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I am submitting herewith a dissertation written by Dennis E. Quillen entitled "A Geographic Analysis of Non-Pedestrian Fatal Automobile Accidents in the Commonwealth of Kentucky, 1969-71." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Geography.

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Thesis
1975
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A GEOGRAPHIC ANALYSIS OF NON-PEDESTRIAN FATAL AUTOMOBILE ACCIDENTS IN THE COMMONWEALTH OF KENTUCKY, 1969-71

A Dissertation

Presented for the

Doctor of Philosophy

Degree

The University of Tennessee

Dennis E. Quillen

August 1975

1228033

DEDICATION

This work, which represents the culmination of my years of academic study, is dedicated to my mother, Rushia C. Quillen, who through her love, understanding, and personal and financial sacrifice, has contributed greatly to whatever success I have achieved or may ever achieve. Words cannot adequately express my appreciation, but, I thank you.

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ABSTRACT

The underlying purpose of this investigation is to provide geographic understanding of non-pedestrian fatal automobile accidents in Kentucky. The specific purpose is to examine fatal automobile accidents in the 120 counties of Kentucky between 1969 and 1971 and (1) to determine the statistical association between county exposure to fatal accidents and total fatal accidents, and (2) to see to what extent the computed statistical association satisfactorily explains the inter-county accident behavior among Kentucky's 120 counties. A further purpose is to determine whether these above-mentioned variables, or other independent variables which may prove to have explanatory power as disclosed in the course of the investigation, can be successfully used as inputs in a statistical model of fatal automobile accidents that would be reasonably predictive of fatal accident occurrences at the county scale.

Data on non-pedestrian fatal accident occurrences in Kentucky, totaling 2,278 accidents, were obtained for the years 1969-71. Utilizing both simple and multiple linear regression, fatal accidents, the dependent variable, were compared with selected independent variables believed to be associated with inter-county accident variations. Four independent variables, annual vehicle-miles, annual rural vehicle-miles, tourism, and the percentage of males 15-34 in the total population were eventually employed. Each variable as an individual was examined in simple regression analysis. The four variables were then examined in

multiple regression analysis. Finally, a simple regression analysis was performed using non-freeway (conventional roads) fatal accidents as the dependent variable and non-freeway (conventional roads) vehicle-miles as the independent variable. The residuals from each regression analysis were mapped and compared in the expectation that hypotheses for further statistical and geographic explanation would be forthcoming. Examination of maps of residuals eventually led to the consideration of four additional variables; terrain, alcoholic beverage consumption, levels of traffic law enforcement, and changes in county population 1960-1970.

The findings of the investigation show that at the county scale one variable, annual vehicle-miles, almost totally dominates in being associated with the inter-county variations in fatal accidents. The difference in rural and urban vehicle-miles driven was also found to contribute slightly to fatal accident variations. Both total and rural vehicle-miles were statistically significant at the .01 level of significance. The index of males 15-34 in the individual counties contributed only a very slight additional explanation in the model and was found to be significant at the .05 level, but not at the .01 level of significance. Tourism, in the multiple regression model, was neither statistically nor geographically significant in explaining accident variations. The four additional variables, terrain, alcoholic beverage consumption, levels of traffic law enforcement, and changes in county population 1960-1970 were also found not to be related to inter-county accident variations.

The model was found to be very predictive in terms of aggregate statewide accidents but only moderately predictive in terms of each individual county. The county unit was found not to be a very satisfactory scale for accident analysis. Future research would appear to be more fruitful at smaller scales of analysis.

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CHAPTER I

INTRODUCTION

About 56,600 people died in traffic accidents on United States highways in 1972.[1] This compares with 34,500 in 1940; 34,800 in 1950; 38,100 in 1960; and over 54,600 in 1970 (Table 1).[2] The number of deaths dropped by 1 percent between 1972 and 1973 to a total of 55,800 deaths. In 1974 and 1975 the death toll is expected to fall short of earlier estimates because of lower automobile speeds and fewer vehicle-miles resulting from the gasoline shortages in 1974, lowered speed limits, and higher gasoline prices.

Traffic accidents account for nearly 50 percent of all accidental deaths and are the leading cause of death in the one to twenty-four age group.[3] In any single year--based upon traffic deaths since 1968--the U.S. loses more people through automobile accidents than the total U.S. battle deaths in any of our wars except for the Civil War and World War II.[4]

These frequently-quoted statistics, dramatic as they may be, can be misleading. Although the number of fatal accidents and passenger fatalities tends to increase each year, the accident rate has been decreasing. Increases in population size, automobile registration, and

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[1] Statistics Division, National Safety Council, Accident Facts (1975 Edition. Chicago: National Safety Council, 1974), p. 13.

[2] Ibid. [3] Ibid., p. 8. [4] Ibid., p. 49.

TABLE 1

TRENDS IN MOTOR-VEHICLE DEATH RATES: 1913-1972

Year	Number of Deaths	Vehicle Miles (billions)	Death Rates Per 100,000,000 Vehicle Miles
1913-17 ave.	6,800	*	*
1918-22 ave.	12,700	*	*
1923-27 ave.	21,800	120	18.20
1928-32 ave.	31,050	199	15.60
1933	31,363	201	15.60
1934	36,101	216	16.75
1935	36,369	229	15.91
1936	38,089	252	15.11
1937	39,643	270	14.68
1938	32,582	271	12.02
1939	32,386	285	11.35
1940	34,501	302	11.42
1941	39,969	334	11.98
1942	28,309	268	10.55
1943	23,823	208	11.44
1944	24,282	213	11.42
1945	28,076	250	11.22
1946	33,411	341	9.80
1947	32,697	371	8.82
1948	32,259	398	8.11
1949	31,701	424	7.47
1950	34,763	458	7.59
1951	36,996	491	7.53
1952	37,794	514	7.36
1953	37,955	544	6.97
1954	35,586	562	6.33
1955	38,426	608	6.34
1956	39,628	631	6.28
1957	38,702	647	6.98
1958	36,981	665	5.56
1959	37,910	700	5.41
1960	38,137	719	5.31
1961	38,091	738	5.16
1962	40,804	767	5.32
1963	43,564	805	5.41
1964	47,700	847	5.63
1965	49,163	888	5.54
1966	53,041	930	5.70

TABLE 1 (Cont'd)

Year	Number of Deaths	Vehicle Miles (billions)	Death Rates Per 100,000,000 Vehicle Miles
1967	52,924	962	5.50
1968	54,862	1,016	5.40
1969	55,791	1,071	5.21
1970	54,800	1,120	4.89
1971	54,700	1,186	4.61
1972	56,800	1,250	4.53
1973	55,800	1,306	4.27

Source: Accident Facts, 1974 Edition (Chicago: National Safety Council, 1974), p. 59.

*Mileage data inadequate prior to 1923.

vehicle-mileage have been greater than increases in accidents. The fatality rate in the U.S. decreased from 18.2 per 100 million vehicle-miles of travel during 1923-27 to 4.45 in 1972 (Table 1). Had the fatality rate prevailing in the 1923-27 period been in effect in 1972, automobile deaths would have amounted to 225,000 instead of the 56,600 actually recorded.[5]

The United States is a highly mobile nation. Passengers using all transport modes traveled approximately 1,230 billion miles in 1971, or an average of about 6,000 miles per person.[6] In 1971 automobiles accounted for about 87 percent of all intercity travel, air accounted for about 10 percent, busses about 2 percent, railroads 0.73 percent, and inland waterways 0.33 percent.[7] Besides its role as the major form of intercity movement, the private automobile is also the most dangerous form (Table 2).

In 1970 the fatal automobile accident rate for the United States as a whole was 4.10 per 100 million vehicle-miles.[8] Considerable variation in rates occurs among the states, with the highest rates occurring in the more rural and less densely populated southern and western states

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[5] Ibid., p. 59 and calculations by author.

[6] United States Bureau of the Census, Statistical Abstract of the United States: 1973 (Washington: Government Printing Office, 1973), p. 538.

[7] Ibid.

[8] Federal Highway Administration, United States Department of Transportation, Fatal and Injury Accident Rates On Federal-aid and Other Highway Systems: 1972 (Washington: Government Printing Office, 1973), p. 5.

TABLE 2

TRANSPORTATION ACCIDENT DEATH RATES, 1970-1972

Kind of Transportation	1972 Passenger Miles (billion)	1972 Passenger Deaths	1972 Death Rate per 100,000,000 Passenger Miles	1970-1972 Average Death Rate
Passenger automobiles and taxis	I,850.0	35,200	1.90	2.00
Passenger automobiles on turnpikes	50.0	540	1.08	1.05
Buses	70.0	130	0.19	0.19
Intercity buses	16.9	31	0.18	0.09
Railroad passenger trains	9.0	48	0.53	0.28
Scheduled air transport planes (domestic)	125.0	160	0.13	0.10

Source: Accident Facts, 1973 Edition (Chicago: National Safety Council, 1973), p. 13.

and the lowest rates in the more urban and densely settled northeastern states. New Mexico, Mississippi, and Nevada, for example, have fatal automobile accident rates of 6.34, 6.14, and 6.10, respectively, while Connecticut, Rhode Island, and New Jersey had rates of 2.43, 2.80, and 2.90, respectively (Table 3).

Accident rates also vary by type and quality of road. The Interstate System has an overall fatal accident rate of 2.19, compared with 4.43 for the Federal-Aid Primary system (FAP) and 5.54 for the Federal-Aid Secondary system (FAS) (Table 3). Differences in the rural-urban components of the above systems are also vividly apparent--urban rates are almost without exception lower than rural rates. Finally, accident rates vary according to the time of day, the day of the week, and the month and the season of the year. Unfortunately, because of the problems of relating volume and deaths to an hourly time frame, national records do not provide specific information on such rates. It is known, however, that most fatal accidents occur between four and eight p.m., that Friday, Saturday, and Sunday are the most common accident days, and that June through October represents the season of greatest accident occurrence.[9]

In 1970 Kentucky had a fatal accident rate of 4.51, which is slightly higher than the national average accident rate.[10] Kentucky ranks twenty-third in population among the states, nineteenth in number

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[9]Statistics Division, National Safety Council, op. cit., pp. 50-51.

[10]Federal Highway Administration, loc. cit.

TABLE 3

FATAL ACCIDENT RATES BY HIGHWAY SYSTEM AND STATE, 1970

State	Federal-Aid Primary Interstate	Federal-Aid Primary Other	Federal-Aid Secondary Total	Non-Federal-Aid Total	Rural Fatal Accident Rate	Urban Fatal Accident Rate
Alabama	2.77	6.28	5.77	5.34	6.21	4.14
Alaska	-	6.68	12.39	5.48	7.52	2.60
Arizona	3.83	6.08	4.18	5.27	6.98	3.25
Arkansas	2.75	4.26	5.74	4.55	5.19	3.14
California	1.81	3.22	5.51	3.66	4.75	3.06
Colorado	3.64	5.27	4.65	4.45	5.44	3.31
Connecticut	2.14	2.74	3.61	2.43	4.20	1.93
Delaware	1.07	4.30	6.02	4.12	5.28	2.88
Florida	1.84	5.93	7.22	4.57	6.92	2.72
Georgia	3.25	6.08	6.13	5.07	7.48	1.99
Hawaii	3.34	4.66	5.84	3.99	5.48	2.97
Idaho	3.48	6.71	7.19	5.82	6.39	4.07
Illinois	1.93	4.77	5.73	3.65	5.43	2.68
Indiana	1.59	4.02	5.11	4.10	4.74	3.12
Iowa	1.83	4.73	6.45	4.13	4.75	2.88
Kansas	3.20	4.45	5.16	4.09	5.05	2.49
Kentucky	2.80	4.67	6.09	4.51	5.41	2.61
Louisiana	2.11	5.73	6.52	5.55	6.82	3.56
Maine	2.91	3.63	5.85	3.81	4.27	2.52
Maryland	1.68	4.49	6.20	3.50	3.88	3.13
Massachusetts	1.66	4.07	1.84	3.18	3.03	3.24
Michigan	1.93	3.22	5.88	3.51	5.39	2.05
Minnesota	1.02	4.44	4.23	3.65	4.18	2.95
Mississippi	2.32	7.08	5.31	6.14	7.26	3.52
Missouri	3.22	5.42	6.40	4.82	5.90	3.71
Montana	5.46	6.57	5.51	5.18	6.05	1.80
Nebraska	2.15	3.36	4.60	3.48	4.19	2.01
Nevada	5.18	6.46	7.50	6.10	7.61	4.06
New Hampshire	2.24	3.43	3.90	3.81	4.35	2.72
New Jersey	1.76	3.93	3.02	2.90	2.98	2.86
New Mexico	5.04	6.67	10.44	6.34	7.58	4.08
New York	1.57	3.07	6.56	4.11	7.59	2.27

TABLE 3 (Cont'd)

State	Federal-Aid Primary Inter-state	Federal-Aid Primary Other	Federal-Aid Secondary Total	Non-Federal-Aid Total	Rural Fatal Accident Rate	Urban Fatal Accident Rate
North Carolina	2.77	3.77	5.57	5.13	6.09	3.11
North Dakota	1.84	4.96	4.37	3.74	4.27	1.49
Ohio	1.72	4.70	6.12	3.96	4.77	3.28
Oklahoma	1.17	2.50	4.28	3.82	4.45	3.04
Oregon	2.60	5.31	5.12	4.34	5.75	2.43
Pennsylvania	1.96	4.44	4.18	3.47	3.99	2.97
Rhode Island	1.17	3.53	3.56	2.80	9.39	1.51
South Carolina	2.50	4.52	7.56	5.11	6.31	2.85
South Dakota	1.85	4.31	5.47	4.01	4.50	2.04
Tennessee	2.39	6.19	10.96	5.56	6.97	3.79
Texas	2.78	4.92	5.76	4.36	5.61	3.29
Utah	2.87	5.14	4.99	4.52	4.62	4.40
Vermont	3.17	4.50	4.80	4.09	4.63	1.90
Virginia	1.78	4.00	5.63	3.75	4.45	2.60
Washington	1.97	3.79	5.13	3.57	5.68	2.19
West Virginia	3.03	6.50	5.02	5.38	6.44	3.25
Wisconsin	2.03	3.41	4.25	3.94	5.31	2.09
Wyoming	4.19	6.57	7.14	5.45	5.98	3.16
Dist. of Col.	1.73	5.44	4.15	3.90	.00	3.90
Total	2.19	4.43	5.54	4.10	5.42	2.86

Source: Fatal and Injury Accident Rates: On Federal Aid and Other Highway Systems, 1972 (Washington: Federal Highway Administration, U.S. Department of Transportation, 1972), p. 5.

of accidents, and twentieth in the rate of accidents.[11] The annual death toll from automobile accidents in the state from 1965 through 1972 averaged about 1,000.[12] Deaths from automobile accidents in 1974 were about 30 percent less than in 1973, presumably because of the lowered speeds and reduced travel resulting from gasoline shortages. The fewer deaths apparently reflects a lower accident rate, rather than just reduced travel, in that the 30 percent reduction in highway deaths in 1974 was associated with only a 3.5 percent reduction in the number of miles driven.[13]

During 1969-71, the period examined in this investigation, Kentucky was averaging around 900 fatal accidents per year, which resulted in just over 1,000 total fatalities, or an average of 1.1 persons killed per fatal accident. The total number of fatal accidents (including pedestrian accidents) for the three-year period varies from a high of 352 in Jefferson County, which includes Louisville, the state's largest city, to a low of one in Robertson County, a rural county and Kentucky's second-smallest (101 square miles). Eight counties had more than fifty fatal accidents. Twenty-seven counties had fewer than ten fatal accidents, and seven of these had fewer than five.

Large numbers of fatal accidents were associated with (a) the large urban counties, such as Jefferson, Fayette, Daviess, and Kenton,

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[11] Ibid., p. 26.

[12] Kentucky Fatal Accident Facts: 1972 (Frankfort, Kentucky: Bureau of Highways, Department of Transportation, 1973), p. 8.

[13] Unpublished records, Kentucky Department of Transportation.

but also included are (b) counties large in area that range from rural to moderately urban and that have large amounts of rural traffic. Christian, Hardin, Warren, and Pike counties fall into this category. Not unexpectedly the counties with the fewest fatal accidents generally include the areally small, rural counties, particularly those without freeways and those not extensively served by Federal-aid primary and secondary roads. The Kentucky accident situation is apparently similar to the national pattern of differences in accidents and accident rates between urban and rural states.

I. STATEMENT OF PURPOSE

Although casual observation of the data tends to support the idea that size of population and rural-urban differences account for most of the variation in county accident totals, one may well wonder (1) if total county population, or some other measure of accident exposure, associates well with fatal accidents and (2) if there are important factors that contribute to accident totals falling significantly below or in excess of the number that would otherwise be expected based on population or other measure of exposure.

The purpose of this investigation, then, is to examine fatal automobile accidents in the 120 counties of Kentucky between 1969 and 1971 and (1) to determine the statistical association between county exposure to fatal accidents (based on total population, automobile registration, traffic volume, or other measures) and total fatal accidents, (2) to see to what extent the computed statistical association

satisfactorily explains the inter-county accident behavior among Kentucky's 120 counties, (3) to determine if rural-urban character, tourism, and young males are also significantly involved in the further explanation of county variations in accident totals, and (4) to isolate any remaining statistically deviant counties for which no geographic and statistical "explanation" has heretofore been disclosed and to examine these counties on a case by case basis in an effort to account for the unusual high or low accident occurrence in these particular counties. A further purpose is to determine whether these above-mentioned variables, or other independent variables which may prove to have explanatory power as disclosed in the course of the investigation, can be successfully used as inputs in a statistical model of fatal automobile accidents that would be reasonably predictive of fatal accident occurrences at the county scale.

This investigation is concerned with answering three main questions relating to the accident problem: (1) Using the county as the spatial unit, where in the state do fatal automobile accidents take place? (2) Does the county pattern of fatal accidents produce a discernible geographic pattern? and (3) To what degree is the variation among counties associated with selected factors that have a logical connection to accident generation? It is hoped that this investigation will provide insight into the general spatial characteristics of fatal automobile accidents and that the county unit will be seen as a viable scale of analysis, lying between the few macro-regional state and international comparisons and the many micro-regional highway segment based studies commonly observed in the literature.

II. LITERATURE REVIEW

A review of the literature reveals an extensive research effort devoted to understanding the widespread phenomena of motor vehicle accidents, particularly fatal accidents. An excellent summary of the findings and trends in highway accident research exists in the works by Little (1970), Haddon (1964), and the twelve-part series published by the Automotive Safety Foundation (1968-71) entitled Traffic Control and Roadway Elements--Their Relationship to Highway Safety-Revised, which is an up-dated version of a 1963 work published jointly by the ASF and the Bureau of Public Roads.[14]

The consensus seems to be that there is no single cause of automobile accidents; rather, the causes are multiple, and many would appear synergistic in nature. J. L. Recht, writing in 1966, seems to have understood well the accident situation:

> A recently completed statistical study of safety activities has clarified the traffic accident problem. The basic picture that has emerged from the study is that the motor-vehicle accident problem does not evolve around one or two dominant factors--it evolves around a large group of factors each contributing a small but significant share to the total problem.
>
> The study indicates that no dramatic breakthrough in motor-vehicle accident experience should be anticipated because of

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[14]Arthur D. Little, Inc. (Prepared from Automobile Manufacturers Association, Inc.), The State of the Art of Traffic Safety: A Comprehensive Review of Existing Information (New York: Praeger, 1970); William Haddon, Jr., Edward A. Suchman, and David Klein, Accident Research: Methods and Approaches (New York: Harper and Row, 1964); Traffic Control and Roadway Elements: Their Relationship to Highway Safety-Revised (Parts 1-12. Washington: Automotive Safety Foundation, 1968-1971).

> the multiplicity of factors. Even complete success [in accident reduction] in one area will have only a small effect on the overall picture.[15]

The principal elements or agents involved in accidents are the car, the driver, and the road and roadway environment. Operating through and lying behind these agents are many complex and interrelated specific factors or causes, such as physically-impaired drivers, whether from alcohol, drugs, and temporary or chronic physical disabilities; vehicle mechanical failure; poorly constructed or narrow roads; speeding; and numerous others. A high percentage of highway accident research has been specifically oriented to certain aspects of each of the accident "causes" suggested above. A much smaller percentage of the research tends to be integrative in approach, i.e., combining the three main "causative" factors in accidents: the vehicle, the driver, and the roadway.

Few geographers have studied motor vehicle accidents. Exceptions are the recently published work by Moellering and the urban accident study done by Ewing as a doctoral dissertation.[16] In addition, Wolfe reported a number of geographic contributions in the area of highway

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[15] J. L. Reche, "How Effective Are Safety Activities?", Traffic Safety (May, 1966), p. 12.

[16] Harold Moellering, The Journey to Death: A Spatial Analysis of Fatal Traffic Crashes in Michigan, 1969 (Michigan Geographical Publication No. 13. Ann Arbor: University of Michigan, 1974); Frazier Stephen Ewing, "A Geographic Analysis of the Distribution and Pattern of Traffic Accidents in a Small City: Example, Hattiesburg, Mississippi, from July 1, 1969 to July 1, 1970" (Doctoral dissertation, University of Southern Mississippi, Hattiesburg, 1971).

and urban transportation, but none of these references specifically dealt with patterns of highway accidents.[17]

Traffic, safety, and engineering professionals, on the other hand, have written extensively on aspects of accidents relating to place, but generally in terms of microareas, i.e., short segments of highways and the immediately adjacent environment.[18] These studies are oriented to the road-related factors that influence accident rates within respective highway segments. In most cases, the studies are limited to one or two variables such as traffic volume, pavement width, intersection design, sight distances, and other types of engineering-design factors.

In recent years highway and safety journals have published increasing numbers of studies employing multivariate techniques in an attempt to relate accident occurrences to highway-related variables.[19]

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[17]Roy I. Wolfe, "Contributions from Geography to Urban Transportation Research," Highway Research Board Bulletin, 326:46-68, 1962.

[18]O. L. Kipp, "Minnesota Roadside Progress Report on Accident, Access Point and Advertising Sign Study in Minnesota," Highway Research Board Bulletin, 38:68-72, 1951; D. M. Belmont, "Accidents Versus Width of Paved Shoulders on California Two-lane Tangents--1951- and 1952," Highway Research Board Bulletin, 117:1-16, 1956; C. E. Billion and W. R. Stohner, "A Detailed Study of Accidents As Related to Highway Shoulders in New York State," Highway Research Board Proceedings, 1957, pp. 497-508; Olin K. Dart, Jr., and Lawrence Mann, Jr., "Relationship of Rural Highway Geometry to Accident Rates in Louisiana," Highway Research Record, 312:1-16, 1970.

[19]Monroe Norden, J. Orlansky, and H. H. Jacobs, "Application of Statistical Quality Control Techniques to Analysis of Highway Accident Data," Highway Research Board Bulletin, 117:17-31; 1956; D. W. Schoppert, "Predicting Traffic Accidents from Roadway Elements of Rural Two-Lane Highways with Gravel Shoulders," Highway Research Board Bulletin, 158: 4-26, 1957; L. G. Goldstein and J. N. Mosel, "A Factor Study of Drivers' Attitudes, With a Further Study on Driver Aggression, Highway

These investigations are useful and interesting, but from the viewpoint of the geographer they appear limited in at least two respects: (1) they lack emphasis on inter-regional differences in accident rates and (2) inadequate attention is given to factors other than roadway design and volume characteristics.

At least two exceptions to the major research orientations are observed in the literature. Earl Allgaier co-authored papers in 1943 and 1956 dealing with variations in fatal accident rates by states.[20] In both of these efforts mathematical models were constructed using multiple correlation and regression analysis. A number of social, economic, and highway characteristics that were believed to be predictive of accident rates among the various states were used as input variables in the models. A total of fourteen factors in 1943 and thirty in 1956, respectively, were employed in the two models. The factors examined in the two studies were found to statistically "explain"

Research Board Bulletin, 172:9-29, 1958; R. C. Blensly and J. A. Head, "Statistical Determination of Effect of Paved Shoulder Width on Traffic Accident Frequency," Highway Research Board Bulletin, 240:1-23, 1960; J. Versace, "Factor Analysis of Roadway and Accident Data," Highway Research Board Bulletin, 240:24-32, 1960; Terrence M. Allen, "A Factor Analysis of Accident Records," Highway Research Record, 79:17-25, 1965; Robert Brenner, Gary R. Fisher, and Walter W. Mosher, Jr., "Statistical Analysis of Accident Data as a Basis for Planning Selective Enforcement," Highway Research Record, 188:44-71, 1967; J. W. Sparks, "The Influence of Highway Characteristics of Accident Rates," Public Works, XCIX, No. 3 (March, 1968), pp. 101-103, 120; Olin K. Dart, Jr., loc. cit.

[20]Earl Allgaier and Kenneth Wood, "Predicting Traffic Death Rates," Highway Research Board Proceedings, 23:396-401, 1943; Earl Allgaier and Sam Yaksich, "Factors Related to Traffic Death Rates," Highway Research Board Bulletin, 142:19-28, 1956.

66 percent and 70 percent, respectively, of the state-to-state variation in fatality rates.

These two works, essentially geographic in approach in that they emphasize areal differences, are among the few examples of macro-regional investigations of fatal automobile accidents. A third example is the study reported by Miller and Recht in which variations of fatality rates from state to state were compared solely on the basis of the percent of travel on rural roads.[21] They found that nearly half of the differences among the state rates was accounted for by this one factor. Swanner and Lauer also discuss several possibilities for predicting traffic death rates among the states, but as far as the present study is concerned, they offer no additional usable technique.[22]

Moellering, in his 1974 work dealing with automobile crashes in Michigan, provides perhaps the best example of geographic interest in the field of motor vehicle accidents.[23] He uses a variety of statistical techniques, including a stepwise analysis of variance and simple correlation and regression in the context of a micro- and a macro-approach in analyzing the spatial aspects of fatal crashes. He is specifically concerned with the length of the fatal crash trip.

In the micro analysis Moellering used three subsets of fatal

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[21]H. G. Miller and J. Recht, "Rural Traffic and the Death Rate," Traffic Safety, 63:12-14, November, 1963.

[22]Clifford O. Swanson and A. R. Lauer, "Predicting Accident Trends and Traffic Improvement," Highway Research Board Bulletin, 161: 48-54, 1957.

[23]Moellering, loc. cit.

crashes as dependent variables: automobile drivers, motorcyclists, and pedestrians and bicyclists. The independent variables included a total of seventeen spatial, temporal, and demographic factors denoting aspects of the crash site as well as attributes of the victims. His analysis showed that the spatial or geographic characteristics of the crash situation, e.g., the point of driver origin, the site of the fatal crash, the road classification in terms of major or minor roads, rural or urban location, and the state police district involved, were more associated with fatal accident trip lengths than temporal factors such as hour of day, day of week, and month of year, and social-demographic factors, such as age, sex, race, and marital status of involvees.

The macro approach was used as a check to reaffirm the micro findings. This approach is the more pertinent with regard to the present investigation. In the macro approach the Michigan county unit provided the setting for the investigation. The population potential based on the Warntz population potential model was determined for each of the Michigan counties and was used as the independent variable in the analysis which followed. Total county population served as a measure of the population at risk and the distance-decay coefficient was determined empirically from analysis of fatal crash records. The dependent variable was the fatal crash occurrence. Using simple correlation and regression the author found that the association between population potential and crash occurrences provided an r^2 value of 0.716. Residuals from regression were computed and standardized and then mapped. The author was then in a position to identify statistically deviant

counties. Specific discussion of the deviant counties, however, was beyond the scope of the investigation and, consequently, was not pursued in the paper. Moellering concludes that at both the micro and macro scales of investigation he finds that "geographic variables" tended to be more significant than the social and demographic variables in influencing the length of the fatal crash trip.

III. SCALE CONSIDERATIONS

The question of the appropriate scale of analysis was a philosophical and methodological problem that had to be addressed very early in the investigation. It was recognized that factors associated with accident and/or fatality occurrences tend to undergo changes in character and importance as one changes the scale of observation and proceeds along the micro--macro region accident continuum. For example, roadway character, such as slope, median width, and shoulder width has been shown to be related to fatal accident rates in studies involving highway segments. At larger scales, on the other hand, factors such as population, roadway density, urbanization, and per capita income have been shown to be related to variations in accident rates.

The use of the meso-regional scale in the present effort may show that the best predictors of fatal accidents aggregated at the county level are not the same factors that are predictive at either larger or smaller scales of observation. It is anticipated, however, that the intermediate scale of this investigation will generally tend to reaffirm factors disclosed by others at the micro and macro scales, but perhaps

in a modified form. It is also expected that additional accident-associated factors will be disclosed as the analytic process unfolds.

The selection of the appropriate scale involves the reconciliation of the quality of convenience afforded by the use of aggregate data with the potential problems of drawing incorrect or suspect inferences from such grouped data. In using aggregated data the researcher needs to be aware of the danger of the "ecological fallacy," i.e., the transferring of inferences from group data to individuals and from individuals to groups.[24] Although caution in the use of aggregate data is demanded, the utility of group data is widely recognized. Erik Allardt in commenting on the value of aggregate data in correlations points out that while it may be preferable in many cases to use individualized data, group data are not used just as a substitute for individual correlations and that group data are not necessarily less valuable than individual data. He goes on to say that ecological correlations may retain their validity even though the ecological and individual correlations are clearly different. According to Allardt, "Ecological correlations may tell something about territorial units, which can be used as contextual properties explaining the variations in the correlated variables."[25]

The scale of this investigation is the county unit. The concern is with the aggregate number of fatal accidents per county and with the

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[24]Erik Allardt, "Aggregate Analysis: The Problem of Its Informative Value," Quantitative Ecological Analysis in the Social Sciences (Cambridge, Massachusetts: The M. I. T. Press, 1969), p. 41.

[25]Ibid., p. 42.

conditions that are associated with inter-county variations in such accident occurrences. Within limitations imposed by time, money, and other constraints, the county scale seems an appropriate scale with which to study fatal accidents. These factors probably outweigh any precision that might be gained from using smaller areal units, assuming even that some of the data could be either disaggregated or generated for smaller areas.

IV. DEVELOPMENT OF PROBLEM

The approach in this investigation is to examine and test selected relationships that have been found previously to be associated with accidents at scales other than that of the county and to determine whether such relationships satisfactorily explain inter-county accident variations in Kentucky. The meso-regional nature of the present investigation, together with the general absence of accident research at the county scale, however, results in uncertainty as to the exact nature of the county aggregate accident relationships.

In determining some of the factors that are associated with fatal automobile accidents at the county scale of analysis, the relationships between fatal accidents and the following four variables are to be examined:

1. total vehicle-miles
2. rural vehicle-miles
3. tourism
4. the percentage of males 15-34 in the total pupulation

Total Vehicle-Miles

The total yearly vehicular mileage per county is probably the variable most predictive of the number of fatal accidents in any county. The association between accidents and measures of exposure, particularly measures dealing with traffic volume, appears to be self-evident and is widely noted in the literature.[26] In fact, the importance of the influence of volume or vehicular mileage[27] on accident occurrences has been so pervasive that it has been the policy of most researchers to eliminate the influence of volume as much as possible through the conversion of absolute volume and total accidents (fatal or non-fatal) to a rate: accidents per 100 million miles of either vehicular or passenger travel. An attempt was made to work with accident rates in the formative stages of this investigation, but it appeared to be conceptually inadequate and was discarded following several attempts to obtain a multiple regression equation with "R" values high enough to produce a strong pattern of standardized residuals. (This prior attempt is discussed more fully in Chapter II.)

Traffic volume, although perhaps the single most important factor

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[26] M. S. Raff, "Interstate Highway Accident Study," Highway Research Board Bulletin, 74:18-45, 1953; John W. McDonald, "Relation Between Number of Accidents and Traffic Volume at Divided Highway Intersections," Highway Research Board Bulletin, 74:7-17, 1953; Belmont, loc. cit.; Earl Moskowitz and W. E. Schaefer, "California Median Study: 1958," Highway Research Board Bulletin, 266:34-62, 1960; Traffic Control and Roadway Elements, op. cit., Chapter 2 (this work alone includes references to forty works dealing with traffic volume and accidents).

[27] In the remainder of this investigation the terms "vehicle-miles" and "volume" will be used interchangeably unless otherwise indicated.

influencing inter-county differences in fatal automobile accidents, will probably fail to explain fully such inter-county differences. Other factors probably play a significant role for individual counties. Variations in both physical and cultural roadway environments are presumably factors in traffic deaths. These variations should be subtly reflected in car operation, driving habits, and roadway conditions, and include such specific "causes" of accidents as drunken driving, "running" stop signs, failure to yield rights-of-way, and speeding.

Total Rural Vehicle-Miles

It is also probable that fatal accidents are relatively numerous in counties having large amounts of rural traffic. In the literature it is frequently noted that high fatal accident rates are associated with rural areas and, conversely, low rates with urban areas. Urban areas, with relatively low speed limits, traffic congestion, numerous intersections and driveways, and traffic lights, tend to have proportionately more accidents, but fewer fatal accidents, than do rural areas. Rural areas, conversely, with a general lack of congestion and both higher posted and operating speeds than urban areas have fewer accidents, but proportionately more fatal accidents.

Consideration of the rural-urban factor is supported by the following: (1) the various state and federal reports show differences in rural and urban accident rates; (2) the reports of the National Safety Council consistently show the rural southern and western states with death rates higher than the urbanized northeastern states; (3) the

specific studies of Recht, Allgaier, and others who have employed the rural component in their own studies show a positive association between fatal accidents and rural traffic volume; (4) the indirect studies that include work done on such topics as congestion, intersections and driveways, and land-use show that as areas become built-up or urban the fatal accident rates begin to decrease.

Tourism

A third, yet untested factor possibly important in explaining inter-county accident variations is volume of out-of-county visitors, particularly tourists. This variable did not appear in the literature review and is being introduced as an original item in this investigation. The assumption is being made that tourists are less familiar with roadway and traffic characteristics than residents. One would, therefore, expect a positive relationship between accidents and the volume of tourist traffic. The tourist, it would seem, might tend to be somewhat more confused by road signs than local residents, might tend to miss traffic lights and regulatory signs, and might be unaware of locally-known hazard spots. Attention of drivers may be distracted directly by interesting and unique natural and cultural roadside attractions and indirectly by the excitement, enjoyment and general carefree attitude related to the trip itself.[28] Fatal automobile accidents are believed to covary positively with the intensity of tourism as measured by the tourism index developed in the course of the investigation.

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[28]Based upon ideas developed in conferences with Dr. Jack B. Humphreys, Department of Civil Engineering, The University of Tennessee, July, 1974.

Young Males

A fourth factor reported in the literature to be associated with fatal accidents and probably somewhat important in influencing inter-county accident variations is the percentage of males aged 15-34 in the population. (This factor will generally be referred to as "young males.") Young males represent the segment of the driving population that has the poorest driving record, i.e., this age-sex group of all the age-sex groups is the one most likely to be involved in fatal accidents. National statistics, as reported by the National Safety Council, show, for example, that in 1972 drivers--male and female--in the under twenty through thirty-four age range represented 42.2 percent of all drivers but had 57.4 percent of the fatal accidents. The only other age category which had proportionately more accidents than would be indicated by the number of drivers was the age 75-and-over category in which 1.9 percent of all U.S. drivers had 2.7 percent of the fatal accidents. Statistics also show that men of all ages have a fatal accident involvement rate over twice that of women of all ages.[29]

Corresponding figures for Kentucky (1972) show that the age range 15-34 (including both males and females) contained 43.3 percent of the licensed drivers but accounted for 62.1 percent of all fatal accidents.[30] Of 547 persons ages 15-34 killed in fatal accidents in Kentucky during 1972, 428 (78 percent) were male and 119 (22 percent female.[31]

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[29] Statistics Division, National Safety Council, p. 54.

[30] Kentucky Fatal Accident Facts, p. 13. [31] Ibid., p. 10.

Considering the tendency for fatal accident involvement to be structured with regard to age and sex, it is believed that the percentage of young males in the total population represents a reasonable measure of potential accident exposure. Accordingly, fatal automobile accidents are believed to covary positively with the percentage of young males in the total county population.

V. THE STUDY AREA

Kentucky was chosen as a study area for the following reasons: (1) the writer's familiarity with the state, (2) convenience and accessibility to field work and data sources, and (3) the availability of a vast amount of accident and highway data that are maintained in a uniform manner both areally and chronologically.

The Commonwealth of Kentucky ranks thirty-seventh in area among the fifty states and twenty-third in population. Its nearly 40,000 square miles of land area is allocated among 120 counties, thereby resulting in a mean county size of about 330 square miles. The range of sizes among the counties lies between Pike County with 782 square miles and Gallatin County with 100 square miles (Figure 1).

Population Patterns

Since total vehicle-miles and flow characteristics of the traffic stream are strongly influenced by population size and rural-urban character, it would appear beneficial to examine the settlement characteristics of the state briefly before discussing the accident patterns themselves. Kentucky's 1970 population was 3,219,311, 52.3

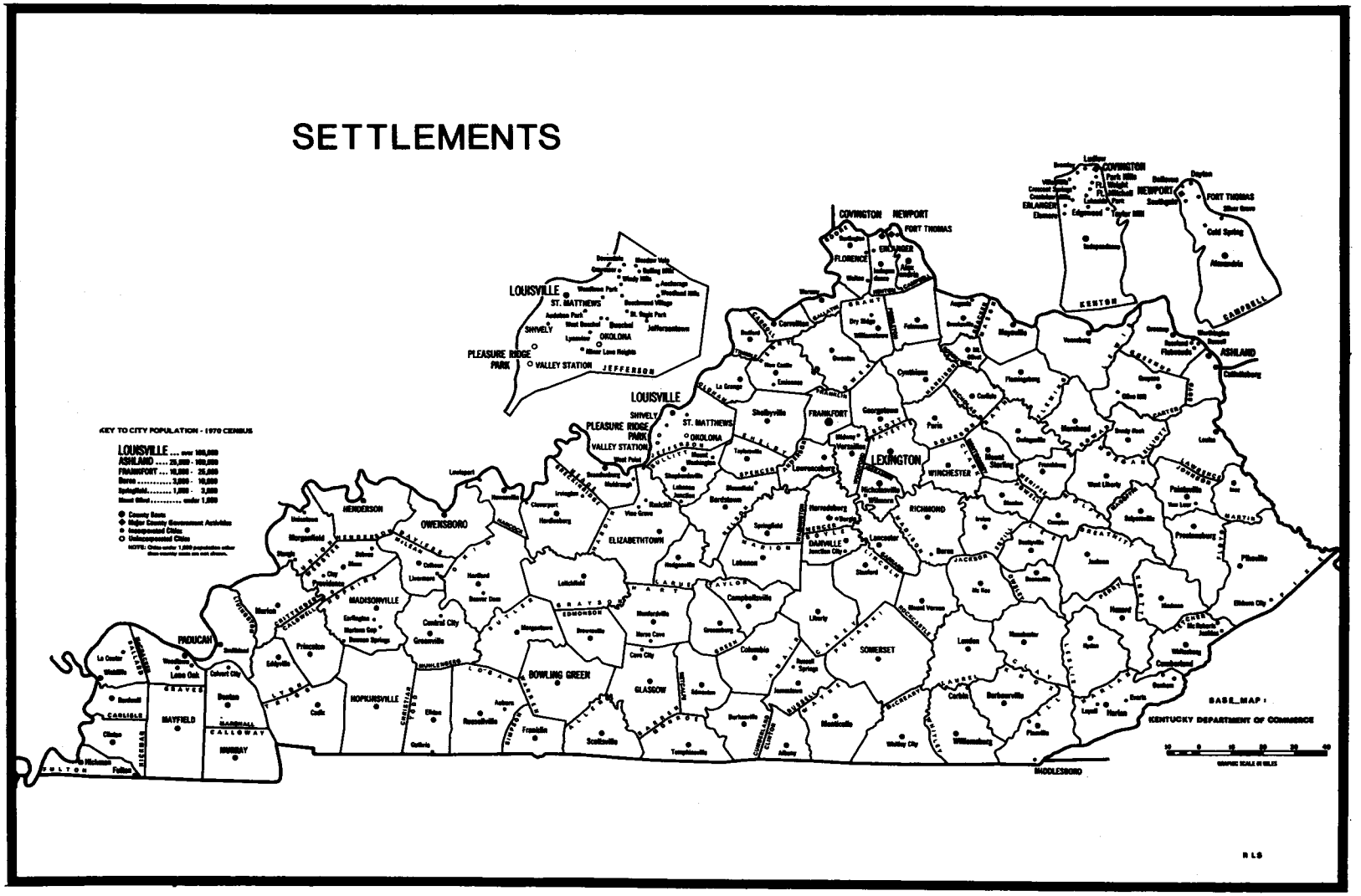


Figure 1. Settlements.

percent of which was urban. This compares with an urban population of 73.5 percent for the U.S. The state's largest city is Louisville (361,958), followed by Lexington (108,137), Covington (52,535), and Owensboro (50,329).[32] Six cities have populations in the 25,000-50,000 size range, and twenty are in the 10,000 to 25,000 range (Figure 1).

Seven Kentucky counties were officially parts of Standard Metropolitan Statistical Areas (SMSA's) in 1970).[33] Boone, Kenton, and Campbell counties are part of the seven-county Cincinnati SMSA; Boyd is a part of the Huntington-Ashland SMSA; Fayette is the sole county in the Lexington SMSA; Jefferson is the only Kentucky county in the three-county Louisville SMSA; and Henderson represents the only Kentucky county in the Evansville, Indiana, SMSA. In eighteen counties more than fifty percent of the population is classified as urban; the population of the remaining 102 counties is classified rural. Fifty-two counties have no urban settlements. The four largest counties in population, Jefferson, Fayette, Kenton, and Campbell, contain one-third of the state's population. The twelve largest counties contain just over one-half of the state's population.

Highway Patterns

In 1970 Kentucky had nearly 69,000 miles of public streets and

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[32] All figures in parentheses represent 1970 population figures.

[33] Following the Census of 1970 eight additional Kentucky counties became parts of SMSA's. Greenup County was added to the Huntington-Ashland SMSA; Bullitt and Oldham were added to the Louisville SMSA; five counties were added to the Lexington SMSA: Clark, Bourbon, Scott, Woodford, and Jessamine.

highways. About 92 percent of this mileage was rural. About 36 percent of the street and road mileage is state-maintained and accounts for nearly 82 percent of the vehicle-miles. Local roads account for 64 percent of the mileage, but only 18 percent of the vehicle-miles (Table 4).

A small percentage of the state's road mileage accounts for a significant percentage of the traffic volume. The Interstate system, with slightly over 1 percent of the state mileage, accounts for nearly 18 percent of the vehicle-miles. The Interstate and Federal-aid Primary (FAP) systems together account for 6.44 percent of the road mileage and over 49 percent of the vehicle-miles.

The state freeway network is comprised of two systems: the Interstate system and the Kentucky Toll Road system (Figure 2). The principal Interstate routes include two major north-south highways and one major east-west highway. Partially-completed I-64 provides the only east-west Interstate route. A fourth Interstate, I-71, connects with I-65 and I-64 at Louisville and extends northeastward to connect with I-75 near Cincinnati.

The state's other primary east-west routeway is provided by portions of the state's toll road system. The Bluegrass Parkway-Western Kentucky Parkway-Purchase Parkway corridor provides an east-west route extending from just west of Lexington, through Elizabethtown, then westward and southwestward to Fulton (Fulton County) at the Kentucky-Tennessee line.

Two other toll roads were of secondary importance in 1970. The

TABLE 4

ACCIDENT RATES FOR KENTUCKY HIGHWAYS: 1970
(FATAL ACCIDENTS PER 100 MVM)

Highway System	Annual Vehicle-Miles		Fatal Accidents		Percent of Accidents
	Millions	Percent	Number	Rate	
Interstate					
Rural	2,180	10.92	64	2.94	7.10
Urban	855	4.28	21	2.45	2.33
Other Federal Aid Primary					
Rural	4,617	23.13	251	5.44	27.86
Urban	1,718	8.61	45	2.62	4.99
Federal Aid Secondary					
Rural	3,850	19.29	265	6.88	29.41
Urban	561	2.81	17	3.03	1.89
Local					
Rural	1,140	5.71	76	6.67	8.44
Local					
Municipal	2,207	11.06	59	2.67	6.55
Urban	6,393	32.03	167	2.61	18.54
Rural	13,567	67.97	734	5.41	81.46
TOTAL	19,960	100.00	901	4.51	100.00

Source: Table TA-1, Apr. 19, 1971, Unpublished Kentucky Department of Transportation report.

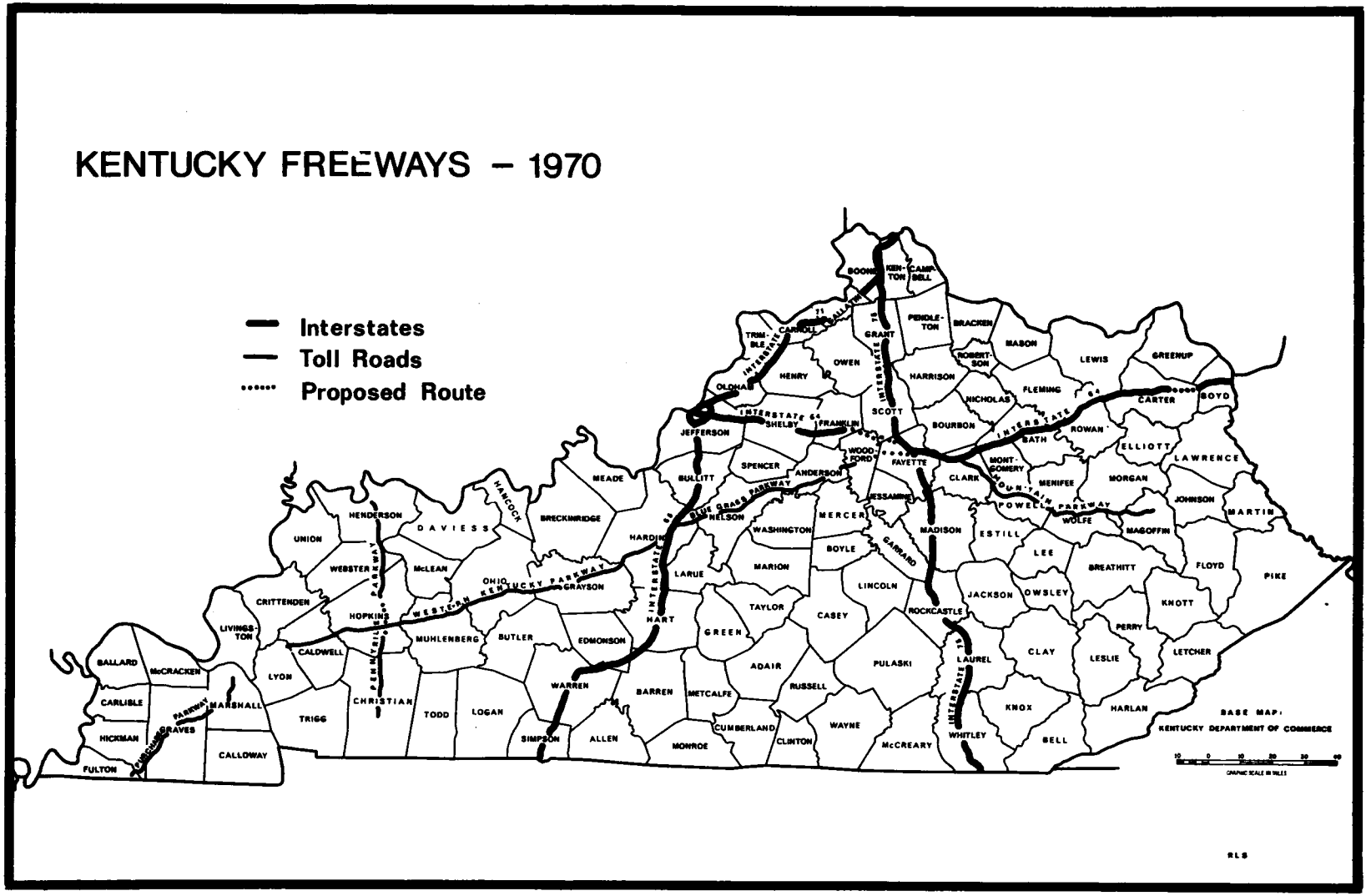


Figure 2. Kentucky Freeways--1970.

Mountain Parkway connects Eastern Kentucky (Magoffin County) with I-64 at Winchester (Clark County). The Pennyrile Parkway connects Henderson (Henderson County) with Hopkinsville (Christian County). The remaining toll road is the Kentucky Turnpike. The Turnpike, however, serves as the roadway for the northern portion of I-65 and is included as a part of I-65.

As a result of the orientation of the principal highways, north-south movement has tended to be easier than east-west. By 1970 east-west movement had been significantly improved by the toll roads and I-64. As of 1970 the largest remaining area of traffic impediment for east-west travel was across the southern part of the state and that for north-south travel was across the extreme eastern part of the state. Since 1970, however, a new series of toll roads extending from an I-65 connection at Bowling Green (Warren County) to Hazard (Perry County) have been partially completed and have tended to improve east-west travel in southern Kentucky.

VI. THE DATA SET

The investigation encompasses the 120 counties of Kentucky for the years 1969-71. The county is the basic unit of investigation for several reasons. (1) It is a convenient areal unit, because most of the data to be used in this investigation were available on a county basis. (2) The relatively small size and uniformity of the counties produce a reasonably fine-textured pattern of reporting units for the state. (3) The county provides a convenient spatial unit for there are

data on "off-highway" social and economic factors believed to influence fatal accidents. (4) The relatively few counties that exist, as opposed to an immense number of road segments statewide, facilitates data gathering and would expedite similar studies in other state or regional comparisons, or in quick comparisons of the same state or region in different periods of time. (5) The unit is one commonly employed in the geographic literature in making interregional analyses.

The three-year period of accident analysis is considered long enough to provide a reasonable sample of fatal accident data but at the same time is limited enough so as to minimize changes in the traffic, highway, and socio-economic environment that might affect accident occurrences. The specific period was selected so that age, sex, and population data obtained from the 1970 Census of Population would relate well with the accident data.

Accident Classes

Types of fatal accidents investigated in this report are limited in the following ways:

1. The concern is with accidents involving motor vehicles, i.e., automobiles, buses, trucks, and motorcycles.
2. Accidents are limited to those officially recorded in the State Police records that have occurred on public streets and highways.
3. The unit of observation is the "fatal accident" and not the individual passenger fatality. For example, an accident involving two automobiles in which three people were killed,

would be recorded as one fatal accident. The use of the accident rather than the fatality is preferable in that it is directly related to the previously-mentioned environmental factors associated with accidents and the use of the accident avoids some data fluctuations, particularly in the small, relatively accident free counties, in which one accident could conceivably account for six or more victims.

4. The accidents exclude pedestrian fatalities except where the same accident involved an automobile in which the driver or passengers were also killed.

Trends

Fatal accident trends in Kentucky have tended to parallel those of the nation as a whole. The state's annual vehicle mileage climbed from 37.7 billion in 1940 to 230 billion in 1972, an increase of 510 percent (Table 5). In the same period the annual number of fatal accidents increased only 73 percent. The fatal accident rate shows that the total volume of traffic is increasing more rapidly than the total number of fatal accidents. The state rate dropped from 14.54 fatal accidents per 100 million vehicle-miles of travel in 1940 to 4.12 in 1972. The long-term decline in accident rates in Kentucky, like the nation as a whole, appears to be tapering off by decreasing at a decreasing rate. Although physical limits would seem to preclude substantial future improvements in the rate in an absolute sense, new highway and automobile technologies in the future may steepen the rate improvement curve.

TABLE 5

KENTUCKY FATAL AUTOMOBILE ACCIDENT TRENDS: 1940-1972

Year	Vehicle Miles of Travel (100 Million)	Number of Fatal Accidents	Fatal Accidents Per 100 Million Vehicle-Miles	Number of Fatalities	Fatalities Per 100 Million Vehicle-Miles
1940	37.7	548	14.54	634	16.82
1945	35.7	513	14.37	563	15.77
1950	72.4	594	8.20	678	9.37
1955	96.9	734	7.57	862	8.90
1960	116.3	663	5.70	765	6.58
1965	147.5	776	5.26	916	6.21
1970	119.6	901	4.51	1,069	5.36
1971	215.0	882	4.10	1,023	4.76
1972	230.0	947	4.12	1.093	4.75

Source: Kentucky Fatal Accident Facts, 1972. Frankfort: Bureau of Highways, Department of Transportation, 1973, p. 8.

CHAPTER II

MODEL BUILDING PROCESS

This chapter discusses (1) the two phases of the variable selection process and (2) the rationale for the selection of the statistical procedures employed. The first section of the chapter is concerned with the selection of variables in an exploratory multiple regression analysis that was performed in the early stages of this investigation and subsequently abandoned. Next, the discussion deals with the variables actually employed in the simple and multiple regression analyses. Finally, the chapter concludes with the justification for the use of regression analysis and residual mapping.

I. EXPLORATORY ANALYSIS: VARIABLES NOT INCLUDED IN FINAL ANALYSIS

Several decisions were involved in trying to establish the appropriate dependent variable for the regression analysis of accidents. The intention initially was to investigate the pattern of all accidents, both fatal and non-fatal, which amount to over 100,000 annually. However, it became evident that reliable statistics on all accidents are not available, because Kentucky does not have a uniform system of traffic accident reporting. Data on fatal accidents, however, are considered complete and accurate.[1] Thus it was decided to proceed with

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[1] In one or two instances the number of accidents reported on the yearly Transportation Department summary sheets for a given county fail

the smaller but more accurate fatal accident population.

A second major decision dealt with the issue of whether to use total fatal accidents per county or fatal accident rates (average number of fatal accidents per 100 million vehicle-miles). Most of the work reported in the literature deals with fatal accident rates. Initially, therefore, it was intended that this work proceed in the same manner.

During the exploratory stages of this investigation the research was directed toward adoption, for the county scale of analysis, of selected variables which had been shown by previous researchers to be associated with accidents at the road segment scale of analysis. In this investigation, as with the cited road segment studies, the dependent variable was the accident rate rather than accident numbers.

Based upon the research findings from the many works cited in Chapter I, two principal factors seemed to contribute to accident variations at the micro- or highway-segment scale: (1) volume of traffic and (2) occurrences such as intersections, driveways, and traffic signal devices which tended to impede the orderly flow of traffic. The latter is interpreted to be a specific measure of roadway environment (non-vehicular) congestion, whereas, the former is interpreted as a measure of traffic stream (vehicular) congestion.

The hypothesis examined in the exploratory investigation was that

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to agree--plus or minus one accident--with the number of accidents indicated on the accident file cards maintained by the State Police. In these rare cases, the card totals are selected as the correct working figure since the cards provide complete accident information and the summary sheets do not.

county accident rates behave in a manner similar to road segment rates. Fatal accident rates were expected to covary positively with increases in congestion. Nine variables were selected as indicators of the level of congestion. Seven were densities of occurrence per mile of county roadway. These variables included:

1. Average Daily Traffic Volume
2. Automobile Registrations
3. Retail Establishments
4. Gasoline Service Stations
5. Eating and Drinking Establishments
6. Hotels and Motels
7. Population

Two additional independent variables were:

8. Density of Roads per County
9. Percentage of the Total Vehicle-Miles Assigned to Freeways

A multiple regression analysis was employed. The county fatal accident rate (fatal automobile accidents per 100 million vehicle miles) served as the dependent variable, and the nine measures of congestion served as independent variables. Essentially all of the statistically explained variation was accounted for as shown in Table 6.

The results of the analysis proved to be somewhat unsatisfactory from at least two viewpoints. First, there existed a relatively low statistical explanation ($R = .4726$, $R^2 = .2234$ for all variables). It was felt that the pattern of residuals based upon the relatively low R values, even though significant in a statistical sense, would preclude

TABLE 6

ABBREVIATED SUMMARY OF NINE-VARIABLE STEPWISE REGRESSION ANALYSIS

	R	R^2	Increase in R^2
Gasoline service stations per road mile	0.3818	0.1457	0.1457
Population per road mile	0.4149	0.1722	0.0264
Traffic volume per road mile	0.4364	0.1905	0.0183
Retail establishments per road mile	0.4650	0.2163	0.0258

acceptable geographical generalization. Second, each of the nine independent variables showed a negative correlation with the dependent variable. The negative association was anticipated with the variable measuring the percentage of the total vehicle-miles assigned to freeways, but the consistent negative association with the remaining eight independent variables was a mild surprise.

The geographically unsatisfactory results appear attributable to several factors, the most significant being the problem of scale reconciliation. Although the variations in congestion have been demonstrated to be positively associated with fatal accidents within given highway segments, at the county scale the opposite is true, i.e., as congestion increases the rate of fatal accidents decreases. Thus, in rural areas, with relatively low traffic volumes, subtle disruption of the traffic flow tends to increase the accident rate, but once traffic volume

increases to a certain critical level the added congestion produces slower speeds and, consequently, a lower rate of fatal accidents. Accordingly, at the county scale, rural-urban differences in speed appear to more than offset the effect of impediments to the normal flow of traffic along specific segments of highway. In retrospect, had the county accident rates been divided into either rural and urban components or into some system of classification based on average vehicular speeds, both a positive and an improved statistical association might have resulted for the county scale.

A related problem is that of reconciling and isolating factors that are associated specifically with fatal accidents as opposed to all accidents. Apparently the selection of variables did not result in proper consideration for this important point.

Finally, the low R value appears attributable, in part, to variables not included in the model and in part to the extreme variations in accident rates between the counties having many vehicle-miles with those having few vehicle-miles. In a lightly traveled county even one fatal accident would result in a very high accident rate.

On the basis of this exploratory investigation it was decided (1) not to work with rates but with total fatal accident occurrences per county and (2) to reconsider the variable selection in light of the scale and fatal-non-fatal classification problems referred to above. The reconsideration resulted in the selection of four variables, vehicle-miles, rural vehicle-miles, tourism, and young males, all of which are discussed in more detail in the following section.

II. SELECTION OF VARIABLES ACTUALLY USED IN MODELS

Dependent Variable

A three-year period (1969-71) was selected to provide a large enough sample to minimize the incidence of counties having zero observations. The 1969-71 accident information was obtained from unpublished file card records maintained by the State Police. Each accident card contains both coded and uncoded information about each fatal accident occurrence. The information summarized on each card is taken directly from the accident report forms filed with the State Police following the accident. A total of 2,693 fatal accidents occurred in the years 1969-71 were the data base. From the information contained on the card about each accident, the following information was recorded:

1. County in which each fatal accident occurred
2. Type of accident: pedestrian or non-pedestrian
3. Location of accident: urban or rural
4. Classification of accident: freeway or non-freeway

The three-year accident totals for each county were summed thus providing the statistic used as the dependent variable.

Independent Variables

It was expected that of all factors influencing inter-county variations in fatal accidents the most significant would be the exposure to accident situations, that is, a measure of the opportunity for accident involvement. Although several indices might serve as an indicator of exposure--such as total population, driving-age population, number

of licensed drivers, automobile registration, or even population potentials--the best indicator seemed to be some measure of traffic volume such as vehicle-miles. The importance of this measure has been reaffirmed by other researchers. Accordingly, a measure of vehicle-miles was chosen for use in this study. Vehicle-miles for all county roads were not available and had to be computed as described below.

Vehicle-miles. Acquisition of total vehicle-miles data proved to be more involved and time consuming than originally expected because traffic counts and volume estimates are generally made only for state-maintained streets and highways. In 1970 state-maintained road mileage accounted for 34.63 percent of Kentucky's rural mileage and 1.53 percent of the state's urban mileage. Though this appears to leave a major gap in the data, it is not as severe as it first appears. The more heavily-traveled state-maintained road system, accounting for only 36.16 percent of the total road mileage, has 81.74 percent of the total annual vehicle-miles.[2]

The "known" county volume (annual vehicle-miles on state-maintained roads) is based upon periodic traffic counts at various statewide locations. Such counts are more frequent on heavily-traveled roads and less frequent on lightly-traveled roads. Thus, busy I-75 in northern Kentucky may in places be checked on a daily basis, whereas a lightly-used state secondary road in rural areas may be checked once every two or three years.

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[2]Unpublished Kentucky Department of Transportation report, Table TA-1, April 19, 1971.

Once the state has determined the Average Daily Traffic (ADT), which represents the number of vehicles passing a specific point in a twenty-four hour period, the count is multiplied by the number of miles of contiguous road sharing the same roadway and traffic characteristics in order to determine the Daily Vehicle Miles (DVM). As a hypothetical example, if a traffic count made between the two I-64 interchanges shows 40,000 vehicles per day/mile and the distance between interchanges is eight miles, the calculation for DVM is 40,000 times eight of 320,000 DVM. In the case of roads with no control of access the assumption is made that vehicles entering/leaving the traffic stream between cordon lines is offsetting.

As a consequence of the general availability of traffic and road mileage data on state-maintained roads--in Kentucky and elsewhere--some researchers working with macro-regional accident studies have used the state-maintained volume rather than total volume from all road systems. In this investigation, however, considering that it is restricted to a reasonably small area, it was decided to work with total volume rather than the more readily-available state-maintained volume. It was assumed that the extra effort involved would produce a more accurate regression equation since the state figures fail to account on the average for nearly 20 percent of the total state vehicle-miles. Total county volume was obtained by combining the available state-maintained volume data with the estimated local volume data. The detailed procedure for determining total volume is explained in the Appendix.

An area in which one might question data reliability is in the

estimate of traffic on local roads in each county, particularly with regard to the local urban estimate. At present there is no satisfactory way to verify the county estimates. This information is simply not available. It may be noted, however, that should even a fairly large error in estimates exist, the effect on the total volume would be relatively small because the heavier weighting of the state-maintained system would minimize the effect of an estimate error on local traffic. As an example, a 50 percent error in estimate of local travel would produce a statewide error of only 9 percent in the final vehicle-mile figures.

Rural vehicle miles. The variable "rural vehicle-miles" was obtained by subtracting the state urban vehicle-miles from total vehicle-miles.

Tourism. The third independent variable, tourism, was considered at some length before the chosen surrogate was finally selected. Two possibilities were contemplated and discarded: total motel and hotel rooms per county and number of hotels and motels. Reliable statistics on rooms were unavailable, and the number of establishments seemed too coarse a measure. Finally, after further examination of available data sources, it was decided to use a measure of tourist expenditures per county expressed in per capita terms. The measure of expenditures is based upon sales tax receipts from what are defined as being "tourist activities."

Tables VI and VII of the 1970-71 Annual Report of the Kentucky Department of Revenue provide county statistics on sales tax collections

for a variety of business services.[3] From a listing of 10 groups of businesses, containing 91 specific functional types of businesses, the investigator selected three as being appropriate indicators of the presence of and extent of tourist activity. These categories include:

1. Hotels and motels
2. Restaurants
3. Amusements

The total sales tax collections for 1970 for these "tourist-related" services were obtained for each county. The sales tax receipts for the three activities were summed, producing a figure believed indicative of total sales tax collections from tourist activities. In an attempt to distinguish "tourist" counties from counties that may have large numbers of tourist facilities simply because of a service to resident populations, the data were transformed into an index of tourism: per capita sales tax collections. This statistic was then used as the tourism variable for each county.

Young males. Data for males ages 15-34 were taken from the 1970 Census of Population. A minor problem occurred with the total population count of young males and the subsequent conversion to a percentage figure of the total population. The assumption was made that in all counties the percent of the 15-34 male population in the driving population would be roughly the same. This would generally appear to be valid reasoning, but circumstances occurred on three occasions that could have

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[3] Annual Report: 1970-1971 (Frankfort: Kentucky Department of Revenue, 1971), pp. A-10-A-23.

some bearing on the "normal" situation. Two counties, Oldham and Lyon, have major penal institutions, and Union County has a Federal Job Corps installation. These institutions are likely to have a number of males aged 15-34 who are not drivers. However, as no practical way was found to determine the exact number of inmates in the specific age range being considered, the data were not changed to reflect the possible lower driving population in the three counties.

III. STATISTICAL METHOD

In examining the inter-county variations in fatal accidents it is useful to employ a procedure that will permit accident patterns and underlying associations to be identified from the accumulated accident data. It is necessary, first, to identify the variables that are associated with fatal accidents at the county scale and, second, to utilize these factors to develop a model that will predict accident occurrences for each county. Patterns of differences between the actual and predicted numbers of accidents constitute the geographical problem that forms the basis for additional hypotheses and further evaluation.

Although any one of several statistical techniques could be used, simple and multiple linear correlation and regression appear to be the most appropriate, considering the type of data and the goals of the study. Regression analysis allows the researcher to analyze the data in such a way as to show the association between combinations of variables and to provide the predicted number of accidents per county. In addition, analysis of residuals from regression permits the mapping of

under- and over-predicted areas and the formulation of additional hypotheses to aid geographic explanation. Linear regression has been used extensively in geographic research in recent years. It has already been noted in the literature review that traffic engineering and safety researchers have also commonly applied regression techniques.

In the absence of any developed theory of automobile fatalities, linearity is assumed to be the appropriate relationship between the independent and dependent variables. Using the least squares technique, the regression line with the best statistical fit will be determined. Residuals from regression will be calculated and analyzed to determine whether any geographical pattern not previously explained is evident in the data. The "unexplained" variation between predicted accidents (y estimate) and actual accidents (y), will be standardized in each case by dividing each of the 120 county accident residuals by the respective standard errors of the estimate. The residuals from simple and multiple regression are expected to be normally distributed about the mean.

One standard error of the estimate is being selected as a reasonable breaking point between normal or predicted counties and those that are abnormal or deviant. In a normal distribution of values, 32 percent of the observations should be outside these statistical limits. Accordingly, in this investigation any values within one standard error of the estimate will be considered normal or "explained"; values falling outside of these limits are sufficiently deviant to be considered "unexplained."

Maps will be prepared showing the location of the counties

containing the deviant residuals from regression. The maps will then be examined in an attempt to detect any geographic relationships that may be suggested by the patterns of residuals.

CHAPTER III

ANALYSIS OF DATA

I. INTRODUCTION

This chapter deals with the geographic implications of the mapping of residuals from regression. First, individual maps showing residuals from simple regression for each of the four independent variables are evaluated in terms of the number of counties represented, the patterns of distribution, geographic relationships, and tentative observations and conclusions. Next, the four independent variables are combined in a multiple regression analysis and again the residuals are mapped and evaluated. Finally, attempts are made to explain more fully the unique or deviant character of the counties not "explained" by multiple regression.

II. RESIDUAL MAP INTERPRETATION

Vehicle-Miles of Travel and Fatal Accidents

The first regression analysis is based on the relationship between total fatal accidents and total annual vehicle-miles per county. Fatal accidents are found to be positively associated with vehicle-miles, $r = .97$, $r^2 = .94$. The r values are significant at the .01 level of significance (Table 7). A total of twenty-eight of Kentucky's 120 counties fall more than one standard error of the estimate from the regression line and are found to be normally distributed (Table 8).

TABLE 7

SUMMARY OF REGRESSION ANALYSIS: VEHICLE-MILES OF TRAVEL AND FATAL ACCIDENTS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Coefficient
Regression	1	69,000	69,000	1836	
Residual	118	4,435	37.58		
Variable					
Constant					7.2333
Total Vehicle-Miles					0.000025

$r = 0.9693$*

$r^2 = 0.9396$

Standard Error = 6.13

n = 120

*Significant at .01 level.

TABLE 8

DISTRIBUTION OF RESIDUALS FROM REGRESSION

Independent Variable(s)	Deviant Counties* More Accidents than Predicted	Deviant Counties* Fewer Accidents than Predicted	Deviant Counties* Total	Percent of Counties Exceeding One Standard Error
Total Vehicle-Miles	15	13	28	23.3
Rural Vehicle-Miles	14	13	27	22.5
Tourism	5	2	7	5.8
Young Males	4	0	4	3.3
Multiple Regression	16	14	30	25.0
Freeway	15	10	25	20.8

*Counties with residuals exceeding one standard error.

Fifteen counties have more accidents than would be predicted from vehicle-miles of travel, while thirteen have fewer accidents than would be predicted.

The high statistical correlation (r = .97) is indicative of a very high degree of association between fatal accidents and vehicle-miles for the set of 120 counties in Kentucky. While a rather close association was to be expected, the magnitude of the association was not. Factors which one might expect to contribute to the variation in fatal accidents, such as landforms and rural-urban differences, apparently have slight impact at the aggregate level. The extent to which these latter factors contribute to the geographic variation in fatal accidents is explored by analyzing residuals from the aggregate regression equation.

Counties with more accidents than predicted. Many of the counties whose numbers of fatal accidents were underpredicted by the model ("high counties"[1]) tend to be associated with the state's submetropolitan areas, i.e., urban counties that are not a part of SMSA's as defined in 1970 (Figure 3). Eleven of the fifteen underpredicted counties contained urban places of 5,000 people or more, and nine of these contained places of 10,000 or more. Only one county, Grant, did not have an urban settlement. Unexpectedly, one SMSA county, Fayette, which contains Lexington, appeared in the underpredicted group.

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[1]On occasion the terms "high" and "low" will be used. "High" refers to counties that are underpredicted, i.e., more accidents than predicted; "low" refers to counties that are overpredicted.

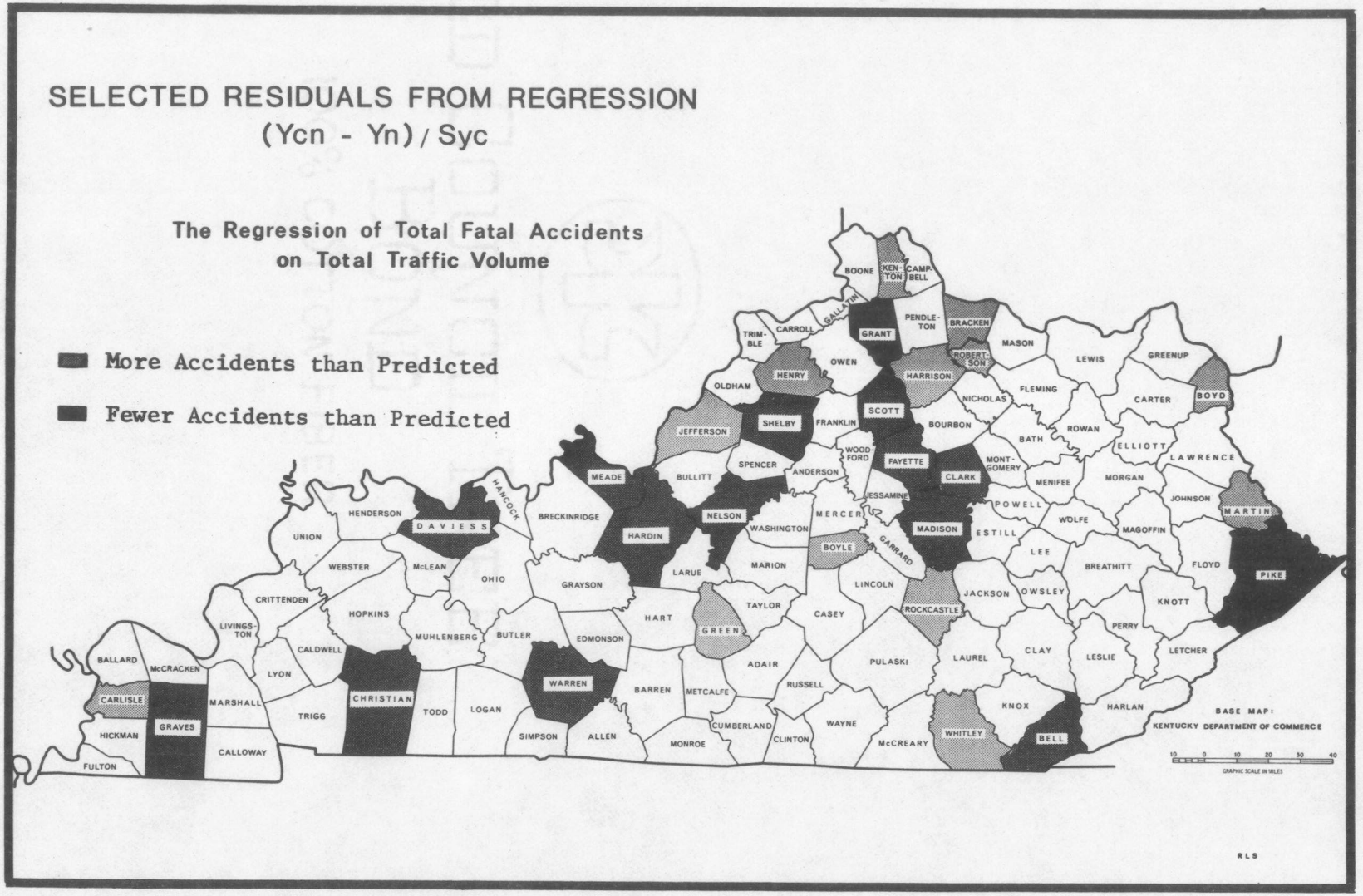


Figure 3. The regression of total fatal accidents on total traffic volume.

Another characteristic of these counties is their association with freeways: twelve of the fifteen counties are served by either the Interstate highway system, the Kentucky toll road system, or both. The most conspicious county grouping is the four-county, I-75 corridor area consisting of Grant, Scott, Fayette, and Madison counties. A secondary group is the pair of counties--Hardin and Nelson--along the axis of the Bluegrass and Western Kentucky parkways.

Counties with fewer accidents than predicted. Metropolitan counties tend to have fewer accidents than would be predicted for their volume of traffic. Jefferson, Kenton, and Boyd are all SMSA counties. One might attribute their over-prediction to their urban character. Fayette, also an SMSA county, is an exception in that it has more accidents than expected. Some over-predicted counties ("low" counties), however, are rural. Only one of the ten non-metropolitan counties, Boyle (largest place, Danville--1970 population 11,542) contains a place over 10,000 population; two other counties, Harrison and Whitley, contain places of 5,000 people or more; seven additional counties contain no urban places. Some association is also shown between counties having fewer accidents than predicted and the presence of freeways, but this association is not as strong as it is with the "high" counties. Six of the fifteen "low" counties are served by freeways.

Rural Vehicle-Miles and Fatal Accidents

The second regression analysis compares the association between rural vehicle-miles and total fatal accidents. Rural vehicle-miles are

positively associated with fatal accidents, $r = .96$, $r^2 = .93$. The r values are significantly at the .01 level (Table 9). The residuals are found to be normally distributed (Table 8, page 50). A total of twenty-seven counties exceed one standard error of estimate from the regression line. Fourteen have more accidents than predicted based upon rural volume; thirteen have fewer accidents than predicted (Figure 4).

Counties with more accidents than predicted. Two clusters of counties are visible: the counties of Breathitt, Clay, and Bell in Eastern Kentucky and a crescent-shaped-cluster near Louisville, consisting of Meade, Jefferson, Spencer, and Nelson counties. All other under-predicted counties exist in random isolation. There appears to be a slight tendency for the under-predicted counties not to contain expressways. Seven of the fourteen have no expressway mileage, and two others, Hickman and Butler, are crossed by expressways only marginally; neither county has an interchange. So, essentially, nine of the fourteen are non-expressway counties.

Counties with fewer accidents than predicted. Two clusters of over-predicted counties are visible, both in the northern part of the state. The larger cluster, containing five counties, is astride the I-65 corridor from Bullitt County in the north to Barren in the south and includes Green County, a non-freeway county lying just to the east of Hart County and I-65. A second cluster is located astride the I-75 corridor from Rockcastle County in the north to Whitley County, adjacent to the Tennessee line, in the south. The five remaining counties are not a part of either contiguous cluster.

TABLE 9

SUMMARY OF REGRESSION ANALYSIS: RURAL VEHICLE-MILES AND FATAL ACCIDENTS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Coefficient
Regression	1	68,130	68,130	1515	
Residual	118	5,305	44.96		
Variable					
Constant					-0.5449
Rural Vehicle-Miles					0.00006

$r = .9632$*

$r^2 = .9277$

Standard Error = 6.71

N = 120

*Significant at .01 level.

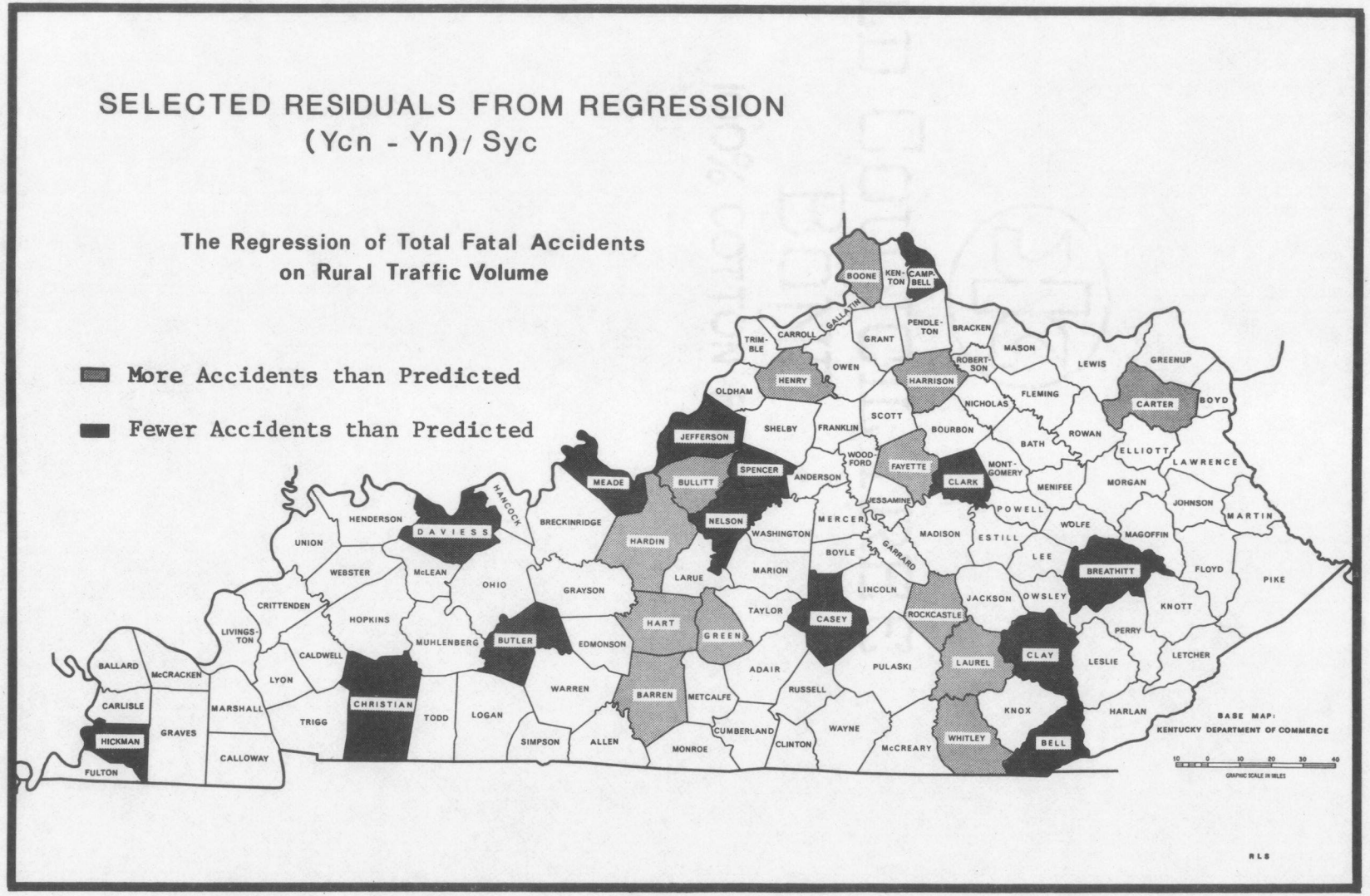


Figure 4. The regression of total fatal accidents on rural traffic volume.

The most obvious relationship noted when considering rural volume and total accidents is the tendency for freeway counties to have fewer fatalities than would otherwise be predicted. In fact, of the thirteen low counties, only two (15.3 percent)--Green and Harrison--contained no freeway. For the state as a whole, 65 counties (54.2 percent) are without freeways.

There also exists a tendency for the over-predicted counties to be rural. The ruralness of the counties may suggest a limited degree of interaction with extra-county activities, thereby contributing to traffic volume that may be largely local and involving drivers that are familiar with county roads.

Tourism and Fatal Accidents

The third analysis examines the relationship between total fatal accidents and the index of tourism (per capita sales tax collections from restaurants, hotels-motels, and amusements). A positive association exists, $r = .40$, $r^2 = .16$. The r values are significant at the .01 level (Table 10).

Seven counties fall beyond one standard error of the estimate from the regression line. Five counties have more accidents than are predicted from the amount of tourism; two have fewer than predicted (Figure 5).

The relatively low r value and large standard error of the estimate (22.9 accidents) may have contributed to the very limited number of deviant residual counties. Tourism is not a sensitive predictor of

TABLE 10

SUMMARY OF REGRESSION ANALYSIS: TOURISM AND FATAL ACCIDENTS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Coefficient
Regression	1	11,710	11,710	22.39	
Residual	118	61,720	523.08		
Variable					
Constant					4.9624
Tourism					3.5498

$r = .3993$*

$r^2 = .1595$

Standard Error = 22.87

N = 120

*Significant at .01 level.

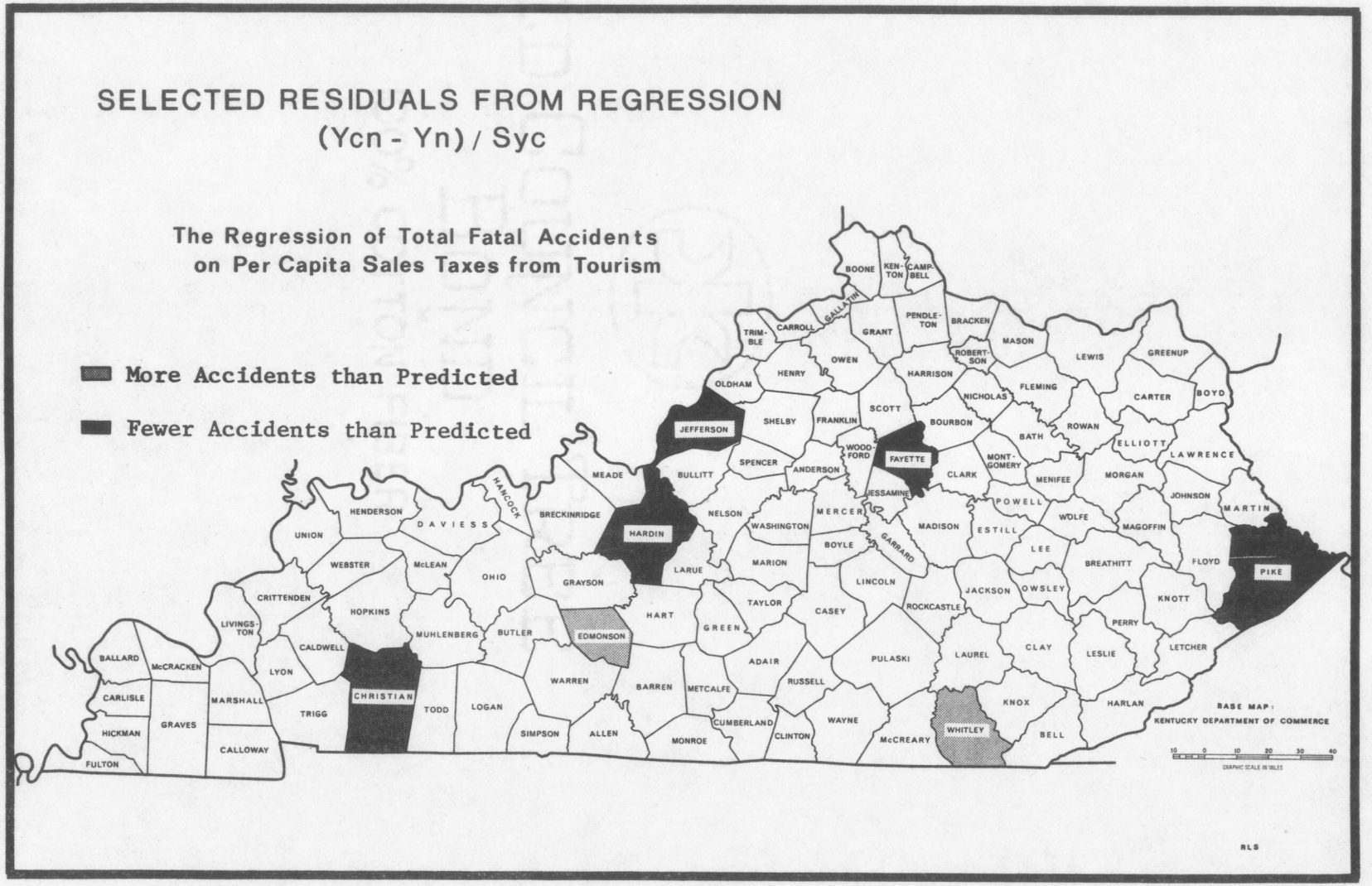


Figure 5. The regression of total fatal accidents on per capita sales taxes from tourism.

the number of fatal accidents in the counties of Kentucky. The lack of sensitivity precludes any meaningful generalizations with regard to the deviant counties, and none are offered.

Young Males and Fatal Accidents

The fourth analysis is designed to show the relationship between fatal accidents and the percent of males aged 15-34 in the total population. The variables are positively associated, $r = .20$, $r^2 = .04$ (Table 11). These r values are insignificant at the .01 level. The conclusion is that at the aggregate level of Kentucky counties the young males factor as defined here is not useful in explaining inter-county accident variations.

The four counties of Daviess, Jefferson, Fayette, and Pike have residuals more than one standard error of the estimate from the regression line; all have more accidents than predicted based on the number of young males in the total population (Figure 6). As with the previous variable, the low r values together with the large standard error (24.5 accidents), the relative rarity of deviant residuals, and the lack of statistical significance makes any further discussion of the patterns meaningless.

Analysis of Fatal Accidents by Multiple Regression

The next step in the investigation involves multiple regression as opposed to the four simple regression analyses completed previously. Total fatal accidents remains as the dependent variable and the independent variables are the same four considered previously: total

TABLE 11

SUMMARY OF REGRESSION ANALYSIS: YOUNG MALES AND FATAL ACCIDENTS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Coefficient
Regression	1	2,919	2,919	4.8884	
Residual	118	70,510	597.572		
Variable					
Constant					-2.2992
Young Males					150.62

$r = .1994$*

$r^2 = .0397$

Standard Error = 24.45

N = 120

*Significant at .05 level; not significant at .01 level.

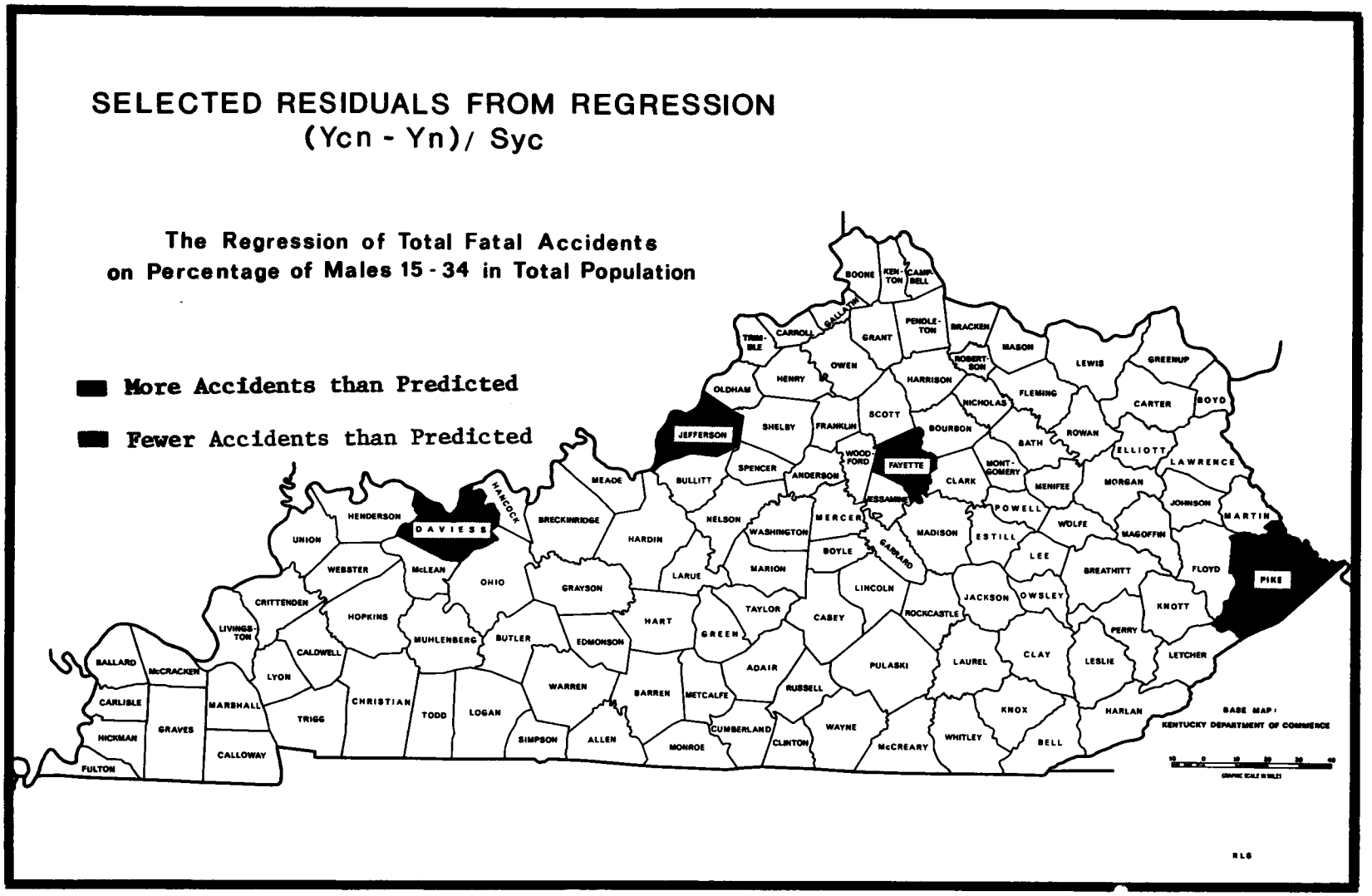


Figure 6. The regression of total fatal accidents on percentage of males 15-34 in total population.

vehicle-miles, rural vehicle-miles, tourism, and young males. The purpose of the analysis is to examine the combined effect of the four independent variables acting upon the dependent variable. Table 12 shows the results of the successive regression steps.

As far as the combined effect of the four independent variables on fatal accident totals for the state's 120 counties is concerned, one variable, total vehicle-miles (R^2 = .94), essentially "explains" the aggregate state variations (Table 13). About 95 percent of the variation in fatal accidents is positively associated with traffic volume and the rural-urban character of the county. Young males only make a very slight additional improvement in statistical explanation and tourism offers no further "explanation." The nearly 5 percent "unexplained" variation is attributed to (a) variables not in the equation or (b) chance.

Analysis of fatal accidents by partial correlation. Stepwise regression analysis provides the opportunity for examining the partial correlation coefficients (Table 14). When vehicle-miles is held constant the relationship between total fatal accidents and the three remaining independent variables shows the following partial correlation coefficients (Table 14).

When the effect of vehicle-miles is removed from consideration the real impact of the remaining variables can be better understood. Rural vehicle-miles still shows moderate correlation with fatal accidents, but the young males variable shows only slight correlation, and tourism shows almost no correlation. The reason for the low explanatory

TABLE 12

SUMMARY OF FOUR VARIABLE MULTIPLE STEPWISE REGRESSION ANALYSIS

Step	Variable Entered	Multiple R	Multiple RSQ	Increase in RSQ
1	Total vehicle-miles	0.9693	0.9396	0.9396**
2	Rural vehicle-miles	0.9772	0.9549	0.0153**
3	Young Males	0.9777	0.9558	0.0010*
4	Tourism	0.9777	0.9558	0.0000

*Significant at F .05 DF 120,4

**Significant at F .01 DF 120,4

TABLE 13

SUMMARY OF MULTIPLE REGRESSION ANALYSIS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Coefficient
Regression	4	70,190	17,550	622.4	
Residual	115	3,242	28.192		
Variable					
Constant					0.34053
Total Volume					0.016
Young Males					25.356
Tourism					0.021
Rural Volume					0.024

$R = .9777$*

$R^2 = .9558$

Standard Error = 5.31

N = 120

*Significant at .01 level.

TABLE 14

SUMMARY OF PARTIAL CORRELATION COEFFICIENTS FROM FOUR-VARIABLE STEPWISE REGRESSION ANALYSIS

Variable	Coefficient
Rural vehicle-miles	.50
Young Males	.30
Tourism	.18

power of the latter two variables in the multiple regression analysis is readily apparent.

Counties with more accidents than predicted. In multiple regression analysis sixteen counties have total fatal accidents exceeding the predicted number by one standard error of the estimate (Figure 7). Of the sixteen "high" counties, eight are totally without freeways, and three--Daviess, Christian, and Butler--have less than 2 percent of their total vehicle-miles related to freeways. Thus for eleven of the sixteen under-predicted counties practically all traffic movement is on the move dangerous FAP, FAS and other state local roads.

Counties with fewer accidents than predicted. In contrast to the under-predicted counties, the over-predicted counties are generally positively influenced by freeway mileage. Nine out of the fourteen have some vehicle-miles associated with freeways. The percentage of freeway volume to total volume in these nine counties ranges from 7.1 percent in Boyd County to 48.3 percent in Boone County. In seven of the nine

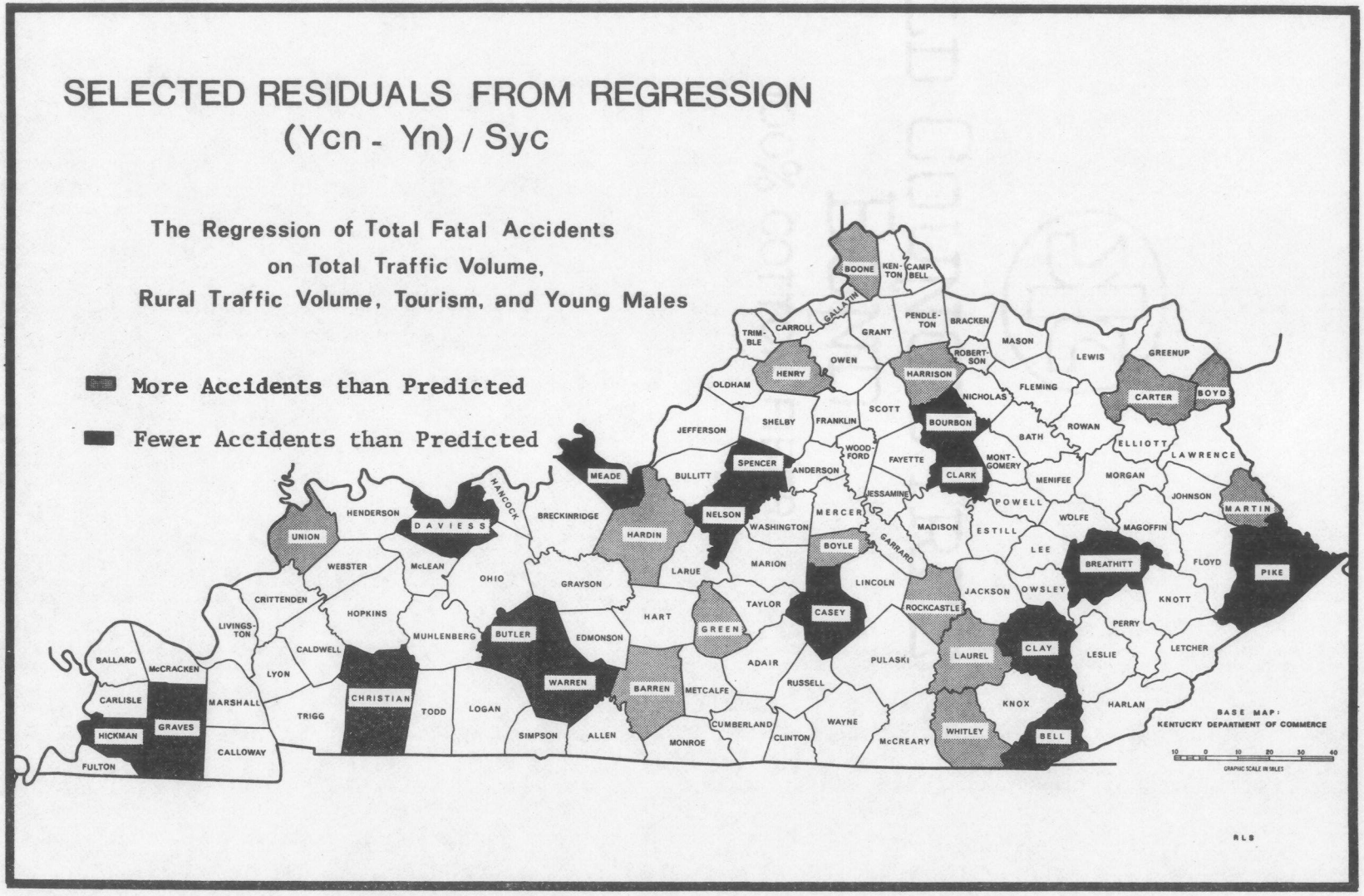


Figure 7. The regression of total fatal accidents on total traffic volume, rural traffic volume, tourism, and young males.

"freeway counties," the freeway volume exceeds 20 percent of the total volume on all county roads.

III. SUBSEQUENT VARIABLE TESTING

Freeways and Fatal Accidents

Comparison of the map of deviant residuals from multiple regression (Figure 7) with the freeway map (Figure 2, page 30) shows at least one discernible pattern that suggests an additional analysis: an apparent association between fatal accidents and the presence or absence of freeways within individual counties. This suggested association is not unexpected. The more uniform traffic flow, median separation of opposing lanes of traffic, absence of frequent access points, and relatively gentle curves and gradients on freeways are designed to make them safer than conventional roads. The accident rate statistics cited in Chapter I (Table 3, page 7) bear this out.

It was decided to attempt one additional simple regression analysis in order to isolate the effect of freeways on county accident totals. The analysis involves the examination of inter-county accidents when freeway traffic volume and freeway accidents are subtracted from the overall state totals. The analysis is designed to (1) test the association between total non-freeway accidents (conventional road) accidents and total non-freeway (conventional road) vehicle-miles and (2) to determine whether counties marked "deviant" by the multiple regression analysis appear to be "normal" in the non-freeway analysis, thereby helping to isolate the effect of freeways. The analysis

involves the modification of two previously-used variables: total vehicle-miles and total fatal accidents. The dependent variable becomes total fatal accidents less those occurring on freeways and the new independent variable becomes total vehicle-miles less freeway vehicle-miles.

This analysis is statistically more significant than the tourism and young males regression analyses. As expected, a positive association exists between fatal accidents on conventional roads and vehicle-miles on conventional roads, $r = .96$, $r^2 = .92$. The r values are significant at the .01 level (Table 15). A total of twenty-five counties fall more than one standard error of estimate from the regression line. Fifteen counties have more accidents than were predicted; ten have less (Figure 8).

Deviant counties. Many of the fifteen underpredicted counties contain medium-sized urban places. Over-predicted counties, with the significant exceptions of Jefferson, Boyd, and Boyle, are rural. The low ranking for Jefferson and Boyd may be associated with the high degree of urbanization in these two counties. The reason for Boyle's low rank is not immediately apparent. The fact that some highly urban counties as well as rural counties are overpredicted indicates considerable geographic complexity at the county level.

Comparison of Maps of Residuals from Regression

Fourteen of the original deviant counties on the residual maps from multiple regression fall within one standard error of estimate from the regression line when the freeway variable is considered. Though not

TABLE 15

SUMMARY OF REGRESSION ANALYSIS: NON-FREEWAY VEHICLE-MILES AND NON-FREEWAY FATAL ACCIDENTS

Source	Degrees of Freedom	Sum of Squares	Mean Square	F Statistic	Coefficient
Regression	1	47,160	47,160	1429	
Residual	118	3,895	33.007		
Variable					
Constant					6.8858
Non-Freeway Vehicle-Miles					0.027

$r = .9611$*

$r^2 = .9237$

Standard Error = 5.75

N = 120

*Significant at .01 level.

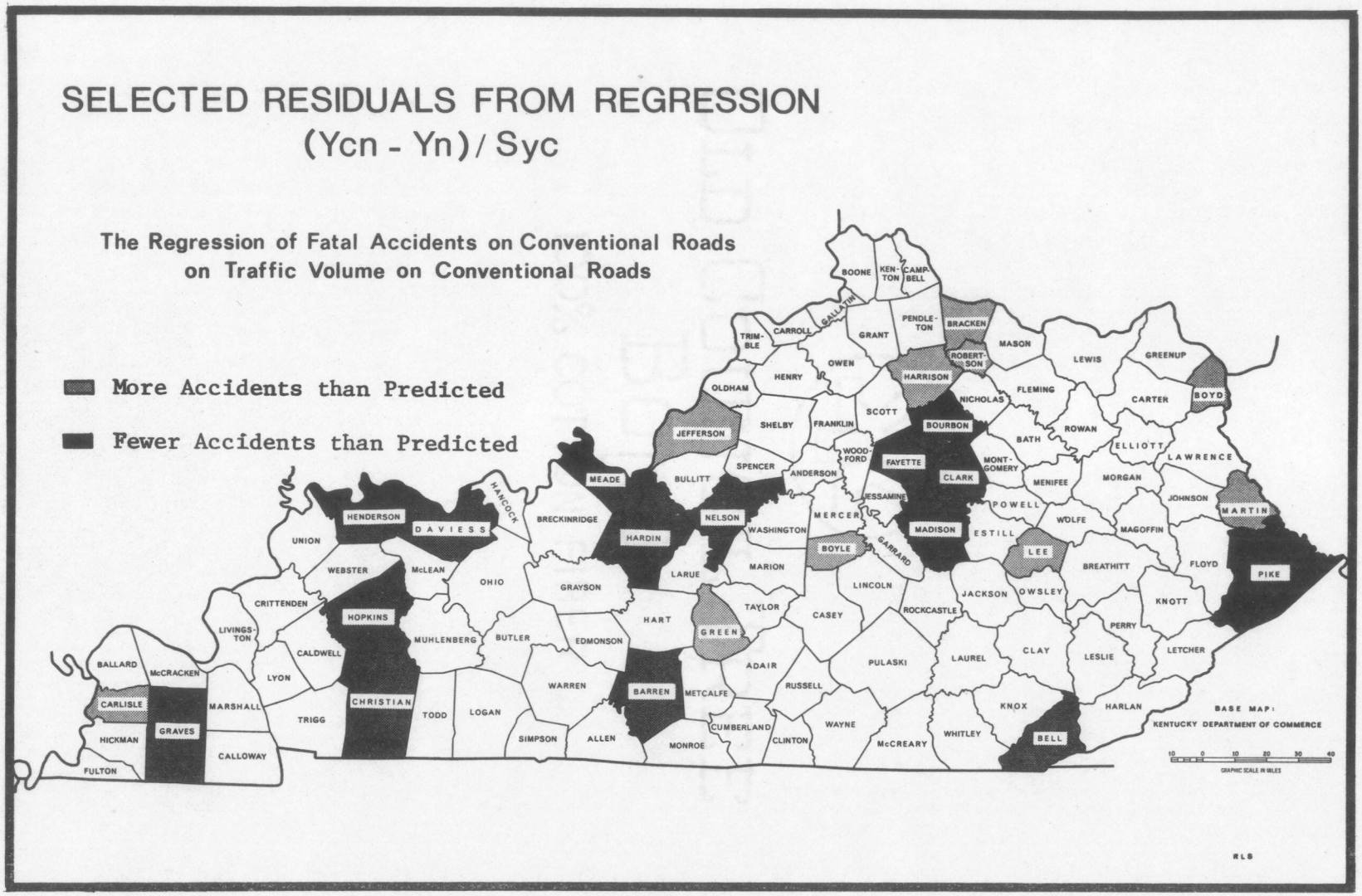


Figure 8. The regression of fatal accidents on conventional roads on traffic volume on conventional roads.

conclusive statistical evidence that the freeway variable is an explanatory factor for the state as a whole, it suggests that the deviant behavior of the fourteen counties may be related to the presence or absence of freeways.

The role of freeway traffic and fatal accidents for these fourteen counties can be examined in more detail by individual comparison of the multiple regression and freeway simple regression analyses. The framework for such a comparison is presented in Table 16. The columns segregate the freeway and non-freeway counties into categories of either more or fewer accidents than predicted based upon multiple regression. The rows, classify the thirty deviant counties according to how they appear based upon the simple regression analysis of freeways only. Graves County, for example, is shown as being a freeway county that has more accidents than predicted on both the multiple regression analysis and the simple regression freeway analysis. A discussion of the fourteen counties in row two of Table 16 follows.

Six counties are in the position of having fewer accidents than predicted based upon the multiple regression analysis and having the predicted number of accidents when freeway volume and accidents are excluded. These counties (with percentage of total vehicle-miles assigned to freeways shown in parentheses) are: (Henry 42 percent), Boone (52 percent), Rockcastle (50 percent), Laurel (26 percent), Whitley (46 percent), and Carter (28 percent). All are crossed by major freeways and a large percentage of their rural traffic is on freeways. Considering the low accident rate associated with freeways and the fact

TABLE 16

CROSS-CLASSIFICATION MATRIX OF THIRTY DEVIANT COUNTIES FROM MULTIPLE REGRESSION WITH SIMPLE REGRESSION ANALYSIS OF NON-FREEWAY VOLUME/FATAL ACCIDENTS

	Multiple Regression Analysis			
	Freeway County		Non-Freeway County	
Simple Regression Analysis: Non-Freeway Volume/Accidents	More Accidents than Predicted	Fewer Accidents than Predicted	More Accidents than Predicted	Fewer Accidents than Predicted
More Accidents than Predicted	Graves Daviess Christian Nelson Clark	Hardin Barren	Meade Bourbon Bell Pike	--
As Predicted	Hickman Bullitt Warren	Henry Boone Rockcastle Laurel Whitley Carter	Spencer Casey Clay Breathitt	Union
Fewer Accidents than Predicted	--	Boyd	--	Boyle Green Harrison Martin

that these six counties exhibit "normal" behavior when freeways are excluded, it seems reasonable to assume that the presence of freeways is a rational explanation for the lower than prediced number of accidents for these counties.

Perhaps a little less obvious is the opposite situation: non-freeway counties that have more accidents than predicted in the multiple regression analysis. Four counties, Spencer, Casey, Clay, and Breathitt are in this category. These counties have all of their vehicular mileage occurring on high-fatality-rate conventional roads. Their appearance among the "high" counties on the multiple regression map appears to be largely attributable to the fact that these counties are being compared with many counties that contain substantial amounts of low-accident-rate freeway mileage.

A third situation exists in Union County. It is in the apparently paradoxical position of being a non-freeway county having fewer accidents than predicted in the multiple regression analysis but behaving as predicted when only non-freeway volume and accidents are considered. In other words, when the county's vehicle-miles--all non-freeway and "high-risk"--is compared with the state as a whole, which includes low-risk freeway volume, Union County has fewer accidents than predicted. But, when only non-freeway volume and accidents are involved, the county appears "normal." The most likely explanation for this anomaly lies in the nuances of the mathematics and Union County's consistent borderline position tendency with respect to classifications of residuals to the "deviant" and "normal" categories. No other explanation is suggested by the data.

Finally, an analysis was made of the relationship between these counties that have freeways and that have more accidents than predicted in the multiple regression analysis, but that are better predicted when freeway data are removed. The counties involved are Hickman, Butler, and Warren. The first two may be accounted for by their being only technically "freeway counties," but not so practically. In Butler County, the Western Kentucky Parkway crosses the extreme northern margin of the county; in Hickman County the Purchase Parkway crosses only the southern panhandle, the narrowest portion of the county. Neither county contains a freeway interchange. Only .02 percent of Butler County traffic is associated with freeways and only .03 percent with Hickman County's freeway. So, essentially, neither county is a "freeway county." They appear to be "high" because of the preponderance of conventional road travel.

Warren County, which is crossed by I-65, presents a somewhat different situation. The county ranks higher than predicted in the multiple regression analysis but is recorded as "normal" when freeway data are deleted. Examination of all six regression analyses shows Warren County ranking "high" in the simple regression analysis for total volume and in the multiple regression analysis, but in the others it performs as predicted.

The accident records for Warren County provide some insight into the situation. In the 1969-71 study period Warren County had forty-seven non-pedestrian fatal accidents, of which thirty-six occurred on conventional roads and eleven on I-65. Further examination reveals that

I-65 had 22.7 percent of the traffic volume and 23.4 percent of the fatal accidents--slightly more than its absolute share of accidents and substantially more than one would expect for a limited access highway. The fatal accident rates (1969-71) for Warren County are as follows: conventional roads, 4.05, which is lower than the state average for all state roads (including pedestrian accidents); freeway (I-65), 4.21, which is substantially higher than the state's Interstate system fatality rate (including pedestrians) of 3.43 or the toll road rate of 2.99 (including pedestrians). Had this study included pedestrians, Warren County's freeway rate would have been 4.97. Thus, it would seem that Warren County's "high" position is at least partially influenced by its high accident rate on I-65 which, in turn, is partially offset by a relatively and absolutely lower accident rate on conventional roads. It is not known, however, why these rate differences exist.

Other Variables and Fatal Accidents

It appears that of the original thirty deviant counties from multiple regression, the deviations in fourteen are associated with the presence or absence of freeways. Sixteen remaining counties are not statistically explained by either the multiple regression or the freeway analyses (Table 15, Rows one and three, page 70).

The next phase of the investigation re-examines the pattern of deviant residuals from multiple regression and seeks other explanatory factors and geographic associations. Data were collected for four additional independent variables, terrain, alcoholic beverage consumption, traffic law enforcement, and changes in county population.

Scatter diagrams were constructed for each of the individual variables and evaluated.

Terrain. Inter-county differences in terrain might logically be expected to be associated with fatal accident variations. Micro studies reported in the literature have shown a positive association between hills, curves, and accidents. Evidence from the literature suggests a complex association and not always one that might initially be expected. For example, one study found that accidents are associated with level land and infrequent curves, not with areas of rugged terrain and numerous hills and curves. For this investigation it is hypothesized that fatal accidents will covary positively with the degree of flatness of county terrain.

In an attempt to obtain a reasonable yet convenient measure of terrain variations, the surrogate "cropland" was chosen to be an indicator of county-wide terrain conditions. The cropland information was obtained from the 1969 Census of Agriculture. Initially, the percentage of the total county land area in cropland was chosen to represent the condition of "level land." Upon further reflection this measure was redefined as the percentage of the county land area in harvested cropland. Harvested cropland seems a better measure of the degree of terrain flatness in that cropland includes pasture land--land that is often more rugged or hilly than harvested cropland.

A scatter diagram (Figure 9) was prepared showing the relationship between fatal accidents and level land. There appears to be no correlation at the county scale.

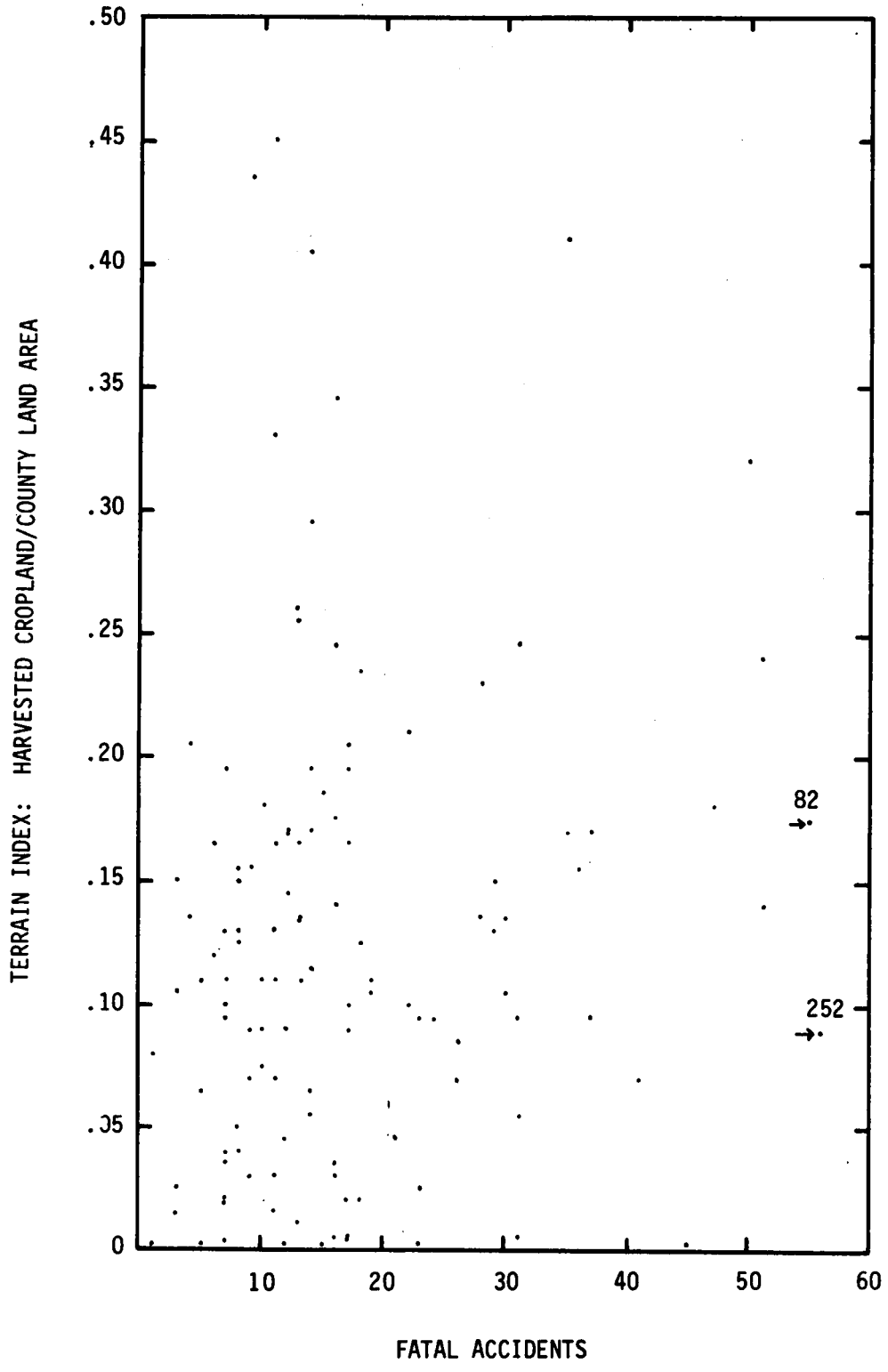


Figure 9. Relationship between fatal accidents and terrain index: Harvested cropland/county land area.

Alcoholic beverage consumption. A second factor that might reasonably be expected to be associated with the distribution of fatal accidents is the consumption of alcoholic beverages. The association between alcohol and accidents has been thoroughly documented in the accident literature. It is hypothesized in this investigation that fatal accidents will covary positively with the degree of alcoholic beverage sales per county.

Several problems handicapped the effort to pinpoint the geographic association between fatal accidents and the alcoholic intoxication of drivers. For example, points of beverage sales within Kentucky are not necessarily points of consumption. Alcoholic beverages probably receive wide dissemination throughout the state regardless of the location of legal beverage sales. In addition, in many of the "dry" border and near-border counties substantial purchases of beverages are no doubt made outside of the State.

Nevertheless, the best surrogate for this elusive statistic remains the alcoholic beverage sales figures reported by the Kentucky Department of Revenue. Their 1970-71 Annual Report (Tables VI and VII) gives county statistics on sales and use tax receipts for two business categories--"Bar or Night Club" and "Package Liquor"--which were taken as indicative of (a) the "wetness" or "dryness" of a county with respect to alcoholic beverage sales and (b) the intensity of such sales and, presumably, of consumption.

The annual sales tax receipts from the two business categories were combined and converted to a per-capita index in order to minimize

the effect of inter-county population differences. A scatter diagram (Figure 10) was prepared showing the relationship between the alcoholic sales index and fatal accidents. The scatter diagram reveals a poor correlation between county beverage sales and fatal accidents. Consequently this variable was dropped from further consideration.

Traffic law enforcement. The level of traffic law enforcement also might logically be expected to be associated with variations in fatal accidents. That increased levels of traffic law envorcement will reduce speeding and reckless driving and, consequently, fatal accidents, is taken to be axiomatic in law enforcement operations. In this investigation it is hypothesized that fatal accidents will vary inversely with levels of traffic law enforcement.

Certain problems arise in analyzing this variable. First, there probably exists a time lag between increased or high levels of enforcement and any subsequent decrease in fatal accidents and vice-versa. Also, citations from law enforcement agencies other than the State Police were infeasible to obtain. If these other citations were available, the combined citations issued by all police would probably be a better surrogate for levels of law enforcement than the one used.

An attempt to measure the effect of varying degrees of traffic law enforcement at the county level was made. Data were gathered from the Kentucky State Police for the years 1969-71 giving the number of arrest citations issued by the State Police for moving traffic violations. Because of the volume of the data and the many computations needed to convert the monthly data to a usable yearly summary, one year,

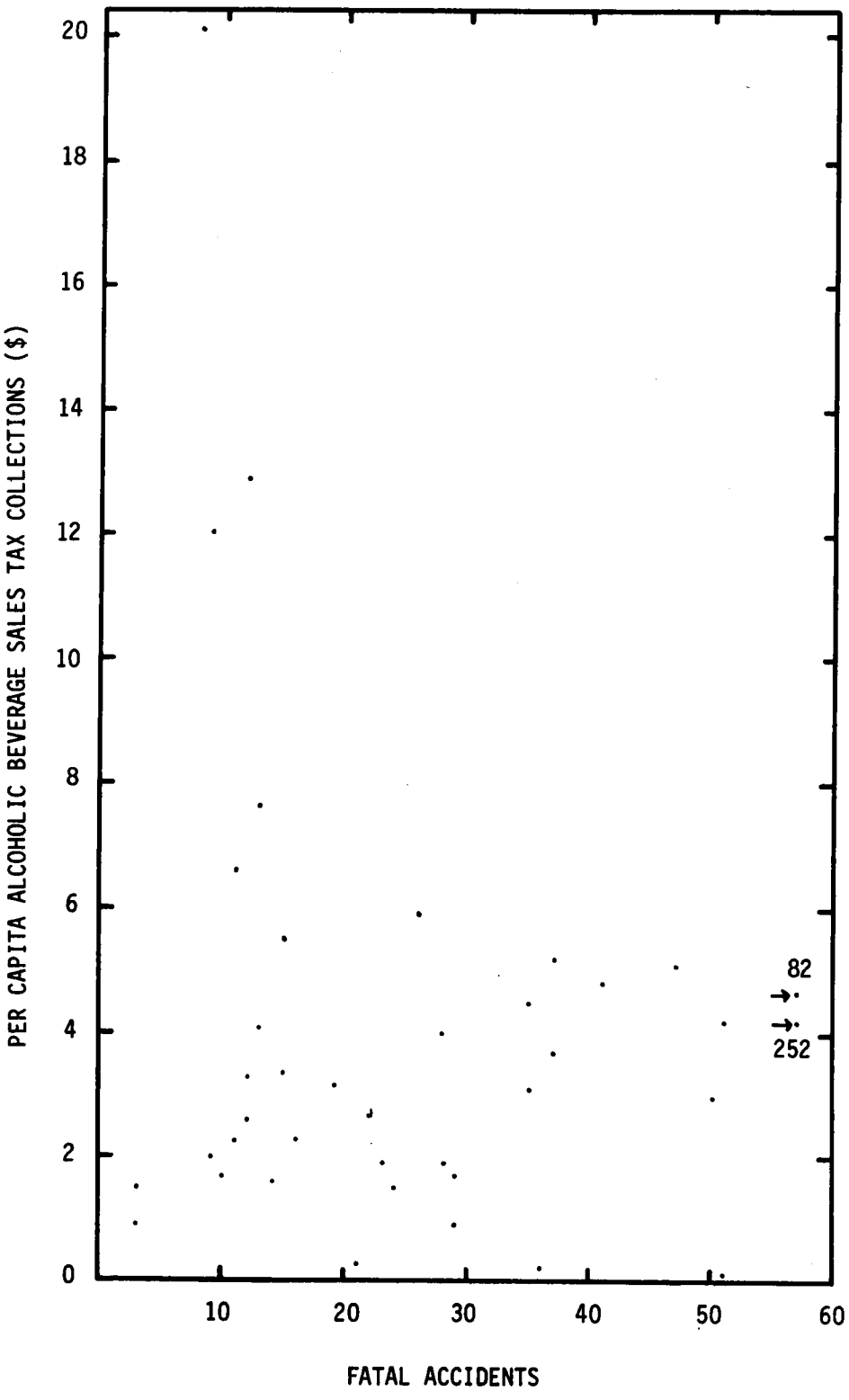


Figure 10. Relationship between fatal accidents and per capita alcoholic beverage sales tax collections. (Includes only counties with legal beverage sales.)

1970, was selected as being representative of the entire three-year period. The total moving violation citations issued for each of the 120 counties was computed. In an attempt to control the effect of traffic volume, the raw totals of arrest citations were converted to an index: arrest citations per rural vehicle-mile of travel.

A scatter diagram was prepared (Figure 11) showing the relationship between total fatal accidents and the traffic law enforcement index. There is a near zero correlation. As a result this variable was also dropped from further consideration.

Changes in county population 1960-1970. A final relationship suggested by the pattern of residuals from multiple regression is that deviant counties may be associated with changes and trends in the county population growth rates. The logic behind such an association is that counties that are experiencing rapid growth have a situation in which (a) new drivers are being introduced to an unfamiliar driving situation and (b) old drivers are having to face changes in heretofore familiar driving situations. On this basis it is hypothesized that fatal accidents will correlate positively with increases in population of counties over the ten-year period.

Population data were obtained from the 1970 Census of Population. The population changes and fatal accidents were plotted on a scatter diagram (Figure 12). No definite association is evident, though there is a slight suggestion of a positive correlation. It was felt, however, that the possible association is much too indefinite to provide evidence of being significant in explaining statewide fatal accident variations. Consequently, the variable was dropped from further consideration.

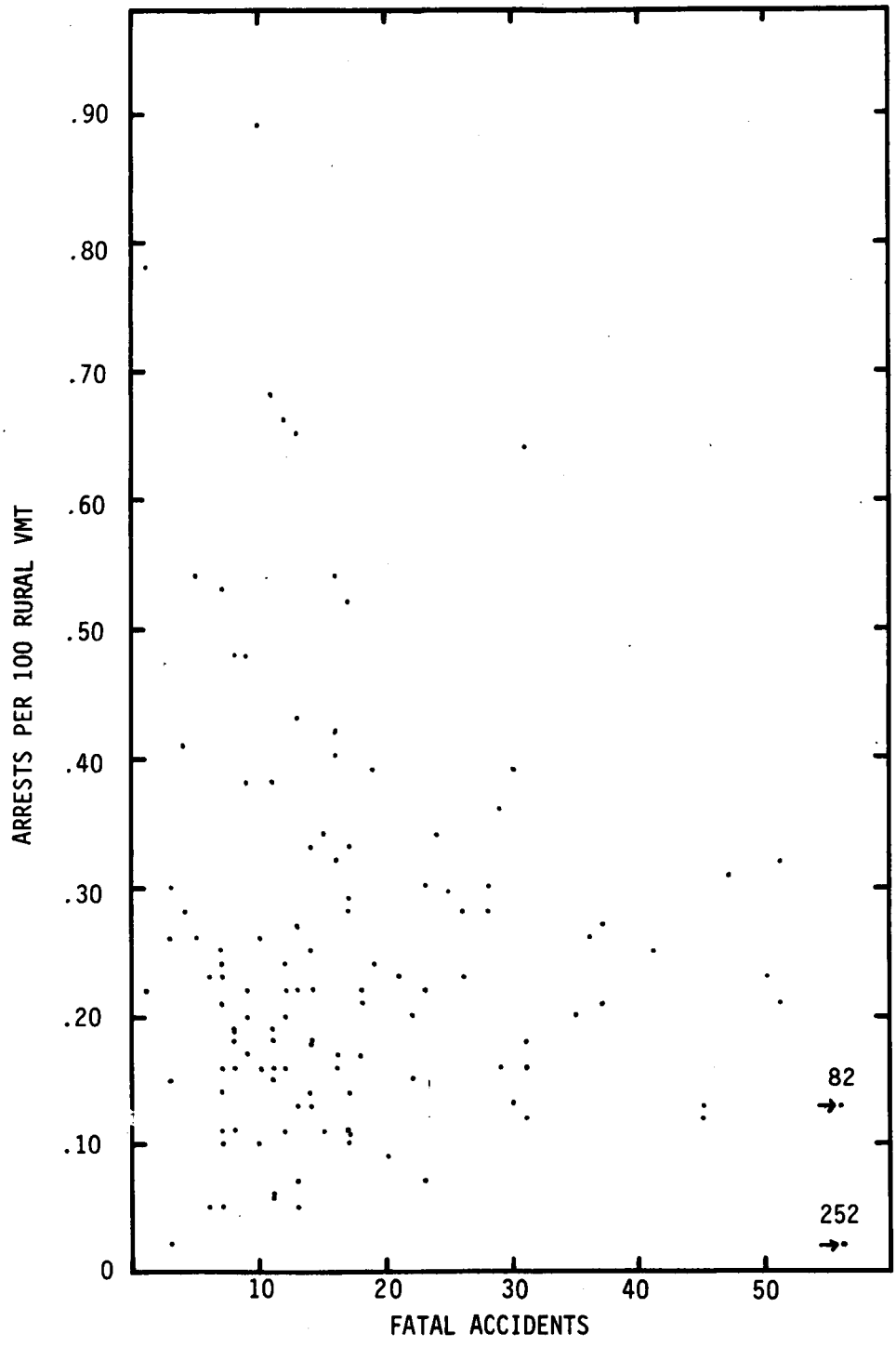


Figure 11. Relationship between fatal accidents and arrests per 100 rural VMT.

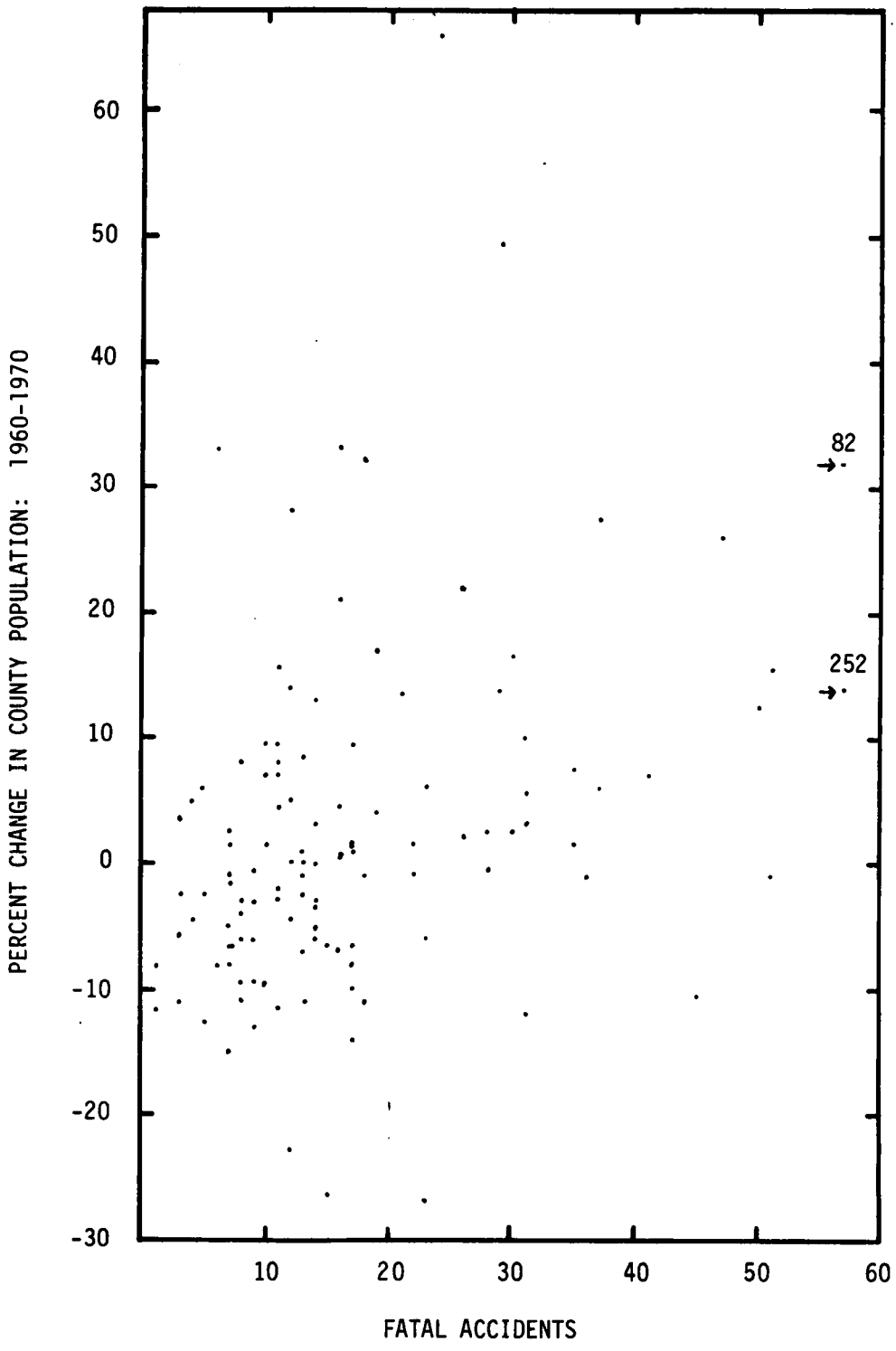


Figure 12. Relationship between fatal accidents and percent change in county population, 1960-1970.

Summary

In summary, in this phase of the investigation four possible additional variables were examined; none, in the final analysis, appears to be significantly associated with county variations in fatal accidents. Accordingly, although other factors certainly influence the deviant counties positively or negatively, no additional explanatory factors appear to be forthcoming within the county-unit framework of this investigation. More intensive follow-up of this topic would seem to be a study in itself and is beyond the scope of the current investigation.

IV. COUNTIES NOT "EXPLAINED" BY RESIDUALS FROM REGRESSION

Attention in this section is directed toward more detailed examination of the sixteen remaining "unexplained" counties in an attempt to disclose any unique factors that may contribute to the deviant fatal accident position of these counties.

Counties with Substantial Freeway Traffic

Hardin and Barren Counties, classified as having fewer accidents than predicted in the multiple regression analysis, possess more accidents than predicted when freeway data are excluded. The indication is that the freeways in the two counties possess unusually low fatal accident rates. A check of the data shows that Barren County had one fatal accident in the study period and Hardin County had eleven. Comparing the fatal accidents with vehicle-miles, one finds that Barren had a

freeway accident rate of 1.27, while Hardin had a rate of 2.65. Barren County's rate is almost exactly one-half the state freeway fatal accident rate of 2.52 (non-pedestrian), whereas Hardin County's rate is just above the state average.

Barren County appears to have fewer accidents than predicted in the multiple regression analysis because of an unusually low fatal accident rate on I-65. This serves to pull the entire county's rate to below "predicted." It is mildly surprising, though, that this section of road should have such a good safety record. Within the 8.4 miles of I-65 in the county are located two important interchanges--Park City and Cave City, both gateways to heavily-visited Mammoth Cave National Park. Interchange areas tend to be the most dangerous parts of freeways.[2] The occurrence of the interchanges in combination with a heavy flow of tourist traffic might cause one to expect this road to have a poorer than normal record rather than the opposite. No definite conclusions can be reached, however, because of the very small sample involved.

Hardin County's situation appears more complex. The county has fewer accidents than expected based on multiple regression analysis and also in the rural vehicle-miles simple regression analysis. In the total vehicle-miles, non-freeway vehicle-miles, and in tourism analyses it ranks "high." Only in the young males analysis is it as predicted.

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[2]Julie Anna Cirillo, Stephen K. Dietz, and Richard L. Beatty, U. S. Bureau of Public Roads, Analysis and Modeling of Relationships Between Accidents and the Geometric and Traffic Characteristics of the Interstate System (Washington: Government Printing Office, 1969).

Apparently a low rural accident rate rather than a low freeway rate causes the multiple regression residual to be low. The freeway rate is a little higher than the overall state rate. The rural vehicle-miles statistic which, apparently, contributes to the overall multiple regression "low" rate is somewhat misleading. The number of accidents compared with rural vehicle-miles probably appears "low" because of the large absolute amount of total rural traffic in the county--third highest in the state behind Jefferson and Fayette counties--a large percentage of which (35.7 percent) is associated with freeways. Hardin County's rural fatal accident rate (3.01) is considerably lower than the state rural rate, 4.26. A higher than normal urban fatal accident rate (4.84) coupled with a sizeable absolute volume of urban traffic and a still larger rural non-freeway volume combine to make the total vehicle-miles and non-freeway residual maps depict the county as "high."

In summary, it appears that the accident record of both Barren and Hardin Counties is influenced by the presence of freeways even though both have more accidents than predicted in the freeway analysis.

Counties with Substantial Urban Traffic

Two counties, Boyd and Boyle, have large volumes of urban traffic. Boyd County (Ashland) is a small county, one of the Huntington-Ashland SMSA counties, and, consequently, is considered metropolitan. Boyle County is not a metropolitan county, the only urban place in the county being Danville, population 11,542. However, over 50 percent of the vehicle-miles in each county is urban. Their urban character could be a primary reason for their having fewer accidents than predicted.

Examination of Remaining Deviant Counties

It should be re-emphasized that local statistical peculiarities may well be important in the statistical fit of the counties to the model used here. In a normal distribution about 32 percent of the observations are expected to lie outside of one standard error of the estimate. Thus, with 120 counties being examined, approximately 38 counties should exceed one standard error of the estimate, about five should exceed two standard errors, and only one time in four hundred would even one county be expected to lie three or more standard errors away from the mean. Accordingly, in an effort to isolate among the remaining counties those that have a high probability of possessing particular attributes that contribute to their "unexplainability" beyond that of chance alone, all counties within 1.5 standard errors of the estimate will be considered as statistically and geographically "explained." In a normal distribution only about 13 percent of the observations would be expected to exceed 1.5 standard errors by chance alone. The remaining counties with residuals from regression in excess of 1.5 standard errors will be examined more closely in an attempt to provide a reasonable explanation for their more extreme deviant behavior.

Three counties, Graves, Bourbon, and Martin fall within 1.5 standard errors of the estimate and, therefore, are considered to be reasonably normal and "explained." On the other hand, nine counties have residuals in excess of 1.5 standard errors of the estimate and four of these counties--Daviess, Meade, Nelson, and Bell--have residual values exceeding two standard errors, which in either instance is about

the total number expected since such values would normally occur about 7 percent and 5 percent of the time, respectively. Daviees County is "high" by nearly three standard errors and Nelson, the most deviant of all the Kentucky counties, is "high" by about 3.5 standard errors. This implies that for Daviess and Nelson Counties, such departures on the basis of chance would occur only about .1 and .02 percent of the time, respectively.

The nine remaining deviant counties, which included seven with more accidents than predicted and two with fewer, were then examined on an individual basis in a final attempt to disclose any unique factors that might account for the significant departure of each of the county residuals from the predicted values. Several different conditions would appear to be associated with the deviant counties, but, as might be expected, no single factor appears dominant.

The most common tendency observed is the apparent association between counties having more accidents than predicted and the presence of military personnel. Four "high" counties (Christian, Meade, Nelson, and Clark) either contain or are adjacent to counties containing military installations. In addition, each of these "military counties" has legal alcoholic beverage sales and all, with the exception of Clark County, rank among Kentucky's top counties in per capita alcoholic beverage sales. Also each county contains extensive amounts of flat terrain, which may be conducive to high-speed driving. The synergistic effect of these three factors may contribute to the high accident residuals possessed by these four counties.

The two counties with significantly fewer accidents than predicted, Green and Harrison, both rural counties, are relatively isolated and automobile traffic appears to be largely local in nature. Green County contains no urban place, and Harrison contains but one. Neither county contains a significant tourist attraction. Neither contains an expressway or a heavily traveled primary roadway. The ruralness and general isolation of the two counties might reasonably contribute to the lower than predicted accident residuals.

The two Cumberland Plateau counties, Bell and Pike, both of which rank "high" in accident residuals would seem to be associated with three unifying factors: poor roads, a high incidence of coal trucks in the traffic stream, and the existence of unusual amounts of congestion in nominally high-speed-driving rural areas because of the numerous "urban-like" string settlements found throughout otherwise rural areas in both counties. Bell County, in addition, contains four major tourist attractions and may therefore attract a number of visitors.

The factors that may be associated with Daviess County are somewhat obscure. This is unfortunate since Daviess County is the state's second most deviant residual county. The factors which contribute to the county's position may include the synergistic effects of the following: the county is high in per capita alcoholic beverage sales, low accident-rate freeways account for only slightly over 1 percent of the total traffic volume, and the abundance of flat terrain may contribute to high-speed driving.

Subsequent Follow-up Interviews

As a last step in the investigation one final attempt was made to disclose additional information about the nine remaining "unexplained" counties. Personal interviews were conducted in October, 1974, with five different individuals who, by virtue of their respective positions in the traffic and safety field in Kentucky, are believed to be among the most informed regarding the statewide accident situation. These individuals and their respective positions include: Lieutenant Colonel James H. Mayes, Director of Operations of the Kentucky State Police; Mr. Marcus Blakemore, Manager, Statistical Section, Division of Planning, Kentucky Department of Transportation; Mr. John Crossfield, Traffic Engineer in Charge of Accident Identification, Division of Traffic, Kentucky Department of Transportation; Mr. Anthony Thomson, Traffic Accident Supervisor, Statistical Section, Division of Planning, Kentucky Department of Transportation, and Mr. Leslie Leach, Director of the Traffic Safety Institute at Eastern Kentucky University.

The general impression by each interviewee was that no "new" or unusual situation, to their knowledge, existed in any of the counties. All were in agreement in their opinion that higher-than-expected numbers of accidents in Christian and Meade Counties were associated with military personnel. Three interviewees felt that military personnel from Fort Knox were associated with the "high" ranking of Nelson County as well. Other opinions regarding Nelson County's position included tourism, the distilling of alcohol and presumed high alcoholic consumption within the county.

None of the interviewees had an opinion as to what contributed to Daviess County's "high" position. Bell and Pike Counties were commented upon by four individuals. Their opinions included such factors as the total absence of freeways, the many small settlements, and, in one case, the opinion was "wild, drinking drivers." Clark County was commented upon by two individuals. One cited the factor of tourism; the other mentioned the idea of increased industrialization and related urban growth.

One interviewee suggested that the deviant position of many of the remaining "unexplained" counties may be associated with the degree of change taking place within each county. Counties that were growing in industry, population, urban sprawl and in new drivers unfamiliar with county roads and traffic conditions, such as Meade, Nelson, Clark, had more accidents than one might otherwise expect. On the other hand, the idea of slow-growth and stability was characteristic of counties such as Green and Harrison. One other interviewee referred to Green and Harrison Counties being "out-of-the-way." The population change factor, however, was previously rejected as one having statewide application.

In summary, in the combined opinions of the highway-safety personnel, the factors associated with the counties having more accidents than expected included military personnel, tourism, uncontrolled traffic access (i.e., lack of freeways), alcohol, and the idea of growth and change. Counties with lower than expected number of accidents were associated with stability and relative isolation.

CHAPTER IV

CONCLUSIONS

I. GENERAL FINDINGS

In general, the research effort has been moderately successful in its attempt to provide a better understanding of the spatial characteristics of fatal automobile accidents. The effort does not provide major facts or interpretations heretofore unknown in the accident literature, and the findings are largely a reaffirmation of previous knowledge.

The orientation throughout, unlike the vast majority of accident studies, is focused upon the spatial inequality of fatal accident occurrences aggregated at the county level. At the county scale the pattern of fatal accident occurrences does not yield the same satisfaction in "explanation" that is suggested in the aggregated findings at the state scale. The model employed is highly predictive of fatal accidents where aggregate totals for all counties are concerned but only moderately predictive in terms of individual counties. The variable of annual vehicle-miles accounts for the statistical variation in fatal accidents almost to the exclusion of all other factors at the state level. County to county variability in fatal accidents is shown to be associated with still other factors such as rural-urban differences, as measured by vehicular travel on rural roads, the presence or absence of freeways, and, to a very modest extent, the presence or absence of large numbers of young males in the total county population.

Interestingly, other regional variables tested, such as tourism, alcoholic beverage sales, traffic law enforcement, terrain, and changes in county population, that conventional wisdom associates with accidents, were determined to have little or no association with accident variations at the county level. Each of the significant variables employed in this investigation is directly related to the traffic stream. At the county scale of observation off-highway influences appear to be unimportant to the pattern of fatal accidents.

With reference to the original statement of purpose, fatal automobile accidents in Kentucky are found to be spatially arranged primarily in accordance with variations in vehicle-miles of travel. The majority of fatal accidents occur in the urban counties, in the counties of large areal extent, which, even with low traffic densities, have large annual vehicle-mile totals, and in the other rural or urban counties that have large amounts of inter-county traffic. The final accident pattern is modified by differences in rural and urban mileage driven, the availability of freeways, such as the Interstate or Kentucky Toll Road systems, and to a limited extent, by whether or not the county tends to possess large numbers of young males, as in a university or military base setting.

It is recognized that vehicle-miles traveled is largely influenced by the regional situation of counties, e.g., proximity to high volume roads on major inter-city corridors, nearness or remoteness to large population centers, and the rural or urban natures of surrounding areas. For example, the fairly significant annual death toll in

counties such as Grant or Scott is not, apparently, particularly attributable to local internal conditions but to the fact that the respective counties possess a large volume of traffic because they lie astride a major north-south route, I-75, and are situated between Cincinnati, Ohio, and Lexington, Kentucky, both major traffic generators.

The model has only marginal ability to predict accidents. Ninety of the 120 counties are within plus or minus one standard error of the estimate (5.3 accidents) from the predicted number of accidents, or an average annual departure of 1.8 fatal accidents. The accuracy of individual county fatal accident prediction, based on percentage deviation, increases as the number of predicted accidents per county increases. For example, the twenty-five counties with the fewest predicted accidents show a mean departure from the predicted number of 32.6 percent, whereas the seven counties that are predicted to have more than forty fatal accidents have a mean departure of only 8.2 percent (Table 17). The average departure for all counties is 20.3 percent, which is rather inaccurate for predictive purposes.

The counties with the fewest annual vehicle-miles tend to have more erratic accident frequencies than the counties with greater vehicle-miles. Thus, the reliability of the designation of a given county as "normal" or "deviant" becomes increasingly questionable as one proceeds form the highest vehicle-mile counties to the lowest.

In terms of classifying county fatal accident experience (based upon regression residuals) for the three-year period as either "predicted" or "deviant," the model appears to be considerably more

TABLE 17

MEAN FATAL ACCIDENT PREDICTION ERROR BASED UPON MULTIPLE REGRESSION

Total Counties in Group	Predicted Range of Total Accidents	Actual Total Accident Range	Sum of Predicted Accidents	Sum of Difference Between Predicted/ Actual Accidents	Mean Prediction Error (Percent)
25	4 - 9	1 - 14	190	62	32.6
62	10 - 19	3 - 37	834	220	2.64
19	20 - 29	12 - 31	452	94	20.8
7	30 - 39	31 - 50	241	42	17.4
7	40 - 253	29 - 252	561	46	8.2
120			2,278	464	20.3

effective than in the exact prediction of total accidents per county. The addition or subtraction of one fatal accident is found to change the classification of only nine counties. Six counties that are classified as deviant, Bourbon, Boyd, Clay, Hardin, Hickman, and Martin, would be classified as normal by a change plus or minus one fatal accident. Three counties, Grant, Lewis, and Ohio, classed as normal would be classed "deviant" by a change, plus or minus, of one fatal accident.

II. PROBLEM AREAS

The major problems encountered in the investigation were: (1) the time lost during the early stages of the investigation because of the lack of familiarity with some of the state records, (2) the reconciliation of available data with the various systems of highway classification used by the Kentucky Highway Department and the Federal Highway Administration, (3) the volume of calculations necessary to modify the originally-collected data to suit the needs of the investigation, and (4) most important, the general difficulties presented in trying to resolve the varying scale problems associated with the county unit.

If the work were to be undertaken again, at least three changes would be considered:

1. The research would either (a) focus on a smaller scale, i.e., the highway segment and immediately adjacent environment, or else (b) retain the county unit but aggregate the counties into regional groupings such as climatic, landform regions, or urban and rural. These regions could be examined on a comparative basis and should be more amenable to the disclosure of additional accident related factors.

2. The use of accident rates would be considered instead of accident totals. Such substitution would certainly lower the explanatory power of the model, but might eliminate volume alone as the overwhelming contributor. This would permit attention to be focused on other contributing factors that may possibly be of more immediate practical value to highway safety personnel.

3. If accident rates were to be used--or even if the dependent variable remained unchanged--it might be advisable to increase the sample from three to five or more years. This would tend to smooth out inter-county variations that result from small samples. The sample increase, however, might present problems, for it would require greater effort to insure that the highway and environmental factors are held constant.

III. FUTURE RESEARCH

The results of the present investigation seem to indicate that little additional knowledge is likely to be gained from further accident research using aggregate data at the county level. However, the investigatory process did generate several ideas for research that may be worthy of future investigation:

1. It may be enlightening to consider the spatial behavior of specific types of accidents, such as single-vehicle, multi-vehicle, and, perhaps, pedestrian. The behavior of sub-classes of accidents may possibly exhibit differing patterns and characteristics. From such patterns additional hypotheses may be suggested that do not come to light when using aggregated accidents.

2. More specific work could be done on the effect of tourists or other visitors on accident rates. It would seem to be valuable to examine in detail the association between driver residence and accident site. Such an investigation might disclose interesting associations between accident location and driver unfamiliarity and fatigue.

3. Perhaps the most promising course of future accident research by geographers would be in the utilization of the vast amount of computerized information on precise accident location and road segment characteristics that is presently being compiled in Kentucky and is currently available in some other states. The information available will make it possible to locate accidents within a fraction of a mile and to examine such accidents with regard to a large number of variables such as place of residence, origin and destination, and other characteristics of the people involved at almost any desirable scale.

The positive effects of the research effort appear rather limited and perhaps incidental in nature. These effects include: (1) The research reaffirms the findings of other researchers on the important role played by traffic volume and freeways on differing accident rates. (2) A mathematical model is developed that may have use as a tool to (a) detect possible irregularities in county accident totals or rates that may lead to the focusing of attention toward remedial action, (b) serve as a yardstick for measuring progress in highway safety programs, (c) contribute, possibly, to safety improvement through the identification of qualities possessed by counties that consistently have fewer accidents than expected. (3) The county scale provides a finer pattern

of analysis than is permitted by working with state units, and it permits broad accident patterns to be quickly identified. (4) The analysis is reproducible for other regions, but the utility of adopting the research procedures appears limited. (5) A technique is introduced that provides the opportunity to allocate state-wide, total traffic volume to a county-unit basis, which may be useful in determining rates of exposure to accidents.

In conclusion, the time and effort involved in the study may well have exceeded the benefits derived. The results were generally, but not entirely, unsatisfactory, and were disappointing in that new, original insights into the fatal accident situation were not revealed. At the county scale and with the measure of total fatal accidents as the dependent variable, vehicle-miles accounts for most of the variation in accidents. At the county scale of analysis, new insights into accident causative factors do not appear promising. Further, too much effort went into the calculation of total vehicle-miles traveled. Any future studies using the county unit may well show that state-maintained roadway vehicle-miles or some other measure of exposure will provide an equally good, perhaps better, index of exposure to fatal accidents. Even if the general technique of modeling accidents for the county unit should be found to be useful for other states, use of the technique should await discovery of a more convenient method of calculation exposure to accidents.

To increase general geographic knowledge of the fatal accident situation, little would seem to be gained from working further with

total vehicle-miles and individual county units. If new hypotheses are to be forthcoming, they will more than likely be disclosed in situations where volume is held constant, where the orientation is toward the immediate highway environment, and where the accident region is micro rather than macro in scale.

BIBLIOGRAPHY

BIBLIOGRAPHY

Allardt, Erik. "Aggregate Analysis: The Problem of Its Informative Value," Quantitative Ecological Analysis in the Social Sciences. Cambridge, Massachusetts: The M. I. T. Press, 1969.

Allen, Terrence M. "A Factor Analysis of Accident Records," Highway Research Record, 79:17-25, 1965.

Allgaier, Earl and Kenneth Wood. "Predicting Traffic Death Rates," Highway Research Board Proceedings, 23:396-401, 1943.

Allgaier, Earl and Sam Yaksich. "Factors Related to Traffic Death Rates," Highway Research Board Bulletin, 142:19-28, 1956.

Annual Report: 1970-1971. Frankfort: Kentucky Department of Revenue, 1971.

Automotive Safety Foundation. Traffic Control and Roadway Elements: Their Relationship to Highway Safety-Revised. Parts 1-12. Washington: Automotive Safety Fouucation, 1968-1971.

Belmont, D. M. "Accidents Versus Width of Paved Shoulders on California Two-lane Tangents-1971 and 1952," Highway Research Board Bulletin, 117:1-16, 1956.

Billion, C. E. and W. R. Stohner. "A Detailed Study of Accidents As Related to Highway Shoulders in New York State," Highway Research Board Proceedings, pp. 497-508, 1957.

Blensly, R. C. and J. A. Head. "Statistical Determination of Effect of Paved Shoulder Width on Traffic Accident Frequency," Highway Research Board Bulletin, 240:1-23, 1960.

Brenner, Robert, Gary R. Fisher, and Walter W. Mosher, Jr. "Statistical Analysis of Accident Data as a Basis for Planning Selective Enforcement," Highway Research Record, 188:44-71, 1967.

Cirillo, Julie Anna, Stephen K. Dietz, and Richard L. Beatty. Analysis and Modeling of Relationships Between Accidents and the Geometric and Traffic Characteristics of the Interstate System. U. S. Bureau of Public Roads. Washington: Government Printing Office, 1969.

Dart, Olin K., Jr. and Lawrence Mann, Jr. "Relationships of Rural Highway Geometry to Accident Rates in Louisiana," Highway Research Record, 312:1-16, 1970.

Ewing, Frazier Stephen. "A Geographic Analysis of the Distribution and Pattern of Traffic Accidents in a Small City: Example, Hattiesburg, Mississippi, from July 1, 1969 to July 1, 1970." Doctoral dissertation, University of Southern Mississippi, Hattiesburg, 1971.

Federal Highway Administration, United States Department of Transportation. Fatal and Injury Accident Rates on Federal-and and Other Highway Systems: 1972. Washington: Government Printing Office, 1973.

Goldstein, L. G. and J. N. Mosel. "A Factor Study of Drivers' Attitudes, With a Further Study on Driver Aggression," Highway Research Board Bulletin, 172:9-29, 1958.

Haddon, William, Jr. and Edward A.Suchman, and David Klein. Accident Research: Methods and Approaches. New York: Harper and Row, 1964.

Kentucky Fatal Accident Facts: 1972. Frankfort, Kentucky: Bureau of Highways, Department of Transportation, 1973.

Kipp, O. L. "Minnesota Roadside Progress Report on Accident, Access Point and Advertising Sign Study in Minnesota," Highway Research Board Bulletin, 38:68-72, 1951.

Little, Arthur D., Inc. The State of the Art of Traffic Safety: A Comprehensive Review of Existing Information. Prepared for Automobile Manufacturers Association, Inc. New York: Praeger, 1970.

McDonald, John W. "Relation Between Number of Accidents and Traffic Volume at Divided Highway Intersections," Highway Research Board Bulletin, 74:7-17, 1953.

Miller, H. G. and J. Recht. "Rural Traffic and the Death Rate," Traffic Safety, 63:12-14, November, 1963.

Moellering, Harold. The Journey to Death: A Spatial Analysis of Fatal Traffic Crashes in Michigan, 1969. Michigan Geographical Publication No. 13. Ann Arbor: University of Michigan, 1974.

Moskowitz, Karl and W. E. Schaefer. "California Median Study: 1958," Highway Research Board Bulletin, 266:34-62, 1960.

Norden, Monroe and J. Orlansky and H. H. Jacobs. "Application of Statistical Quality Control Techniques to Analysis of Highway Accident Data," Highway Research Board Bulletin, 117:17-31, 1956.

Raff, M. S. "Interstate Highway Accident Study," Highway Research Board Bulletin, 74:18-45, 1953.

Recht, J. L. "How Effective Are Safety Activities?", Traffic Safety, Vol. 55, No. 5, May, 1966, pp. 12-13, 33.

Schoppert, D. W. "Predicting Traffic Accidents From Roadway Elements of Rural Two-Lane Highways with Gravel Shoulders," Highway Research Board Bulletin, 158:4-26, 1957.

Sparks, J. W. "The Influence of Highway Characteristics on Accident Rates," Public Works, Vol. 99, No. 3, March, 1968, pp. 101-103, 120.

Statistics Division, National Safety Council. Accident Facts. 1974 Edition. Chicago: National Safety Council, 1974.

Swanson, Clifford O. and A. R. Lauer. "Predicting Accident Trends and Traffic Improvement," Highway Research Board Bulletin, 161:48-54, 1957.

United States Bureau of the Census. Statistical Abstract of the United States: 1973. Washington: Government Printing Office, 1973.

United States Bureau of the Census. Census of Agriculture, 1969. Area Reports. Part 30: Kentucky. Section 2. County Data. Washington: Government Printing Office, 1969.

United States Bureau of the Census. Census of Population: 1970. Vol. I. Characteristics of the Population. Part 19, Kentucky. Washington: Government Printing Office, 1970.

Versace, J. "Factor Analysis of Roadway and Accident Data," Highway Research Board Bulletin, 240:24-32, 1960.

Wolfe, Roy I. "Contributions from Geography to Urban Transportation Research," Highway Research Board Bulletin, 326:46-68, 1962.

APPENDIX

APPENDIX

CALCULATION OF TOTAL COUNTY TRAFFIC VOLUME

Total traffic volume information is obtained by combining the state maintained road volume with the estimated volume for local roads and streets computed by the writer. The basic source of traffic flow information is the unpublished state inventory maintained by the Planning Division of the Department of Transportation entitled: "Annual State Mileage, Detailed Listing: January 1, 1971," which consists of a series of computer printout sheets covering all 120 counties. Each printout sheet contains fourteen categories of information, more information than could be advantageously used in this study. Numerically coded information contained on the sheets provides information such as: Average Daily Traffic (ADT), Daily Vehicle Miles (DVM), length of roadway segment, date of construction, pavement character, number of lanes, highway route number, urban or rural classification, and a variety of other statistics. The information, drawn from original construction contracts, is organized in terms of individual roadway segments of varying lengths, perhaps as short as one-tenth of a mile to twenty miles, or more. Thus, the obtaining of information on a single route in one county could involve the addition of as much as twenty or more different segments.

A second valuable unpublished record source maintained by the Planning Division used in determining volume is the record entitled "County Maintained Road System and City Maintained Street System:

January 1, 1971." This record is also compiled from computer printout sheets. The record provides detailed highway mileage for each road or street in the state regardless of whether it is state-maintained or local in nature. The information contained therein is classified according to two systems: rural or municipal and by functional type: Federal, state or local. This source provides the necessary local urban and rural road mileage data used in the calculation of local DVM.

A third useful source of information contributing to the calculation of volume is the "TA-1 Report" (Table TA-1--"Statewide mileage, travel, non-fatal and fatal injury accidents, 1970"). The report is prepared by the Planning Division and is submitted to the Federal Highway Administration in accordance with a predetermined FHA format. This report issued annually summarizes accident and volume characteristics according to the functional classification of roadways. This report is useful for two important reasons: (1) it sets up the basic parameters for establishing the estimate of local traffic volume in the individual counties and (2) its organization helps to clarify the Federal highway classification system.

Method for Deriving Total Volume of Traffic

The procedure for deriving the total daily and yearly volume of traffic on all county roads--whether part of the state-maintained system or not--is based on information contained in the unpublished state records or inventories mentioned above. The actual calculation of the total yearly volume of traffic for the state as a whole and

individually for each of the 120 counties was done in the following steps:

1. The daily summaries of Average Daily Traffic (ADT), i.e., the number of vehicles passing a specific highway point during a twenty-four hour period and Daily Vehicle Miles (DVM), i.e., the ADT multiplied by the total number of road miles, on state-maintained roads for each of the counties were taken directly from state records and recorded on a work sheet. Separate columns were used for rural volume, urban volume, and total volume.
2. The DVM of each county was multiplied by 365 to arrive at the Annual Vehicle Miles (AVM) for the rural, urban, and total categories for the entire 1970 year.
3. The AVM's for each county were summed and the total subtracted from the TA-1 Report figures that give the estimated "official" total yearly volume of traffic on all Kentucky roads. (The statewide AVM total is based on a nationally used formula that estimates vehicular mileage from statewide gasoline sales tax receipts.) The subtraction of state-maintained volume from estimated total volume--as determined by the state and shown on the TA Reports--leaves the remainder: yearly volume of traffic on non-state-maintained roads, i.e., local roads and streets.
4. Next, the AVM for local rural and local urban traffic was assigned on a county-unit basis by the following additional steps:

(A) Rural. The assignment of the local rural AVM is fairly time consuming, but still less troublesome than the urban assignment which follows.

(1) First, the assumption was made that there exists a determinable mathematical relationship between traffic on local rural roads and traffic on what is believed to be the nearest state equivalent, the non-Federal-aid roads classified on the "TA-sheets" as "other state roads." In this category "other state roads" there are contained certain road types that obviously are not suggestive of or analogous to local rural roads. Such roads include the Kentucky Toll roads and certain non-Federal-aid roads that are parts of the numbered Federal Primary highway system. These roads were deleted from the data.

(2) Next, the state mileage records were examined and the road mileage and daily vehicle miles were recorded for "other roads."

(3) From this information the ADT per mile of "other roads" was calculated for each county and for the state as a whole. (The state average daily volume = 360.34 vehicles for "other" roads.)

(4) Next, each county's ADT for "other roads" was divided by the statewide figure, 360.34, determined above, thereby resulting in a percentage figure that shows

mathematically the relative departure of the county--either plus or minus--from the state average. It was assumed at this point that a given county's traffic volume on "other state roads" is proportinate to traffic on local rural roads. Thus, for example, if a county has 75 percent of the state average ADT on its "other state roads" it should also have 75 percent of the statewide average local rural ADT.

(5) The calculated ADT per mile of local road, 95.92, was multiplied by the appropriate percentage referred to in Number 4 above for each county, thereby providing the estimate of the county average ADT per mile of local road.

(6) The mean ADT per county was multiplied by the local rural road mileage, resulting in an estimate total vehicle-miles per day for local rural roads for each county.

(7) The estimated DVM's per county were summed and compared with the local rural vehicle mileage that was calculated from the TA-sheet. The sum of the county estimates was about 3 percent higher than the TA-sheet derived traffic volume figure.

(8) A correction factor was calculated. The factor, .9739, was multiplied by the previously determined county

estimate of vehicle-miles. This procedure reconciled the estimated county figures with the state's total estimate of total local rural volume. The error, thereby, was proportionately distributed among the 120 counties.

(B) Urban. The local urban estimate was considerably more difficult to make than the preceding rural estimate. Originally, it was intended to follow essentially the same procedure as used with the rural traffic above, except that in place of "other state rural" and local rural roads, the categories of "other state municipal" and local municipal were to be substituted. This technique when used with municipal (urban) streets and roads resulted in nearly a thirty-two percent error on the high side in reconciling the calculated local urban volume with the TA-report local urban figures. As a consequence, this technique as far as the urban estimate is concerned, was abandoned.

The method finally used to estimate local urban DVM per county was to make a series of calculations based on information contained in a table in a 1968 Functional Classification Study done by the Urban Section of the Planning Division, Kentucky Department of Transportation, which shows road mileages and traffic volume estimates according to various road types for different sized urban places.

The table employs a 6 x 7 classification system. First, there are shown six functional classes of urban roads and streets. These are arranged in rows across the page: (1) Interstate, (2) Freeways and Expressways, (3) Other Principals, (4) Minor Arteries, (5) Collectors, and (6) Locals. Second, seven sub-classes of urban areas, contained under two major headings, form vertical columns. Under "Individual Urbanized Areas" are listed: (1) Louisville, (2) Covington-Newport, (3) Lexington, and (4) Ashland. Under "Small Urban Areas" are the following population group headings: (1) 5-10,000, (2) 10-25,000, (3) 25-50,000. With this information in hand, the following steps were performed:

(1) The mean ADT was calculated for each of the seven column headings.

(2) The mean ADT's for each column were observed to be distributed in a hierarchial arrangement (according to population) and ranged from ADT's of 3,486 for Louisville, the largest city, to 1,608 for the places in the 5-10,000 range.

(3) Since no estimate has been prepared by the state for urban places (Census definition) and municipalities under 5,000 population, no figures are available for calculating the ADT. It was, therefore, decided to arbitrarily assign an ADT value of 1,500 for places under 5,000 population.

(4) Using the estimate 1,500 ADT for small urban places (under 5,000) as a base, a ratio between the base ADT and the ADT's for each of the seven other population classes was calculated:

		Ratio
Louisville		2.324
Covington-Newport	2.209	
Lexington	2.101	2.155*
Ashland		1.492
Places 25-50,000		1.379
Places 10-25,000		1.178
Places 5-10,000		1.072
Other places		1.000

*Covington-Newport and Lexington combined into one figure for cities in 100,000-plus class.

(5) Based on U. S. Census (1970) information, each place in Kentucky, other than the specifically-identified cities shown above, were assigned to a population class contained among the last four listed above.

(6) The local urban or municipal road mileage for each of the places classified above was obtained and recorded in a format conforming to Number 5 above. (For example, Barren County has 12.30 miles of local urban streets in places less than 5,000 population and 15.42 miles in one settlement having between 10-25,000.)

(7) The total street mileage for each population class for the state was determined and recorded.

(8) The next step involved assigning the 6,260,127 vehicle-miles of local urban traffic for 1970, as determined by

subtraction from previous calculations, to each of the counties according to the number of street miles in each of the urban size categories.

(9) The following formula, using the mileage of each of the population classes and the ratio calculated in Step 4 above, was employed in arriving at the appropriate value for "x," the multiplier for places under 5,000:

$1329.47(x) + 479.91\ (1.072x) + 528.49\ (1.178x) +$
$235.11\ (1.379x) + 1,153.67\ (2.324x) + 151.63\ (2.155x)$
$+ 347.19\ (2.155x) + 161.11\ (1.492x) + 208.68\ (1.492x)$
$= 6,260,127.03$ annual vehicle-miles.

$\therefore 1,329.47x + 514.46352x + 622.56122x + 324.21669x$
$+ 2,681.12908x + 326.76265x + 748.19445x + 240.37612x$
$+ 311.35056x = 6,260,127.03$

$\therefore 7,098.52429x = 6,260,127.03$

$x = 881.89133$

(10) In making the final assignment of weights, Boone, Kenton and Campbell counties were assigned together as all three are a part of the Cincinnati SMSA and include Covington and Newport. Owensboro and Henderson, both part of SMSA's following the 1970 Census, were assigned the weighting for cities of 50,000 and up.

(11) The following weights were assigned:

County(s)	Weighting
Jefferson	2049.515450
Fayette, Boone, Kenton and Campbell	1900.475816
Boyd, Daviess, Henderson	1315.781864
Places 25-50,000	1216.128144
Places 10-25,000	1038.867986
Places 5-10,000	945.387505
Places under 5,000	881.891330

(12) The appropriate weighting for each population class road mileage for each county was multipled by the number of miles of street in each population class, thereby providing the daily vehicle mileage for local urban streets in each county.

5. The calculated local rural and local urban DVM's were then added to the previously-recorded state-maintained rural and urban totals. This results in a total DVM for the state that is in agreement with the "official" state VMT total shown on the TA-report. A second result is that a county by county estimate of total DVM is available. Thus, the important independent variable--total traffic volume--is available for inclusion in the model.

VITA

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He is married to the former Rebecca Kathleen Rumery of Knoxville, Tennessee. They have two children, Dawn Elizabeth and Shay Jackson.