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Environmental Justice Assessment for Transportation

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Abstract

Application of Executive Order 12898 to risk assessment of highway or rail transport of hazardous materials has proven difficult; the location and conditions affecting the propagation of a plume of hazardous material released in a potential accident are unknown, in general. Therefore, analyses have only been possible in geographically broad or approximate manner. The advent of geographic information systems and development of software enhancements at Sandia National Laboratories have made kilometer-by-kilometer analysis of populations tallied by U.S. Census Blocks along entire routes practicable. Tabulations of total, or racially/ethnically distinct, populations close to a route, its alternatives, or the broader surrounding area, can then be compared and differences evaluated statistically.

This paper presents methods of comparing populations and their racial/ethnic compositions using simple tabulations, histograms and Chi Squared tests [2] for statistical significance of differences found. Two examples of these methods are presented: comparison of two routes and comparison of a route with its surroundings.

Introduction

Executive Order 12898 requires that:

> "To the greatest extent practicable and permitted by law, and consistent with the principles set forth in the report on the National Performance Review, each Federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and lowincome populations in the United States and its territories and possessions, the District of Columbia, the Commonwealth of Puerto Rico, and the Commonwealth of the Mariana Islands."

For highway or rail transportation of hazardous materials, there is a distinction relative to issues connected with locating facilities at fixed sites: the highways or railways are in place and cannot be relocated. Therefore, all alternatives (except the no-action alternative) are between existing routes (predominantly on Interstate highways or mainline railways), and total avoidance of impacts on minorities or low-income population is generally impossible. Estimation of the potential radiological risks associated with highway transport of radioactive materials (RAM) with the RADTRAN computer code [1] requires input data describing the densities of populations within some distance (usually 0.8 km) of all portions of a candidate route (Proximate populations). Until recently, population-density data distinguishing minority and non-minority

populations near hundreds (or even thousands) of kilometers of potential routes were not available with adequate spatial resolution within acceptable cost.

With the advent of commercial geographic information systems (GISs) and databases describing highways, U.S. Census Blocks (identified here as "block(s)") and other information that is geographically distributed, it became feasible to determine and tabulate population characteristics along transportation routes with 1-kilometer resolution and to tabulate any population category included in the block data. A means of gathering the necessary population-density data along potential transportation routes, based on a commercial GIS, was developed recently at Sandia National Laboratories (SNL) which automatically compiles data on all block-population categories for routes hundreds of kilometers in length (on a kilometer-by-kilometer basis, if desired) in a few hours. Compilations of such data for two or more alternative routes may then be compared to each other or to the regions surrounding the routes.

Statistical Evaluation

In the absence of specific guidelines for assessing environmental justice issues related to transportation, we have developed a method based on the Chi Squared (χ^2) test for goodness of fit [2] that takes advantage of the new availability of pertinent population data describing transportation routes.

Population-density data compiled for any route and its alternates may be used to construct histograms and cumulative distributions describing the population densities of concern, e.g. ratios of "non-white" to "white" population density for each route. Since all U.S. Census block-data categories are equally available, each can be investigated separately, if desired. Also, similar cumulative distributions can be constructed for surrounding counties or other appropriate environs. With the χ^2 test, a route may be compared critically with alternate routes or with the population distribution of the region or regions through which the route passes. Comparisons of this type may prove more informative and acceptable than simple averages or ratios of aggregated data.

Sample Applications

Two sample analyses are presented to illustrate the comparisons possible with the methods described above. In the first two alternative routes through a congested area ("Silicon Valley") are compared, and in the second general surroundings of a route without immediate alternatives are compared to the immediate vicinity of the route.

Comparison of Two Routes

Two possible routes through a mixed industrial and residential area south of San Francisco, CA, in Santa Clara County were characterized and compared. The two routes (Interstate 280 and US101) are shown in Figure 1 together with the highlighted U.S. Census Blocks included in the analysis (Proximate populations). The racial/ethnic characteristics, as they are tabulated in the block data, of these populations are summarized in Table 1 (Note that the "white" population fraction is higher for I280). Figures 2 and 3 present histograms and cumulative distributions of

Table 1 – Comparison of US101 and I280 Proximate Populations

	TOTALPOP	WHITE	BLACK	AMERIND	ASIAN	OTHER	HISPANIC
I280	195464	130843	7011	1162	30937	25511	50789
Fraction of Total	1.00	0.67	0.04	0.01	0.16	0.13	0.26
US101	131252	77251	5852	890	25390	21869	42947
Fraction of Total	1.00	0.59	0.04	0.01	0.19	0.17	0.33

the ratios of "non-white" to "white" population for each kilometer of each route and Figure 4 offers a direct comparison of the two cumulative distributions. These histograms make the differences in proportion of minorities for each route very clear . The cumulative distributions are not as easily understood but are a convenient form for side-by-side comparison.

The statistical significance of the apparent differences between the proportions of the two populations along these two routes may be determined by means of a χ^2 evaluation of the goodness of fit between the two cumulative distributions in Figure 4. Calculation of χ^2 for these distributions is summarized in Table 2, which includes the intervals, counts and chi-squared values (the counts for I280 were scaled to have the same total as US101).

Table 2 – Chi-Squared Calculation for Distributions in Figure 4

Intervals	US101	I280	Chi Sq.
= 0	47	68	6.48
>0 - .05	15	37	13.36
>.05 - .1	47	56	1.53
>.1 - .15	43	95	28.25
>.15 - .2	67	98	9.55
>.2 - .25	61	77	3.50
>.25 - .3	58	68	1.47
>.3 - .35	38	41	0.18
>.35 - .4	50	32	9.67
>.4 - .45	43	26	10.79
>.45 - .5	65	25	66.83
>.5 - .55	49	21	36.56
>.55 - .6	47	15	67.86
>.6 - .65	28	11	28.63
>.65 - .7	28	19	4.33
>.7 - .75	15	16	0.02
>.75 - .8	9	7	0.80
>.8 - .85	8	4	2.81
>.85	7	9	0.65
Total Chi Sq			293.27

For 18 degrees of freedom, the value of χ^2 for a significance level of 5% obtained from a table [2, Table A.VII.2c] is 28.9. Since the calculated value of 293.3 is much larger, the two distributions clearly describe distinct populations. The differences in distribution of racial/ethnic group in

Table 1 were also found to be statistically significant by a χ^2 test: computed value was 5382 and the tabulated value for 5 degrees of freedom and a significance level of 5% is 11.1.

Comparison of a Route and Surroundings

Part of a standard, hypothetical truck route for spent nuclear fuel (SNF) was analyzed: over 400 km of I70 between St. Louis and Kansas City, Missouri. This route and the suburban loops (also Interstate Highways) at each end are shown in Figure 5. Summary information for each race/ethnic group tabulated in U.S. Census blocks for the 3734 blocks having some portion within 0.8 km of the route centerline (Proximate population) was compared to data for the 10 counties traversed by the route. Table 3 presents these two sets of data for a simple, numerical comparison.

Table 3 – Comparison of County and Proximate Population by Race/Ethnic Group

Counties Intersected by the Route								
No. of Blocks	COUNTY	Total Pop.	White	Black	Amer. Indian	Asian	Other	Hispanic
11696	189-St.Louis	993529	836232	139318	1477	14167	2335	9811
3654	183-St.Charles	212907	205424	4963	528	1431	561	2308
946	219-Warren	19534	18903	513	46	33	39	152
1378	139-Montgomery	11355	11015	289	12	20	19	45
1865	027-Callaway	32809	30937	1579	104	120	69	171
2531	019-Boone	112379	100055	8377	394	3129	424	1226
1003	053-Cooper	14835	13557	1147	55	47	29	96
1651	195-Saline	23523	21974	1352	45	61	91	208
2043	107-Lafayette	31107	29976	880	106	69	76	219
11696	095-Jackson	633232	478849	135649	3032	6446	9256	18890
	Total =	2085210	1746922	294067	5799	25523	12899	33126
	Fraction of Total =	1.0000	0.8378	0.1410	0.0028	0.0122	0.0062	0.0159
Summary of 3734 Blocks within 0.8 km of the Route								
	Total =	231000	213111	12866	587	3503	933	3046
	Fraction of Total =	1.0000	0.9226	0.0557	0.0025	0.0152	0.0040	0.0132
	Average Pop./Block =	61.86	57.07	3.45	0.16	0.94	0.25	0.82
	Std. Dev. of Pop./Block =	142.83	132.36	19.84	0.69	5.08	1.08	2.73
	Std. Dev. as Frac. of Total =	0.0006	0.0006	0.0015	0.0012	0.0014	0.0012	0.0009

As in the previous example, Figures 6 and 7 present histograms and cumulative distributions of the ratios of "non-white" to "white" population for each kilometer of the entire route and the ten Missouri counties traversed by the route. The two cumulative distributions are superimposed in Figure 8 for easier comparison; note that the county population is more heavily weighted toward larger minority fractions. To determine whether this difference in distributions is statistically significant, χ^2 was calculated. The intervals used, corresponding counts from each distribution, and χ^2 values are listed in Table 4 (the counts for County were scaled to have the same total as Proximate). For twelve degrees of freedom, the value of χ^2 for a significance level of 5% is 21.0.

Since the calculated value of 270.9 is, again, much larger, the two distributions describe distinct populations. Calculation of χ^2 for the racial/ethnic distributions in Table 3 yields a value

Table 4 – Chi-Squared Calculation for Distributions in Figure 8

Intervals	Proximate	County	Chi Sq
= 0	1465	1322	15.47
>0.00 - 0.05	453	382	13.20
>0.05 - 0.1	275	223	11.95
>0.10 - 0.15	148	119	7.29
>0.15 - 0.2	66	71	0.36
>0.20 - 0.25	49	52	0.16
>0.25 - 0.30	27	33	1.12
>0.30 - 0.35	20	29	3.04
>0.35 - 0.45	27	44	6.81
>0.45 - 0.55	25	36	3.23
>0.55 - 0.65	22	34	4.48
>0.65 - 0.80	15	44	19.22
>0.80	19	221	184.58
Total Chi Sq.			270.91

of 32525 (dominated by the difference in "Black" populations) and the tabulated value for a significance level of 5% is 11.1; clearly the distributions are distinct.

Conclusions

In the first example, Table 1 yields a mixed assessment of which route potentially imposes the smallest minority ("non-white") impact: I280 has the **smaller fraction** of minorities (1.0 – 0.67 = 0.33 versus 1.0 – 0.59 = 0.41) but a **larger number** of minorities (195464 – 130843 = 64621 versus 131252 – 77251 = 54001). However, the concern in addressing environmental justice (EO 12898) is "disproportionately high" impacts on minorities, which suggests the fractional comparison is preferable.

Figures 2-4 graphically indicate that a relatively greater fraction of minority persons will be impacted by use of US101 than I280 , i.e., the frequencies of larger minority fractions are greater in Figure 2 and the cumulative distribution for US101 does not rise to 1.0 as quickly in Figure 4.

In the second example, impacts to minority groups do ***not*** appear to be disproportionate; this is evident from the larger "White" fraction of the total for the Proximate population than for the County population. The single group which would appear to bear disproportionate impacts is the "Asian" population which constitutes 1.52% of the Proximate population compared to 1.22% of the County population. If it were desirable to investigate impacts to such sub-groups of the total minority population, similar data could be tabulated, using the GIS, on a county-by-county basis rather than limiting analysis to the aggregated data shown in Table 2.

For this case, comparison of total numbers of persons is obviously inappropriate since the total population (or any of its racial/ethnic components) of a county is very unlikely to be less than that of a narrow strip along an Interstate highway.

While specific cases may lead to some disagreement regarding what constitutes disproportionate impact, we conclude that for transportation scenarios, comparison of two alternative routes (on a fractional or total numbers basis) is appropriate and fully achievable with the tools demonstrated by the first example. For situations in which an immediate alternative route is not available, the second example demonstrates that a similarly instructive analysis is possible with these same tools. Either approach offers a quantitative (and a simpler graphic) comparison of the differences in potential impacts on minorities from shipments of hazardous materials along existing transportation routes.

References

1. Neuhauser, K. S., and Kanipe, F. L., "RADTRAN 4 - Vol. 3: User Guide," SAND89-2370, Sandia National Laboratories, Albuquerque, NM (1992).
2. Meyer, Stuart L., Data Analysis for Scientists and Engineers, John Wiley & Sons (1975).

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Figure 1 – Map of Analyzed Portions of I280 and US101 in Santa Clara County, CA

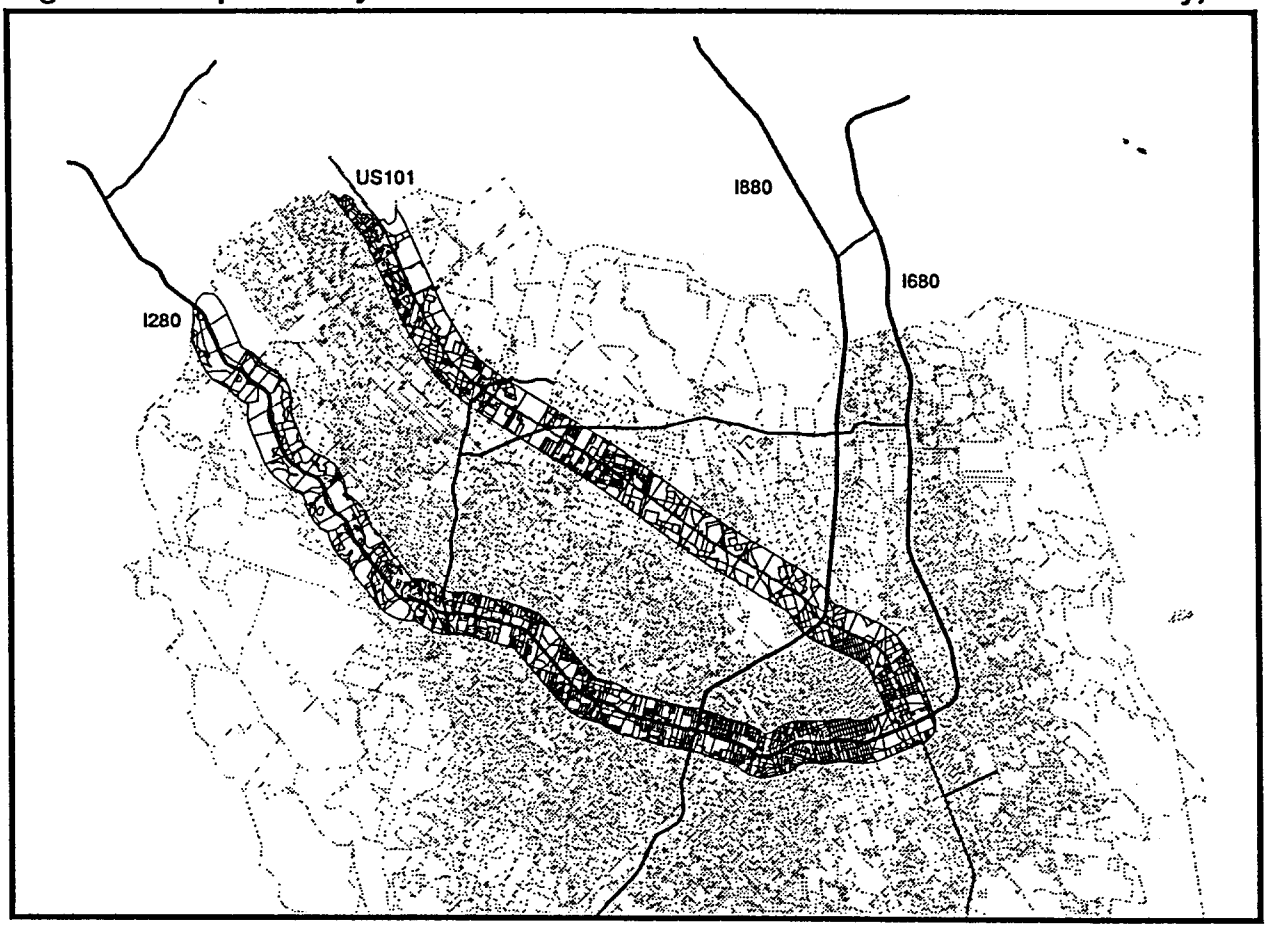

Figure 2 – Histogram and Cumulative Distribution of Ratios for the US101 Proximate Population

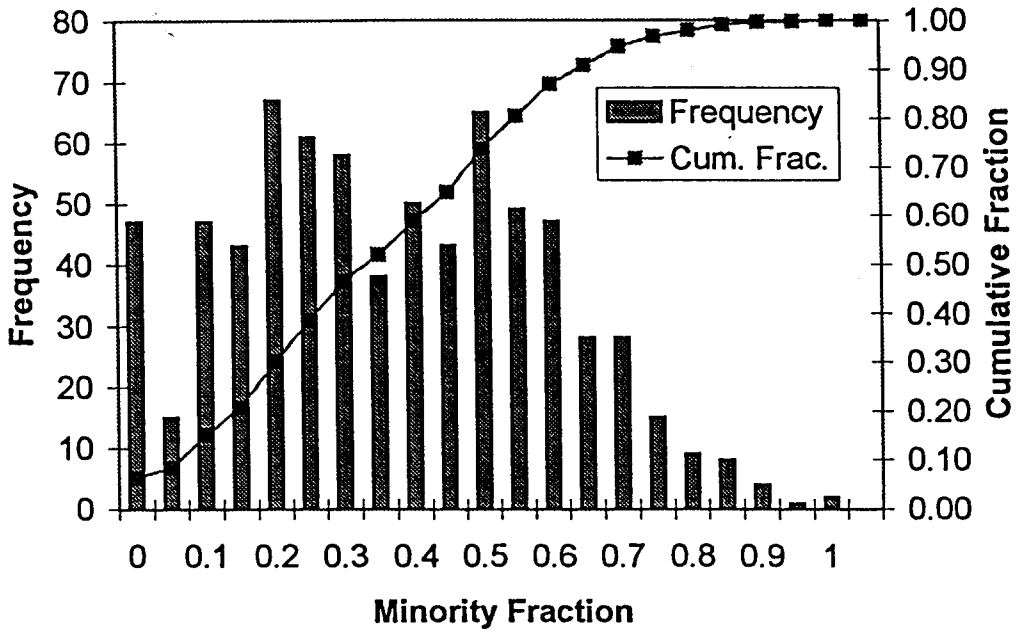

Figure 3 – Histogram and Cumulative Distribution of Ratios for the I280 Proximate Population

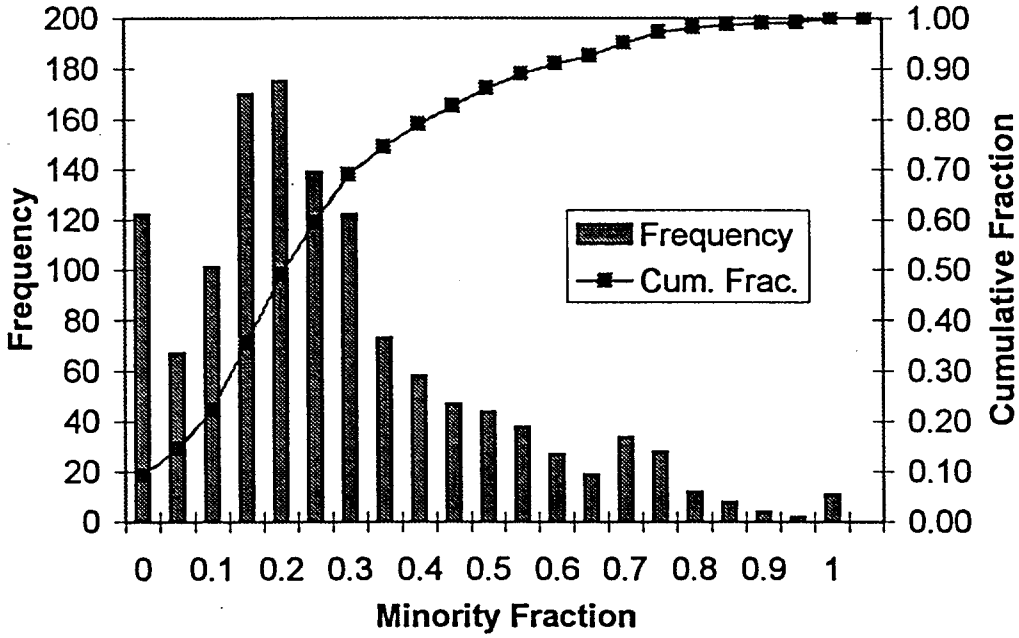

Figure 4 – Comparison of Cumulative Distributions for US101 and I280 Populations

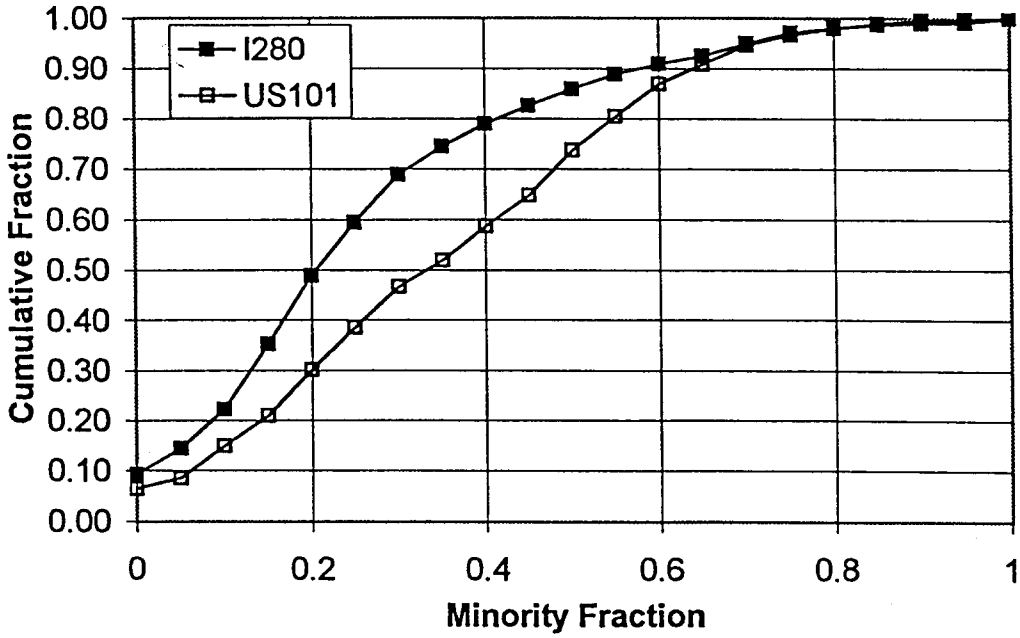

Figure 5 – Map of Test Route Across Missouri

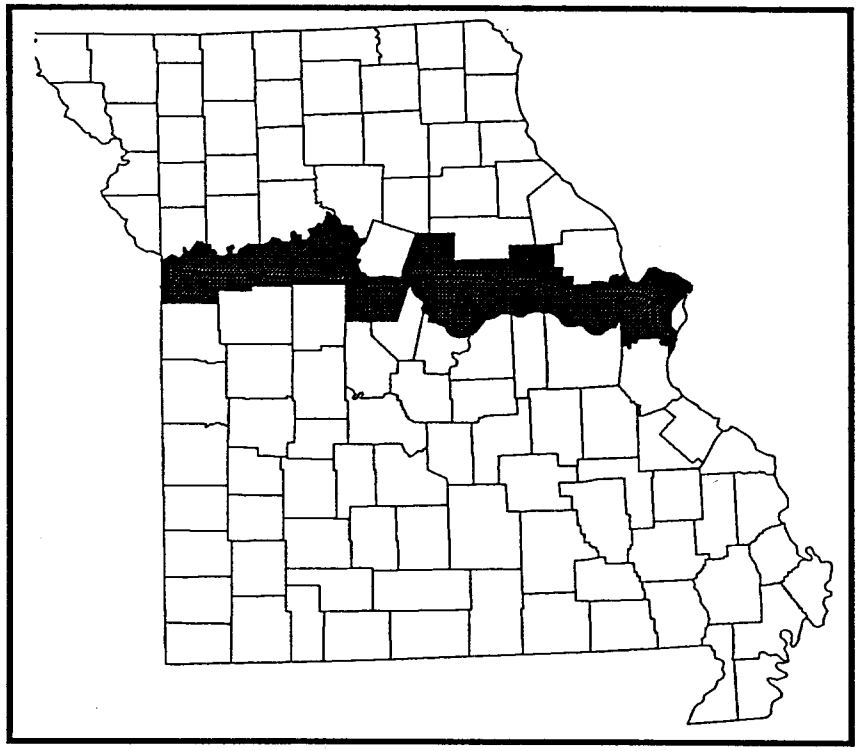

Figure 6 – Histogram and Cumulative Distribution of Ratios for the Proximate Population

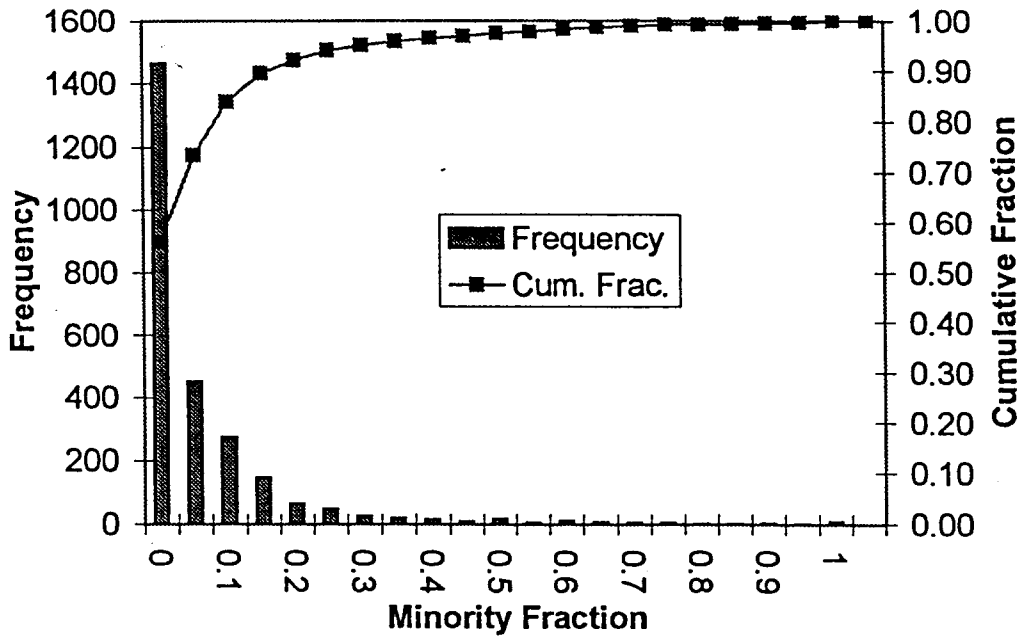

Figure 7 – Histogram and Cumulative Distribution of Ratios for the County Populations

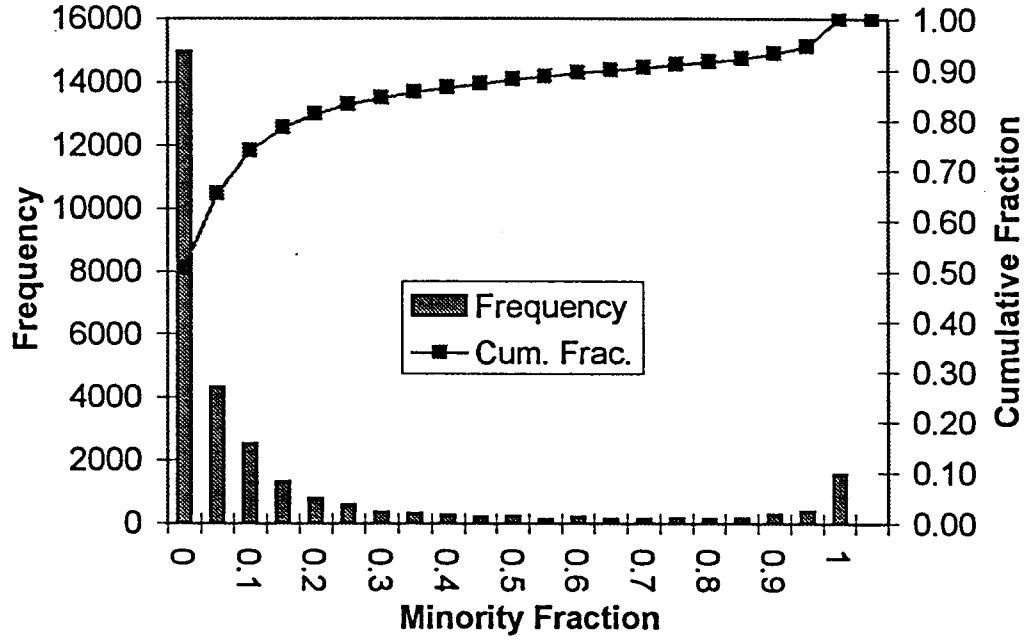

Figure 8 – Comparison of Cumulative Distributions for Proximate and County Populations