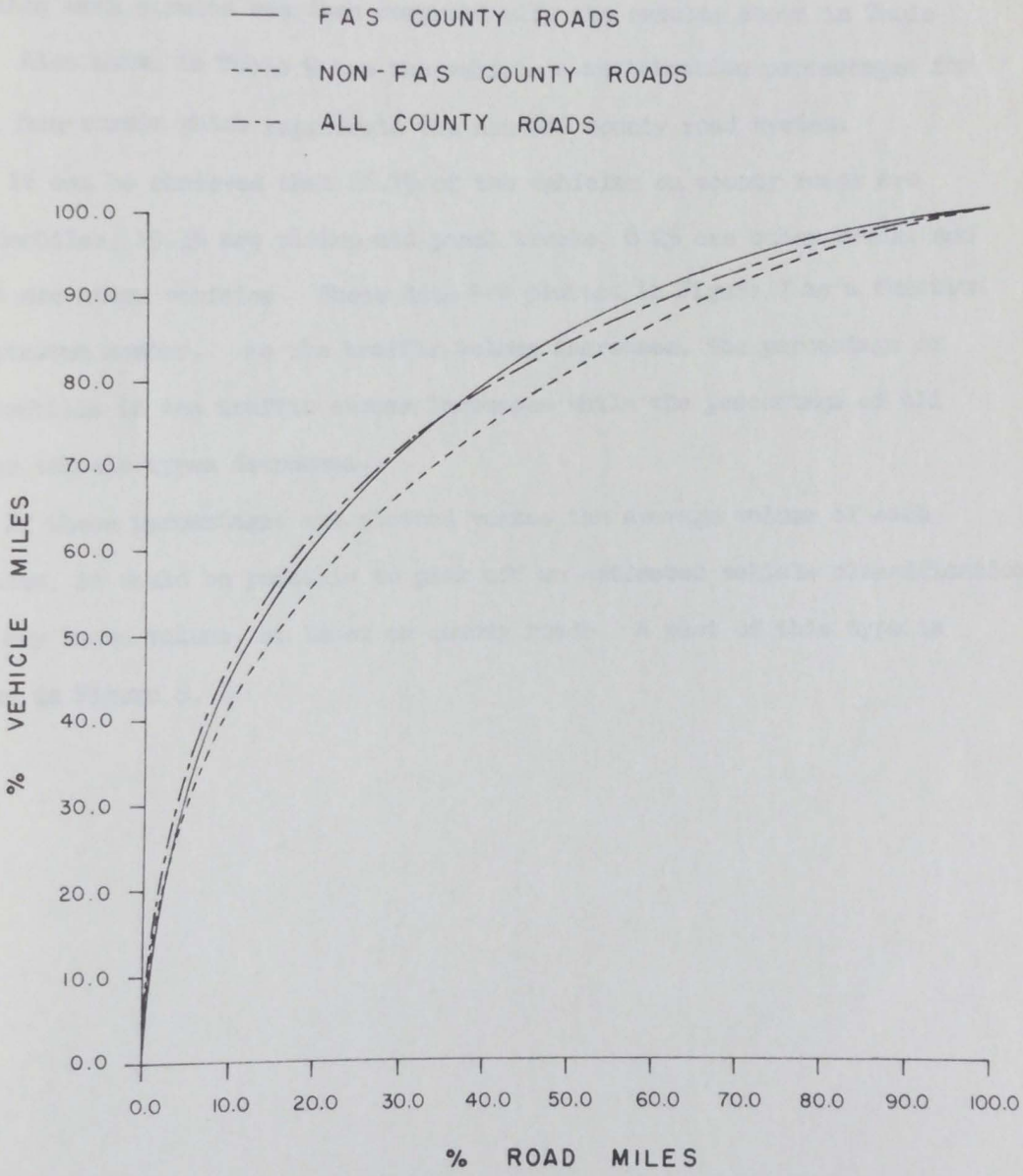

FIGURE 6. CONCENTRATION OF TRAFFIC

individual counties from Table 5. The average number of each vehicle type within each stratum was then computed, this average being weighted by the length of each road section. The percent of each vehicle type within each stratum was then computed with the results shown in Table 9. Also shown in Table 9 are the vehicle classification percentages for all four strata which represents the non-FAS county road system.

It can be observed that 66.7% of the vehicles on county roads are automobiles, 19.3% are pickup and panel trucks, 8.2% are other trucks and 5.9% are other vehicles. These data are plotted in Figure 7 as a function of stratum number. As the traffic volume increases, the percentage of automobiles in the traffic stream increases while the percentage of all other vehicle types decreases.

If these percentages are plotted versus the average volume of each stratum, it would be possible to pick off an estimated vehicle classification for any known volume, at least on county roads. A plot of this type is shown in Figure 8.

TABLE 9

Vehicle Classification

Stratum	Vehicle Type (% Within Each Stratum)			
	Cars	Pickups & Panels	Other Trucks	Other Vehicles
1	77.9	13.7	6.7	1.7
2	73.5	16.1	7.4	3.1
3	68.2	18.6	8.3	4.9
4	62.0	21.4	8.5	8.0
all	66.7	19.3	8.2	5.9

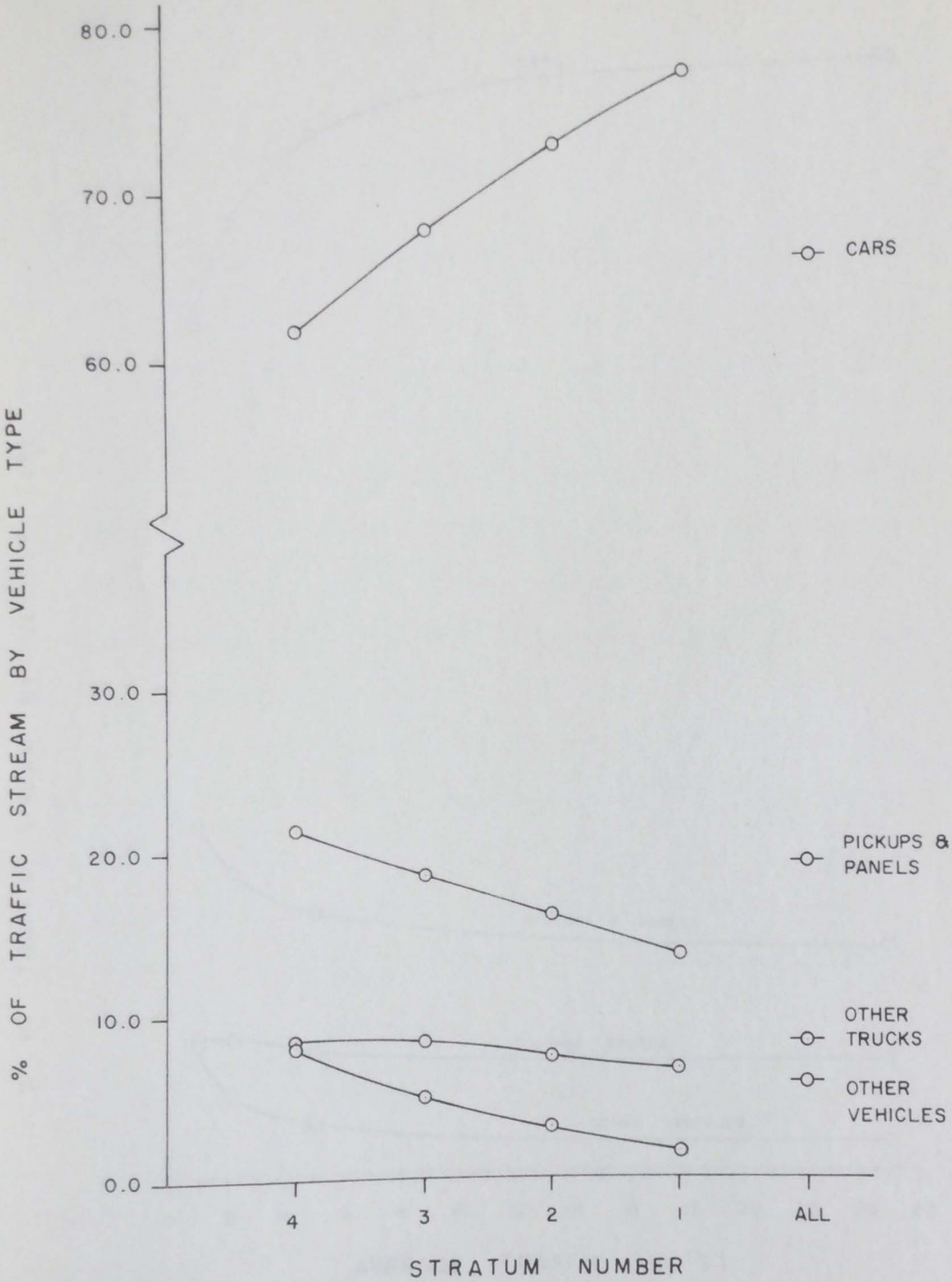

FIGURE 7. VEHICLE CLASSIFICATION - PERCENT OF VEHICLE TYPE BY STRATUM NUMBER

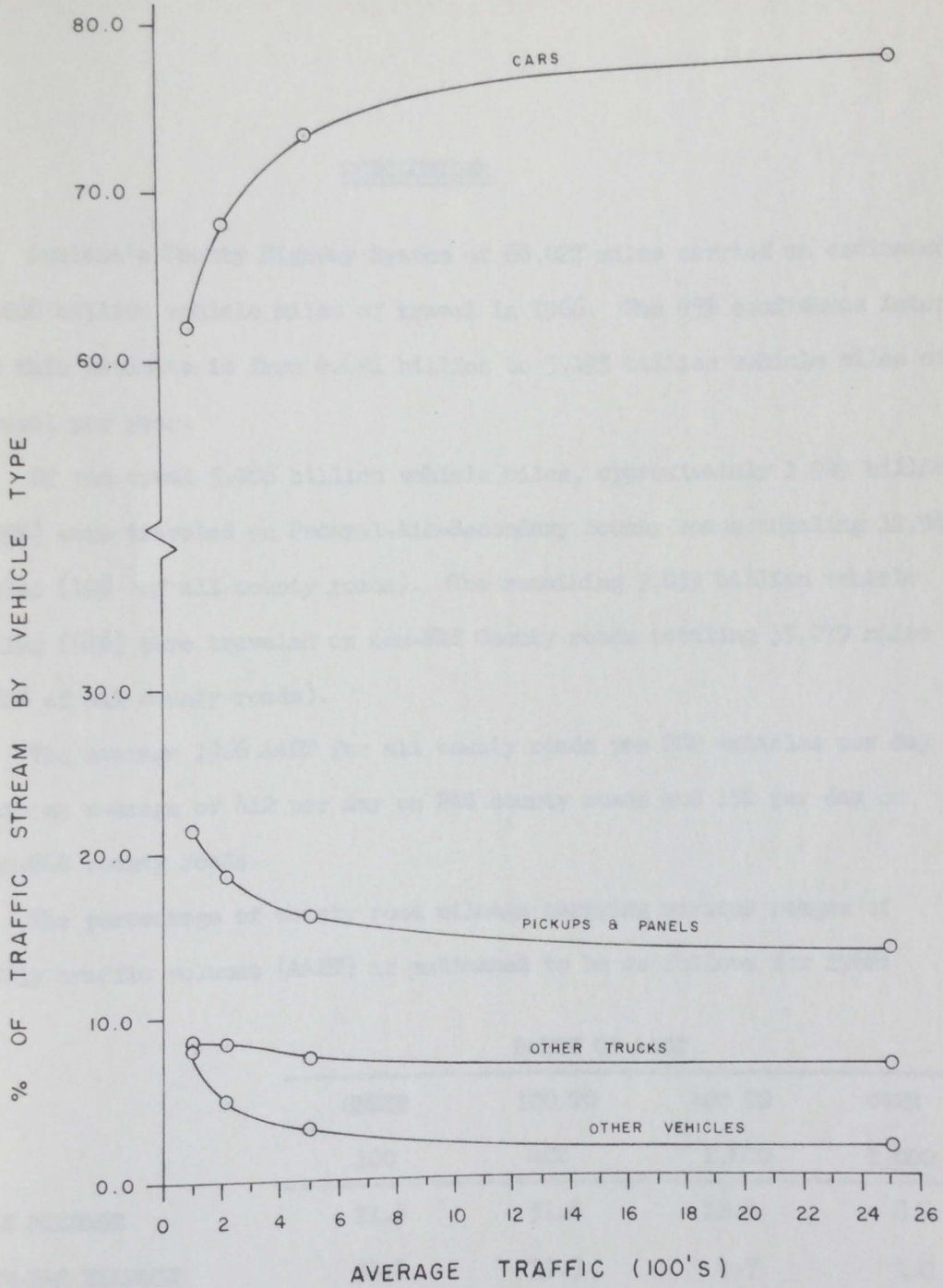

FIGURE 8. VEHICLE CLASSIFICATION - PERCENT OF VEHICLE TYPE BY AVERAGE AADT OF EACH STRATUM

CONCLUSIONS

Indiana's County Highway System of 68,027 miles carried an estimated 5.008 billion vehicle miles of travel in 1966. The 95% confidence interval on this estimate is from 4.821 billion to 5.195 billion vehicle miles of travel per year.

Of the total 5.008 billion vehicle miles, approximately 1.949 billion (39%) were traveled on Federal-Aid-Secondary county roads totaling 12,948 miles (19% of all county roads). The remaining 3.059 billion vehicle miles (61%) were traveled on non-FAS County roads totaling 55,079 miles (81% of all county roads).

The average 1966 AADT for all county roads was 202 vehicles per day with an average of 412 per day on FAS county roads and 152 per day on non-FAS county roads.

The percentage of county road mileage carrying various ranges of daily traffic volumes (AADT) is estimated to be as follows for 1966:

	RANGE OF AADT			
	UNDER 100	100 TO 400	400 TO 1,000	OVER 1,000
FAS MILEAGE	21.4	51.8	18.4	8.4
NON-FAS MILEAGE	54.8	39.3	4.7	1.2
ALL COUNTY ROADS	48.2	41.8	7.4	2.6

The classification of vehicles by percent for all non-FAS county roads is estimated to be as follows for 1966: 67% automobiles; 19% light trucks; 8% other trucks; and 6% other vehicles.

BIBLIOGRAPHY

1. "A Study of Local Rural Highways in Allen County, Indiana," John E. Baerwald, Joint Highway Research Project, Traffic Engineering Services Unit, Purdue University, 1955.

2. "Handbook of Facts and Figures on Indiana County Roads," Jean E. Hittle, Highway Extension and Research Project for Indiana Counties, June, 1965.

3. "Sampling Techniques," W. G. Cochran, John Wiley & Sons, 2nd edition, 1963.

4. Unpublished data and information from the Indiana State Highway Commission.

APPENDIX I

SELECTED EXHIBITS

SELECTED EXHIBITS

The exhibits shown on the following pages are generally self-explanatory. However, they are listed individually below as a guide.

TRAFFIC STUDY PROPOSAL
from
Indiana Association of County Commissioners

To H.E.R.P.I.C. Advisory Board:

The Highway Needs Study Committee, created by the 1965 General Assembly, is in the process of studying all highway systems, State, County and Cities in the State. The future amount of funds for highway use will be governed by the report of this committee. One of the significant factors contributing to the need for construction and highway maintenance is the type and volume of traffic using highways. It is essential that accurate traffic information on use of county highways be made available to the Highway Needs Study Committee. The State has available facilities for traffic study, the cities by reason of the nature of their streets and highways also possess adequate facilities for traffic study. The counties of the State do not have these facilities available.

The funds H.E.R.P.I.C. operates on are county funds distributed from the Motor Vehicle Highway Account, and the representatives of Purdue University, acting as consultants to H.E.R.P.I.C., have always cooperated to provide effective information concerning county highways. It is requested by the Board of Directors of the Commissioners' Association that H.E.R.P.I.C. enter into a traffic study program to provide information for the assistance to the counties of the State in the highway needs of the State.

The study should show the type of traffic using county highways, number and amount of traffic and if possible the origination and destination of traffic. H.E.R.P.I.C. with the assistance of Purdue University should have no

difficulty in planning and engaging in these studies for the reason that the Civil Engineering Department in Purdue University has engaged in this type of program for a number of years. Although the consultants to H.E.R.P.I.C. are far more qualified to determine the type of study to be made, it is recognized that when time is available the study can be made of only a sampling of Indiana Counties. It is suggested that the sampling include one large county, one small county, two industrial medium size counties, and two rural non-industrial medium size counties. For example, the counties which might be included in the study are Vanderburgh, Madison, Tippecanoe, Decatur, Hendricks and Wabash.

The immediate attention of the Advisory Board is requested to permit all of the necessary information which can be obtained on traffic use on the county highways be made available to the Highway Needs Study Committee prior to the next Session of the General Assembly.

Glen Lake, Pres.	Joy Brown, N.E. Dist. Pres.
Richard Eckerle, V.Pres.	Tom Bell, N.W. Dist. Pres.
Byron Pike, Secy-Treas.	Arthur Himsel, W.C. Dist. Pres.
Claude Hodson, Exec.Secy.	Ernest Vance, S.E. Dist. Pres.
Nelson G. Grills, Counselor	Richard Eckerle, S.W. Dist. Pres.

February 28, 1966

Board of County Commissioners
Hancock County
County Court House
Greenfield, Indiana

Gentlemen:

The Highway Extension and Research Project for Indiana Counties (HERPIC) at Purdue University is conducting a study of travel characteristics on the county highways of Indiana at the suggestion of the Indiana Association of County Commissioners.

The enclosed paper, "Notes on Procedure - Travel on the County Highway System of Indiana," is a brief description of how the study will be performed and clearly states the assistance which will be required of the involved counties. Your county is one of those which has been selected for participation. It was selected on a sampling basis and as such it is important that you do participate so that the results will be reliable.

The very first item which must be completed by you is the designation of a qualified county representative to act as a liaison between the county and HERPIC staff. It is mandatory that this man be familiar with the road system of the county and that he have the authority to arrange for the needed personnel to assist in the conduct of the study.

As soon as this man has been designated (this must be done by March 15) please notify the following:

Walter C. Vodrazka
New Civil Engineering Building
Purdue University
Lafayette, Indiana 47907

Mr. Vodrazka, a member of the HERPIC staff, is in charge of the study. Some preliminary work, as explained in the enclosed paper, must be done prior to actual counting operations so it is important that the contact man be known as soon as possible.

After you receive this letter, you may attend one of the current series of HERPIC area Road Schools. I would be most happy to answer any questions you have at that meeting or perhaps I have discussed this matter with you at one of the meetings held the week of March 1-4. In any event do not hesitate to direct any questions to us.

Sincerely yours,

Jean E. Hittle
Research Engineer

Indiana Association of
COUNTY COMMISSIONERS
521 Board of Trade Building
Indianapolis, Indiana 46204

Area Code 317 · 639-1634

CLAUDE HODSON, Executive Secretary

Gentlemen:

During the last three Sessions of the General Assembly, there has been legislation introduced to change the formula of distribution of Highway funds among State, County and City Highway Departments. One of the big arguments used was the one that the counties carried only 7% of the traffic and got 32% of the funds. This we think is a very false statement, as some of the county roads we know carry more traffic than some state roads, and many of the city streets. At a recent meeting of the H.E.R.P.I.C. Board your President and Executive Secretary proposed that a traffic count be made in a representative group of counties to find out what the traffic count on some of the county roads really is. They have selected your county as one in which they wish to make a study.

In an accompanying letter they will explain the details of how and when they wish to make this study. If you already have taken some counts in your county you can show them what you have and they will work out with you what they need. This, along with the Highway Needs Study, should show that instead of taking some funds from the counties, they need more funds as do the State and Cities. With this thought in mind, we propose to ask for additional funds for everyone instead of fighting over what we have.

We hope, with your cooperation, that this study will give us the additional information we need to use in our legislative program and it should prove valuable to you in planning future highway programs in your own county.

Our Association, along with H.E.R.P.I.C., wish to thank you for your assistance in this project!

Sincerely,

Indiana Association of County Commissioners

/S/ Claude Hodson

Claude Hodson
Executive Secretary

COUNTY HIGHWAY TRAFFIC STUDY

County_____ Date_____ Name_____

Counting Location_____

TIME	VEHICLE CLASSIFICATION Passenger Cars	Pickup and Panel Trucks	Other Trucks	Other Vehicles
AM 8:00 - 9:00				
9:00 - 10:00				
10:00 - 11:00				
11:00 - 12:00				
LUNCH	12:00 noon	to	2:00 PM	
PM 2:00 - 3:00				
3:00 - 4:00				
4:00 - 5:00				
5:00 - 6:00				

REMARKS:

COUNTY HIGHWAY TRAFFIC STUDY

General Instructions:

Counting operations will start tomorrow morning. The count will begin at 8:00 AM and last until 6:00 PM with a two hour lunch break from noon until 2:00 PM.

You should be at your location by not later than 7:45 AM so that you can find a suitable parking place for your own car or a suitable spot from which to count if you do not use your car.

Vehicles moving in both directions along the roadway should be counted. First observe the vehicle classification. There are four: 1) passenger cars; 2) pickup and panel trucks; 3) other trucks and busses; 4) all tractor & horse drawn vehicles, and motorcycles. Then in the proper column for vehicle classification and opposite the current time interval, tally the vehicle as shown below. For instance, if a passenger car is observed between 9:00 and 10:00 AM, the tally sheet should look like this:

TIME	Passenger Cars	Pickup and Panel Trucks	Other Trucks	Other Vehicles
AM				
8:00 - 9:00	⧸⧸⧸⧸ ⧸⧸⧸⧸ ///	⧸⧸⧸⧸ /	///	//
9:00 - 10:00	/			

Thus, each vehicle is shown by a slash. The tally after 4 vehicles looks like this, //// . Indicate passage of a 5th vehicle by drawing a line through these 4 slashes like this, ⧸⧸⧸⧸ . After passage of the 6th vehicle, the tally would look like this, ⧸⧸⧸⧸ / . This process is continued through each of the 8 hourly intervals. In the figure shown above, the count from 8:00 - 9:00 AM is complete and the first vehicle counted during the 9:00-10:00 AM interval has been tallied.

APPENDIX II

DETAILED STUDY PROCEDURE

DETAILED STUDY PROCEDURE

The study reported on in this paper was carried out in the following manner:

1. A letter was written to each County Commissioner of each of the 25 included counties. The letter explained the purpose of the study and asked that a qualified county representative be appointed to act as liaison with HERPIC staff in charge of the study. A copy of this letter is included in Appendix I of this report. The man most often appointed was the county road supervisor and occasionally the county engineer.

2. Those roads which were classified as State primary and secondary roads and Federal Aid Secondary (FAS) county roads were delineated on the General Highway and Transportation Map of the county by different colored, thin tape strips. The remaining miles of road were thus county roads and included the sampling program. Volume counts for the FAS county roads were available from the Indiana State Highway Commission's Division of Planning which conducts a continuing volume count program on all State and Federal-Aid highways. A vehicle mile determination was made separately for the FAS county system. The county representative checked this map carefully for errors in delineation and divided the county roads into sections using his best judgment.

3. Each roadway section was then placed into its proper volume stratum as carefully as possible. In the actual mechanics of this step, sectioning and stratifying were done simultaneously to obtain the best results. Ideally, the county representative would study the roads and decide which roads belonged in stratum 1, i.e. with an ADT of over 1,000. He would then mark these roads with a colored pencil, performing the sectioning

operation as his judgment dictated. The process would then be continued through the remaining three strata using a different colored pencil for each.

4. Each road section of each stratum was scaled from the map to the nearest tenth of a mile. The stratification of each county's roads was checked for its feasibility and those of 3 counties were rejected and analyzed separately from the remaining counties. One of these counties claimed almost 6 times the number of miles of stratum 1 roads as the 24 remaining counties combined while the other two counties claimed as many miles of stratum 2 roads as the remaining 23 counties combined.

5. The number of counts in each volume stratum for each of the 22 counties was then determined. All of the information necessary for making the sample allocation was not available when sampling operations were scheduled to begin. The sample sizes were estimated in the following manner. Proportional allocation could not be used due to the high variances and low mileage totals of the two higher volume strata. Optimal allocation required the sampling of the entire first stratum and virtually all of the second stratum road miles. Since the additional data for making proper allocations for the third and fourth strata were not available, these strata were considered as a unit and the necessary quantities estimated. A variance of 20,000 and an average ADT of 200 were assumed. A necessary sample size of 800 miles resulted. While the size of the third and fourth stratum was thought to be about 50,000 miles, the sample had to be selected from the approximately 12,000 miles found in these two strata in the 22 counties. The sample size of 800 miles divided by 120 resulted in a figure

of about 6.7 miles of sample per 100 miles of road. Since the average section length was thought to lie between 1.50 and 2.0 miles, a sample of 4 counts per 100 miles of road was used. Three of these counts were allocated to stratum 3 roads and one to stratum 4 roads. Thus, the sample in each county consisted of one count for each stratum 1 road section, a count for almost all the stratum 2 sections, and three stratum 3 counts and one stratum 4 count for each 100 miles of strata 3 and 4 roads. The road sections on which counts were made were selected at random from the sections falling into each volume stratum.

6. The county representative was notified of the number of people required to perform the count and the date on which the count would be made. Each county was responsible for arranging to have the required number of personnel on hand for a short instructional session prior to counting and then for the actual counting itself. Personnel used in making the counts were paid by the individual counties and either were employees of the county or of neighboring counties, or were especially hired for the one day necessary to make the count, and in some instances were volunteers performing a public service.

7. The general procedure in making the counts was as follows. A HERPIC staff member left the Purdue University campus on Monday morning for the scheduled county. A meeting was held that afternoon with the county representative to iron out all the details such as determining that all roads on which counts were proposed were open to traffic, determining the location at which the count was to be made along the road section and so forth. When all problems had been resolved, an instructional meeting was held with the count personnel. Each counter was given a data

sheet, an instruction sheet, and a map of the county showing the exact location where he was supposed to count. This meeting generally lasted about 20 to 30 minutes. A copy of the data and instruction sheets are included in Appendix I of this report. The HERPIC staff member then installed 5 automatic recording traffic counters at 5 selected locations throughout the county. These were generally located on low volume state numbered routes. The counting operation began on Tuesday morning and counting extended from 8:00 AM to noon and again from 2:00 PM to 6:00 PM for a total of 8 hours. During the day, the HERPIC staff member drove the county to check on the automatic traffic counters and to visit each counter to make sure there were no problems. All data sheets were picked up that night, and on Wednesday morning, the HERPIC staff member moved on to the next county where the entire procedure was repeated. With the two HERPIC men assigned to this phase of the study, a maximum of four counties were counted each week. This was not done each week, however, as several counties had problems in scheduling with their own operations or with such things as county fairs and not being able to recruit the necessary personnel.

8. All data were returned to HERPIC at Purdue University for processing and analysis.

9. A letter of thanks for the cooperation and courtesies extended to the HERPIC staff in the conduct of the study was sent to each county representative. In addition, each county was sent a summary of the data collected within the county along with a map showing the specific road sections counted.

APPENDIX III

NOTES ON SAMPLING FOR ESTIMATES OF TRAVEL ON COUNTY ROADS

NOTES ON SAMPLING FOR ESTIMATES OF TRAVEL ON COUNTY ROADS

The relative precision of the stratified random sample to a simple random sample for the estimate of AADT for the non-FAS county road system was calculated to be about 246% for this study.

When the sampling allocation is far from proportional, as was the case here, the following simplified expression:

$$v(\bar{a})_{ran} = \frac{M - m}{M\,m}\left[\sum \frac{M_h}{M} s_h^2 + \sum \frac{M_h}{M} \bar{a}_h^2 - \left(\sum \frac{M_h}{M} \bar{a}_h\right)^2\right]$$

may be used for calculating the variance of the mean for a simple random sample provided that the sample size of each stratum is greater than 50. This variance was found to be 43.27 as compared to the variance of 17.6 calculated for the stratified sample. Thus, it appears that volume stratification of the county road system is worthwhile.

However, the fact that the stratum sizes were not known and only estimated introduced a bias into the estimates of the mean and the population total. The amount of bias could not be measured, of course, since to do so would have required the volume measurement of all roads.

In an effort to determine, at least the direction of the bias, an analysis was made wherein each road section was stratified on the basis of its measured AADT and each stratum size then corrected proportionately. The resulting vehicle miles of travel were about 12.5% higher for this analysis than that based on the as-stratified road sections. This figure, however, has no statistical justification other than it does appear to

indicate that the estimate of 5.008 billion vehicle miles is on the conservative side.

It is felt, however, that the large variances and small sizes of the higher volume strata justify and do make worthwhile the attempt to stratify road sections prior to selection of the sample. It may be noted that the total length of road miles estimated as belonging in the highest volume stratum comprised less than one-half of one % of the total miles of non-FAS roads but its computed variance was almost 450 times larger than that of the lowest volume stratum which comprised about 72 % of the road miles.

Another indication that the estimate of vehicle miles of travel was conservative is the fact that neither Marion or Lake Counties were included in the sample for the estimate for the non-FAS road system. Several county roads in Marion County carry average traffic volumes in excess of 20,000 vehicle per day while the largest AADT in the sample for the non-FAS county road system was 6830 vehicles per day and for the FAS county road system, 10,140 vehicles per day.

The several recommendations which follow are presented with a view toward improving the study if a similar one should ever be conducted.

1. The principle of volume stratification of road sections should be used. However, it appears from the experience gained in this study that an experienced research person and a representative of each involved county should stratify the roads rather than allow the county representative to attempt it by himself. This was done in three counties in this study and the resulting information was more accurate and also more readily coded.

2. The volume ranges used in setting strata boundaries for this study were used because design and tolerable standards for local roads used the same volume ranges. Thus, it was thought that most county representatives might better be able to stratify their roads. If these volume ranges change for the setting of standards, then so should the stratum boundaries.

3. It may be advisable to have all counties stratify their road systems and not just those counties included in the study. This procedure may provide a better estimate of strata sizes than the method of proportional expansions used in this study. However, those counties submitting stratification plans which are unrealistic should still be analyzed separately as was done in this study or a realistic stratification should be obtained.

4. Some additional thought should be given to the method of selecting the sample of counties in which counts will be made and subsequently, to the analysis of the data. A systematic sampling of counties may be a possibility. With the method of selection used in this study, consideration was given to analyzing the data as 28 strata rather than 4. The number 28 comes from the 4 volume strata within each of 7 county groups. In other words, volume stratum 1 roads in the first county group might be considered as one stratum and so forth. However, it was decided that this refinement and the additional analysis time was not worth the increase in precision that might result.

5. The precision achieved in this study was quite good in spite of the gross underestimates made for the stratum variances. This was due to several factors: the inclusion of all stratum 1 and most stratum 2 roads and, probably more significantly, the selection of sample size based

on trying to achieve a certain precision on the within stratum mean rather than on the stratified mean. This was done as a precautionary measure due to doubt of the accuracy of the estimated variances and because its use resulted in a reasonable number of counts.

It is recommended that the following procedure be used in determining the sample sizes of any future study: If the calculated variances given in Table 2 of this report for each stratum are used in the sample size expression for simple random smaples, it is found that the miles of road to be sampled in strata 1 through 4 are approximately 180, 774, 1530, and 1395 respectively in order to measure the within stratum mean to plus or minus 5 %. Each of these sizes divided by the total of 3879 provides sample weights, w_h. The following expression:

$$m = \frac{\sum (W_h^2 s_h^2)/w_h}{V + (\sum W_h s_h^2)/M}$$

may then be used to compute m for the stratified sample size where:

W_h is the stratum weight, M_h/M,

s_h^2 is the within stratum variance (from Table 2)

M is the total system length, and

V is an estimate of the variance of the stratified mean.

V may be estimated by:

$$V = (d/t)^2$$

where d is the maximum desired deviation of the mean ($\pm$ 5 %),

and t is the t-statistic (1.96).

This yields a value of m of 1419 miles. Applying the sample weights, w_h, to m the sample sizes of strata 1 through 4 are 66, 283, 560, and 510 miles respectively. The actual sample sizes used in this study were

53.3, 358, 925.5, and 339.7 miles respectively. The sample sizes finally decided upon should be increased by some percentage over those calculated in order to account for possible inaccuracies in the estimates of stratum means and variances. The sample size will also be subject to the available time and funds.