1995

RACE AND ENVIRONMENTAL EQUITYA GIS BASED SPATIAL ANALYSIS OF PROVIDENCE, RHODE ISLAND

Sangeeta Jain
University of Rhode Island

RACE AND ENVIRONMENTAL EQUITY - A GIS BASED SPATIAL ANALYSIS OF PROVIDENCE, RHODE ISLAND

BY

SANGEETA JAIN

A RESEARCH PROJECT SUBMITTED IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF
COMMUNITY PLANNING

UNIVERSITY OF RHODE ISLAND

1995

MASTER OF COMMUNITY PLANNING

RESEARCH PROJECT

OF

SANGEETA JAIN

Approved:

Major Professor

Farhad Atash

Dr. Farhad Atash

Acknowledged:

Director

Marcia Marker Feld

Dr. Marcia Marker Feld

Acknowledgments

This study owes its genesis to my exposure to the world of Geographic Information Systems (GIS) during the past one year. I would like to thank several people for their help in this research project.

First of all I would like to thank Dr. Farhad Atash for his encouragement and timely comments on the "just-in time" drafts. I would also like to thank Maia Peck, for her sincere prodding and help with conceptual and technical GIS issues from time to time. Dr. Marcia Feld, as my second outside reader, was also a source of encouragement and deserves my thanks.

Clint Webb, at Vannasse Hangen and Brustlin, deserves my special thanks for his cooperation and understanding on the days I would vanish from work and pursue completion of my thesis instead.

Finally, I would like to dedicate this study to my family: my children Selina and Kabir and my husband Kapil for the many nights when I was around but not really around and yet they accepted it.

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CHAPTER 1: INTRODUCTION

Environmental equity has recently emerged as an important issue both in the media and within the Federal government. The issue of environmental equity refers to whether people bear the burden of our technological advances -- environmental pollution -- evenly across society. In particular, the issue addresses whether or not racial minority and low-income communities bear a disproportionate share of exposure to pollution and environmental risk.

PROBLEM STATEMENT

The environmental movement and the civil rights/ anti-discrimination movements both began contemporaneously in the 1960s. Each, in its own way, has since made measurable strides with tangible results in both public awareness and legislation. However, the question of social equity and distribution in clean-environment efforts is still significant. Recent studies strongly suggest the presence of a disproportionate exposure of minorities to environmental hazards through their proximity to waste dumps, landfills, and commercial toxic releases. This project seeks to expand on this growing literature by using GIS, a relatively new and powerful methodology, to study the extent of environmental equity with respect to race and income in Providence, Rhode Island.

Providence provides an interesting case study from many perspectives. An urban area in the New York - Boston corridor, it has a history of high industrial activity. In addition, it is presently experiencing a rise in its proportion of minority residents, largely through

immigration. The geo-demographic composition of Providence offers a rich distribution of socio-economic strata that, coupled with a large number of toxic waste sites, offers a suitable site for studying the question of environmental equity.

Previous studies of environmental equity have included both bivariate and multivariate analyses. However, the use of Geographic Information Systems (GIS), in this study, will provide the opportunity for a more accurate look at the impact of environmental hazardous sites on populations within their "domain of influence (DOI)" rather than on just census defined geographic bounds.

STUDY OBJECTIVES

This study has two main objectives:

1) - to determine the extent of environmental inequity in the city of Providence and to provide a measure of the hazardous exposure to various socio-economic strata.

- to study whether inequity, if present, is related to race.

2) - to compare the results of analysis, based on (a) the traditional approach using census block groups as the unit of analysis, with (b) the GIS based approach using the "domains of influence" of each toxic release site as the unit of analysis.

STUDY SIGNIFICANCE

Ever since a report, produced by the US General Accounting Office (US General Accounting Office, 1983), found that three of the four landfills in the Southeast (that were studied) were located in predominantly poor and African-American communities, a variety of other reports have documented wide-spread environmental inequity. "Toxic Wastes and Race in the United States" (United Church of Christ Commission for racial Justice, 1987), another prominent report, found that minorities, mainly African and Hispanic Americans, are strikingly over represented in communities with commercial hazardous waste facilities. The study found that more than fifteen million African Americans and eight million Hispanic Americans lived in communities with one or more hazardous waste sites. The disproportionate impact on minority racial communities were also found for uncontrolled toxic waste sites.

Providence has a large and growing minority population consisting of African Americans, Hispanics, and Asian immigrants. In this respect, if national trends hold true, one should expect to find evidence of environmental inequity in Providence as well. Further, previous studies support a linkage between environmental hazard exposure and the community's economic state. Poorer communities cannot afford the luxury of being concerned about the state of their environment when confronted by basic survival-related economic problems. They are more likely to accept the trade-off in return for employment and economic development with or without the knowledge of associated risks. Such a trade-off clearly carries longer-term risks whose costs, in fact, must often be borne by the larger community, both the minority and the majority.

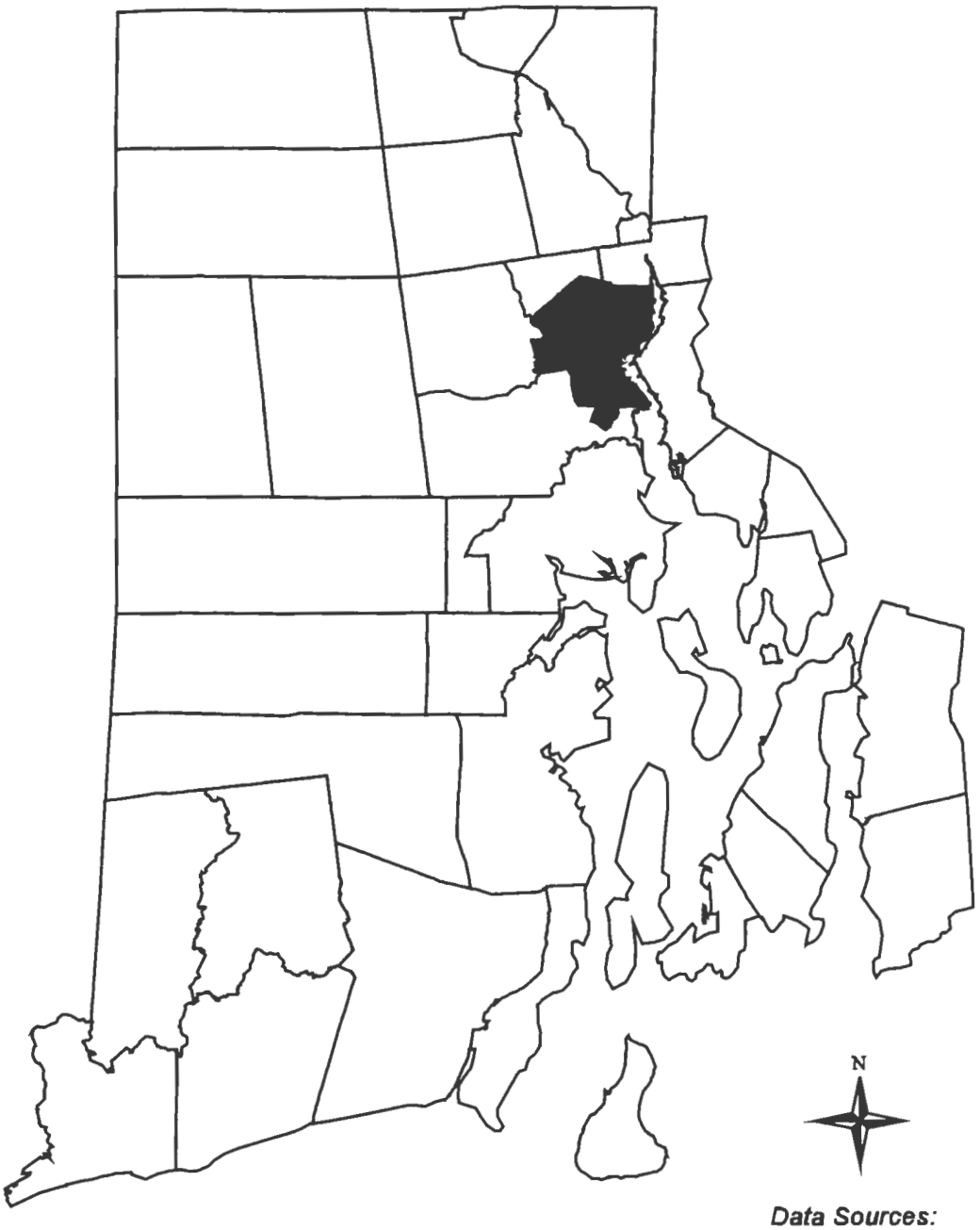
Identifying and eradicating such discrimination is clearly in the interests of the public and should be a public policy imperative. This study will yield not only a measure but also a graphic representation of the environmental inequity, if any, in Providence. Such data should serve public policy makers well, in their efforts to make Providence equally hospitable to all residents.

STUDY AREA DESCRIPTION

Providence is a city made up of physically, economically, and socially diverse neighborhoods. It was developed near a natural harbor by its early settlers, in the 17th century, to establish a coastal trading route. The city kept gaining economic significance, and by the turn of the 20th century it had become the economic center of the most industrialized state in the nation. The rich history of about 200 years has contributed to a mix of architectural forms, economic functions, and social groups, characterizing the city today. Figure 1 shows the location of Providence within the State of Rhode Island.

The city of Providence reached its peak population of 253,504 in 1940. Since then, the population has been declining and reached its lowest level of 156,804, in 1980. This major loss, occurred partly due to the suburbanisation taking place across the nation. The 1990 census, however, recorded a minor increase in the population of Providence at 160,199. The median age increased from 29.9 years in 1980 to 33.8 years in 1990. In 1980, about 19 percent of the population was classified as non white, whereas this

Study Area - Providence, RI



City of Providence
Town Boundaries

0 10 20 Kilometers

Data Sources:
RIGIS

Map produced by
Sangeeta Jain
CPAD, URI (1995)

Figure # 1

figure was 23 percent in 1990. The rapid growth of the non-white population was primarily caused by an increase in the numbers of migrant Southeast-Asians.

GEOGRAPHIC INFORMATION SYSTEMS (GIS)

Geographic information system are being used for a variety of applications. It has made valuable contributions to the understanding and solution of key socio-economic and environmental problems. It allows us to access data based on geographical locations. GIS could be best described as a database system that allows the manipulation and analysis of geographic data. It is a collection of computer hardware and software that integrates computer graphics with a relational database, for the purposes of managing data about geographic locations (Garson, 1992).

GIS comprises of three distinct but overlapping views -- maps, database, and spatial analysis (Maguire: 1991). The map view focuses on the cartographic aspects of GIS, and could be seen as map processing . The second view emphasizes the importance of a well designed and implemented database that allows for complex analytical operations. The third view, emphasizes the importance of spatial analysis.

REPORT OUTLINE

The rest of this report is arranged in chapters that flow logically beginning with a discussion of previous efforts in this area, followed by the hypotheses and methodology for this study and, finally, the results and conclusions from the empirical analysis.

Chapter 2: Environmental Equity - A Review

This chapter will provide a review of past research on environmental equity, summarizing the contexts studied, methods employed, and findings. Also discussed will be the role of government in both, initiating such studies and incorporating research findings into legislation, and in hazardous site location decisions.

Chapter 3: Hypotheses and Methodology

This chapter will provide a detailed description of the hypothesis and assumptions used in this study. It will also provide a discussion of data sources and accuracy issues, details on the operationalization of variables, and a description of the analytical methods applied.

Chapter 4: Analysis and Results

This chapter will include a detailed analysis of the results of the study. The first part includes a descriptive analysis of all the key variables at the block group level. The second part analyzes and compares the relationship between racial composition and

hazardous exposure with the census block groups and DOIs as alternative units of analysis.

Chapter 5: Discussion and Conclusions

This chapter will continue discussion of the results in light of the findings made by previous research, and derive implications for public policy and land-use decisions in Providence. It will conclude with a discussion of this study's limitations and recommendations for future research.

CHAPTER 2: ENVIRONMENTAL EQUITY -- A REVIEW

Evidence of environmental inequity comes from various studies, that show how hazardous waste sites have been located in communities with higher proportions of disadvantaged (in terms of race/income) population groups. This chapter includes a review of literature on environmental inequity and various federal and state initiatives to address this particular problem.

The term 'environmental inequity' refers to the uneven distribution of any known or potential environmental risks, across different demographic groups. When environmental risks are higher in residential areas with higher proportions of minority populations, the inequity is referred to as 'environmental racism'. Another commonly used term- 'environmental justice' -refers to a political movement aimed at achieving environmental equity (Burke 1993).

MAJOR PREVIOUS STUDIES

The awareness and concern about inequity in the distribution of hazardous waste sites have been increasing steadily in the past decade. The first event to focus the nation's attention on the issue of environmental injustice occurred in Warren County, North Carolina incident, in 1982. Residents of Warren County, dominated by African-Americans, protested for four years against the siting of a polychlorinated biphenyl

(PCB) landfill (Lee 1990). The campaign was unsuccessful in preventing the siting of the unwanted landfill, but was successful in many other ways. The most important outcome was that it lead to a further investigation of racial demographics and hazardous site locations.

GAO Study

The first major study of the relationship between community demographics ant the siting of toxic waste was conducted by the US Government's General Accounting Office. The objective of this study was to determine the correlation between the location of hazardous waste landfills and the racial and economic status of the surrounding communities (GAO 1983). The GAO report found that three out of the four hazardous waste landfills in the Southeast part of the country (EPA's Region IV - Alabama, Florida, Georgia, Kentucky, Mississippi, North Carolina, South Carolina, and Tennessee) were located in black dominated communities. The percentage of black population in the region was about 20, but for the communities with the landfills, the corresponding percentages ranged from 38 to 90 percent.

The GAO study was limited in scope, in as much it researched only four landfills in one region of the nation. It was not designed to study the relationship between the location of hazardous waste sites and the socio-economic status of the people residing around those sites, throughout the United States (Lee 1990). Since the GAO report was the first study of its kind, it could not be an indication of any national pattern. Nonetheless, it served a critical purpose in initiating more systematic inquiries into environmental inequity.

United Church of Christ Report

The next major study "Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities Surrounding Hazardous Waste Sites" was published by the United Church of Christ Commission (UCCC) for Racial Justice (UCCC 1987). This study, released in 1987, was the first comprehensive, national-level study, to document the location of hazardous waste sites in racial and ethnic communities. This report was very influential in raising public awareness about the disproportionate burden of pollution on minority population groups.

The report, a culmination of over five years of work, found that the racial composition was the single most important variable in explaining the presence of commercial hazardous waste facilities in any community. The UCCC report comprised of two studies - the first analyzed the relationship between demographic patterns and "commercial hazardous waste" sites, and the second study studied the relationships between the demographic patterns and "uncontrolled toxic waste" sites. Commercial hazardous waste sites are facilities that accept hazardous wastes from a third party for a fee, while uncontrolled toxic waste sites are those that have been closed and abandoned by US Environmental Protection Agency (EPA).

The first study, focusing on commercial hazardous waste sites, used five digit zip code level demographic data as its unit of analysis. The locational data, on the then operating hazardous waste sites, were collected from the EPA's 1986 Hazardous Waste Data Management System. The study tested five variables - minority percentage of the

population, mean household income, mean value of owner-occupied homes, number of uncontrolled toxic waste sites per 1,000 persons, and pounds of hazardous waste generated per person.

The major findings of the first study were the uncovering of a consistent national pattern in the location of hazardous waste sites. The pattern consisted of:

- Race proved to be the most significant variable in location of hazardous waste facilities,
- Although socio-economic status appeared to play an important role, race proved to be more significant, and
- Communities with a higher percentage of minorities had a greater number of commercial hazardous waste facilities (UCCC 1987).

The second study in the report, focused on the communities surrounding the over 18,000 uncontrolled toxic waste sites from the EPA's Comprehensive Environmental Response, Compensation, and Liability Act Information System (CERCLIS). This study was aimed at quantifying the number of persons from different racial and ethnic groups, living in communities with uncontrolled toxic waste sites.

The findings of the second study in reported alarming statistics:

- Three out of five African Americans live in communities with abandoned toxic waste sites,
- Minorities comprised 24 percent of the total population in communities with one hazardous facility, compared to only 12 percent in communities with no toxic facility,

- Three of the five largest commercial hazardous waste landfills are located in predominantly African-American or Latino communities, and account for 40 percent of the nation's total estimated landfill capacity in 1986, and
- African Americans are heavily over-represented in the population of cities with the largest number of abandoned toxic waste sites.

Mohai and Bryant Study

Another prominent empirical study was conducted by Mohai and Bryant in 1992 to provide additional evidence on the issue of environmental equity (Mohai & Bryant 1992). The main objective of the study was to assess the effect of race on the distribution of commercial hazardous waste sites. They used a sample survey to collect data on race and income from the residents of three counties surrounding the city of Detroit area. The locations of 16 hazardous waste facilities and the 289 respondents were mapped and distances between the two were measured to the nearest tenth of a mile.

The study found that in the Detroit area, 48 percent of the minorities sampled lived within a mile of a hazardous waste site. As the distance increased to a mile and a half, the ratio dropped to 18 percent. The study also found that the relationship between race and location of hazardous waste sites is independent of income. However, when the data were analyzed for the entire population of three counties. The results showed that on average 4 percent of the population live within a mile of a hazardous site, and the number is 11 percent for blacks and 3 percent for all whites.

Burke's Study of Los Angeles County

Burke conducted a case study to examine environmental equity in Los Angeles County, California (Burke 1993). The objective of the study was to determine whether minorities suffer a greater degree of environmental pollution. Data was collected for more than 700 toxic release sites (TRI) in the county. The socio-economic data collected at the census tract level included median per capita income, population density, and the racial composition of the population.

The results of the study indicated that on average the number of toxic waste sites increases with the increase in minority population or a decrease in per capita income. The study treated all toxic waste sites as uniform, and census tracts were used as the unit of analysis.

Other Case Studies

Numerous other studies have been done that show evidence of environmental racism. In 1979, a major empirical study was conducted that linked municipal solid waste siting with the race of adjacent area residents in the city of Houston, Texas. The study reported that until the 1970s, all the publicly owned landfills and six out of eight garbage incinerators were located in African American neighborhoods (Bullard 1992). From 1970 to 1978, three of the four privately owned landfills were located in African American neighborhoods. Although the population of African American neighborhoods made up of 28 percent of total population, 82 percent of total solid waste sites were located in the neighborhoods dominated by them.

In 1992, the National Law Journal (NLJ) published results of an analysis of environmental lawsuits. The NLJ conducted a study of all suits held in the previous seven years in the United States. The major finding of the study was that the penalties imposed for environmental law violations in areas inhabited by people of color, whether they are rich or poor, are lower than those imposed for violations in areas largely inhabited by White. The average penalties were six times more in White dominated areas ($336,000 versus $55,000) than African American dominated areas, under the Resource Conservation & Recovery Act's hazardous waste law enforcement (Lavalle & Coyle 1991).

ENVIRONMENTAL EQUITY - GOVERNMENT INITIATIVES

EPA's Position

The EPA set up the Environmental Equity Workgroup to assess the available evidence on whether the disadvantaged population groups bear a higher environmental burden than the general population. The group released its report, Environmental Equity - Reducing Risk for all Communities in 1992. The report reviewed existing data on the distribution of environmental exposures and risks across population groups (Reilly 1992).

- The workgroup's report provides a cautious, conservative balance to the more assured conclusions of discrimination provided by many other studies. Some of the major findings of the study included :
- Although there are clear differences between racial groups in terms of disease and death rates, there is an absence of data to document the environmental contribution to these differences.
- It is possible to document differences in observed and potential exposure to some environmental pollutants by socio-economic factors and race.
- There is a lack of data on health risks posed by multiple industrial facilities, cumulative and synergistic effects, and multiple paths of exposure.

EPA's stand on the issue can be summed up as follows "... Racial minority and low-income populations experience higher than average exposures to selected air pollutants, hazardous waste facilities, contaminated fish, and agricultural pesticides in the work place. Exposure does not always result in immediate or acute health effects. High exposure and the possibility of chronic effects, are nevertheless a clear cause for health concerns." (Burke 1993)

Federal Policies

Until very recently, there were no government procedures established to address the environmental equity issue. At best, Resource Conservation and Recovery Act of 1976, (RCRA) creates comprehensive federal guidelines for the production, management, transport, treatment or any other kind of hazardous materials handling. This is a very

basic procedure, leaving states with broad guidelines from EPA and RCRA to handle hazardous waste issues (Godsil 1992).

A major achievement at the federal level was the Presidential Order in 1994. President Clinton signed an Executive Order - Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations, in 1994, emphasizing protection of disadvantaged population groups. The Order directly addresses the issue of environmental justice:

"....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 health of its programs, policies, and activities on minority populations in the United States..." (Executive Order 12898 of February 11, 1994).

State Initiatives

The strength of public opposition is the major obstacle faced by the states attempting to evenly distribute the burden of hazardous waste facilities. The Not In My Back Yard (NIMBY) syndrome is one of the important reasons that minorities are disproportionately burdened by hazardous waste facilities. Many states have set up hazardous waste management programs to bypass any local opposition that may arise (Godsil 1991).

There are four general approaches that states take to address the location of any type of hazardous sites - super review, site designation, local control, and incentives approach. As per the super review process, the developer chooses a site and applies

for a permit. The states will typically look for natural resources or constraints, like topography, geology, soils among others around the area for environmental compatibility. The states focus only on the site chosen by the developer. Since the developer chooses a site, it often tends to be in an area with lower land values and that is inhabited by the poor.

Under the second approach, some states create an inventory of possible sites that could be used for locating such sites. Since the state is not motivated by the profit motive, the possibility of siting these sites in poor neighborhoods is less likely. However, there are two syndromes that limit the ability of this approach to address equity issues - "Not In My Term Of Office" (NIMTOF) and "Not In My Election Year" (NIMEY) (Godsil 1992). Therefore, a community least able to sustain the NIMBY syndrome, usually a poor and minority community, becomes a host to the site.

The local control approach permits local communities to develop regulations that control the siting of hazardous waste sites and these regulations cannot be preempted by state regulations. California and Florida are the only two states currently practicing this approach. The state thus delegates responsibility for waste site location to the local communities. As a result, the NIMBY syndrome actually gets accentuated. To counter this, states have to offer incentives to communities.

The incentives control approach, essentially rests on the belief that hazardous waste sites cause an undue burden on neighboring communities while the rest of the state enjoys the benefits. Hence, cooperating communities should be offered economic

incentives. Economic incentives are clearly more desirable to poorer communities which, in turn, are often minority communities. Minority communities, hence, become more susceptible to the location of hazardous waste sites. Therefore, current state hazardous waste management programs do not adequately address the equity issue.

CONCLUSION

The studies described above were performed at differing scales (ZIP code, county, census tract, etc.), used a wide range of analytical methods (correlational, regression, LOGIT models, etc.), and examined a variety of types of hazardous sites (commercial, uncontrolled, landfills, etc.). Together, these studies and reports provide significant evidence of environmental inequity.

This project will focus on the extent of environmental inequity in Providence, Rhode Island.

CHAPTER 3: HYPOTHESIS AND METHODOLOGY

This chapter provides a description of the study hypotheses and the methodologies employed to test them. It begins with a description of the study hypothesis and assumptions, discussion of data sources, variables used in the analysis, and description of the analytical methods applied.

STUDY HYPOTHESIS

The relationship between race and hazardous exposure can be modeled from at least two perspectives. The economic perspective can be used to understand locations of hazardous sites from a cost-benefit trade-off by the concerned parties. From a slightly different perspective, although not mutually exclusive, location of such sites can also be modeled on the basis of the political unity and action-orientation of the residents of affected areas.

Classic economic theory would predict that poverty plays a role. The economically disadvantaged people disproportionately suffer a greater share of pollution than those better-off economically. Since poorer people have lesser economic resources, they have more limited choices regarding places to live in. Given limited monetary resources, one might choose to better one's self in a multitude of ways including better housing, better education, healthier environments, or even more consumer goods. How

a particular person chooses to use his/her buying power is not the issue. Rather, the fact remains that greater buying power affords one a greater set of choices for all purchases, including the choice of where to live. The poorer one is, the less choice one has regarding where to live. Hence, a fundamental assumption of this perspective is that money offers choice. A corollary of this is that wealthier people tend to live in cleaner neighborhoods.

Over and above the set of feasible choices is the issue of trade-offs one makes in spending one's buying power. It is certainly possible to maximize on the cleanliness of one's living environment while sacrificing other benefits, say consumer goods, within one's budget constraints. However, poorer people generally can not afford the luxury of being concerned about the state of their environment when confronted by basic survival-related economic problems and are more likely to accept a trade-off for an uncleaner living environment in return for employment and/ or cheaper housing. In fact, the criteria used in judging the relative merits of choice options may also differ substantially among poorer and wealthier communities. Poorer communities may be less knowledgeable of the implications of the various choice options. Additionally, when survival is a salient issue, long-term implications of choices may appear totally irrelevant.

Minorities are typically more economically disadvantaged than Whites for a myriad of reasons. These often include being new arrivals to an area, language differences, educational disadvantages, and the restructuring and suburbanization of industry (Eggers & Massy, 1992). Being more economically disadvantaged, minorities face a narrower set of choices of places to live in and are more limited to lower-cost housing.

Land values are also cheaper in polluted neighborhoods and, hence, minorities tend to live in neighborhoods that are polluted by hazardous waste sites.

The locations of industrial facilities in a landscape are the result of a complex set of physical, economic, and political factors working together, in addition to an element of chance. The location of transportation corridors and waterways; zoning regulations; local taxes; property values; land availability; and proximity to a market, labor force and input resources are among the plethora of factors that affect where a facility might be located.

Due in part to industrial zoning, industries are often located in the less densely populated parts of an urban landscape, and often along transportation arteries. Residential property values are typically lower near industrial areas than in areas without industry (Asabere & Huffman, 1991). For this reason, low income communities could develop in and around industrial areas, as the industry offers the dubious appeal of making the area a less desirable place to live and lowering property values and rents. This premise, that areas with polluting industries tend to be less expensive places to live accounts for the potential circumstance of people with low incomes choosing to live in areas with industrial facilities.

The political-clout perspective is much more appropriate in cases involving the siting of new facilities. As mentioned previously, many factors affect locational choice. But, as environmental awareness has increased over the last twenty years, so has community resistance to the siting of new potentially polluting facilities such as the NIMBY

phenomenon. NIMBY (Not In My Back Yard) implies an acceptance of the need for the given facility, as long as it is sited outside of the relevant area or "backyard" of those resisting the facility. (This differs from the more ideological "Not In Anybody's Back Yard" which encourages fundamental changes in industry and waste management, thereby eliminating the need for some facilities.) If a facility is perceived as undesirable, there is the chance that there will be resistance to its siting. Facility siting often follows the path of least resistance, coupled with considerations of minimizing costs and maximizing profits. The path of least resistance could include targeting areas where people are not politically active or well connected, have not indicated tendencies toward environmental activism, or perhaps do not have English as their first language (Dear, 1992). All other things being equal, the siting of facilities which are perceived as undesirable often follows the path of least resistance. Minorities, in general, tend to be less politically active and are therefore much more vulnerable to new hazardous facilities being located in their backyards.

The two perspectives discussed above suggest different causal orders. The economic approach, by itself, does not distinguish between the situation wherein a poorer resident chooses to locate himself/herself in the proximity of an existing hazardous facility and the situation wherein a poorer resident chooses to accept a new facility in his/her backyard. The political perspective, on the other hand, focuses on the acceptance of new facilities only. Distinguishing between these two models would require longitudinal data that permits one to test the implied causality.

In this study, the objective is not to test the appropriateness of a process model that would explain the relationship between race and hazardous exposure. Rather, the objective is simply to determine whether race is a significant factor in the relationship with environmental pollution when the effects of other significant variables are removed. As stated earlier, minorities tend to be more economically disadvantaged, have less choices about where to live, and for reasons for affordability might choose to live in areas close to industry. For these socio-economic reasons alone, one would expect to see a disproportionately higher number of minority residents in areas exposed to hazardous emissions. But, the question of interest here is whether or not there is an effect related to race over and above that which can be expected from economic factors alone.

To state the hypothesis of this study in statistical terms: If one were to control for the effect of variables such as income level and population density and then examine the number of polluting facilities in a geographic area as a function of race, the null hypothesis states that the coefficients associated with the racial variable(s) are equal to zero. The alternative hypothesis states that for at least one of the racial variables, the coefficient is non-zero, with a statistically significant degree of confidence.

This statistical analysis examines the relationship between the explanatory variables and the dependent variable for a single point in time. As such, this analysis provides no information on changes over time, but rather, quantifies the current relationship.

METHODOLOGY

In the last fifteen years, a number of studies have investigated the relationship between disadvantaged population groups and hazardous exposure (Anderson 1986, Asch and Seneca 1978, Bryant and Mohai 1992, United Church of Christ 1987, Zimmerman 1986). This literature has indicated that minorities and the poor are likely to be more exposed to environmental hazards than their white and/or richer counterparts. Further, these studies have also established that the costs of environmental degradation are also borne more heavily by minorities and the poor than by other groups. Most of the work in this area, including a review of the studies, is compiled in a recent work by Bryant and Mohai (1992). In their review, Bryant and Mohai (1992a) have tabulated over a dozen studies that addressed the issue of environmental inequity. The majority of these studies, looking at the relationship of income and race with environmental hazard exposure, found both income and race to be significantly related. More importantly, race usually had a greater effect than income after removing out the effect of income.

Besides the uniform findings of all these studies, the other theme common to them all is their mode(s) of analysis. Typically, various measures of environmental hazard level are correlated with corresponding socio-economic data using either bivariate or multiple regression methods. The link between the hazard and the exposed population is some measure of geographical location such as zip codes, census tracts, or counties. The exposed population is thus defined as the population in the relevant zip code area, census tract, or county, as the case may be.

This mode of matching hazardous site location to affected population opens the door to inaccuracies. For example, assume that a minority dominated census tract abuts a more white dominated tract. A hazardous site located on the fringe of the minority census tract would be considered, in the previous studies, to affect only the minority population. In reality, though, the white population in the adjacent census tract are equally exposed. Such a phenomenon, when aggregated across many sites could have led to the results obtained in previous studies. Ideally then, one needs to better define the hazardous site's DOI and focus on the socio-economic characteristics of this area.

This study, used a Geographic Information Systems (GIS) approach to link sources of environmental hazards with affected populations. A geographic information system can be defined as a constellation of hardware and software that integrates computer graphics with a relational database for the purpose of managing data about geographic locations (Garson: 1992). These geographic data are both spatial and descriptive in nature.

GIS based methods link spatial location information with data bases, allowing population elements to be analyzed / combined with hazardous waste sites. The spatial information can be used to create a buffer, which is an area of measured distance from a selected map element such as a point, line, or a polygon. In the context of this study, the spatial information can be used to demarcate a particular site's Domain of Influence[1] (DOI), which can be linked to socio-economic characteristics of the resident population,

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[1] The term Domain of Influence (DOI) has been coined for this study to define buffers around each TRI site.

allowing study of the relationship between extent of hazardous exposure and minority characteristics. Burke (1993) used GIS to study race and environmental equity in Los Angeles. However, her analysis was limited to modeling at the census tract level and did not use GIS to identify buffers, and she recommends that future analysis " be implemented by buffering facilities, and then analyzing the characteristics of the "affected population" within the buffer." Burke (1993).

The rest of this chapter outlines the methodology used to test the relationship between environmental exposure and race for the City of Providence. A description of the various data sources that are used is followed by a discussion of the variables and their operationalizations. Finally, an overview of the analysis phases is presented.

DATA SOURCES

Three major data sources were used in this analysis - the U.S. Census Bureau, U.S. Environmental Protection Agency (EPA), and Rhode Island Geographic Information System (RIGIS). The 1990 census data was combined with the census block group boundaries from the RIGIS coverages. The EPA's Toxic Release Inventory system (TRI) provided data on the sites that handle toxic chemicals in substantial amounts in the study area for the year 1992

First, block group boundaries were created in ARC/INFO using U.S. Census Bureau TIGER files. Next, demographic information at the block group level was merged from

the RIGIS coverages with these block group boundaries. Census data was used to evaluate the socio-economic characteristics of Providence at the census block group level. The data includes information on population size, race, ethnicity, median housing prices, and median per capita income at the level of block groups. 195 census block groups are included in the analysis.

EPA's TRI data, which is the most comprehensive source of data on facilities releasing toxic substances to the environment was used to locate the distribution of toxic emissions sites within Providence. The TRI system was required by the Emergency Planning and Community Right to Know provisions (Title III) of the Superfund Amendments and Reauthorization Act (SARA). The Act provides for the collection and public release of information about the presence and release of toxic chemicals in the communities. The goal is to help citizens, officials, and community leaders to be better informed about toxic and hazardous materials in their communities. The TRI data base also provides information on the type of facility by industrial category and type and amount of chemical(s) released into the air, water, and land. There are 41 TRI sites distributed among the census block groups within the scope of this study.

Within the GIS, two data sets were developed for analysis. First, a point in polygon overlay was performed in order to determine which census block group each TRI facility lies in. The resulting data set permits a comparison of the demographic characteristics of TRI site affected block groups with those that do not contain TRI sites. By 1992, 21 out of the 195 census block groups (11%) contained TRI sites.

Second, a buffer zone of one-fourth of a kilometer (250 meters) radius was created around each TRI site[2]. This buffer zone is defined as the particular TRI site's DOI. Note that each DOI can overlap several census block groups. The socio-economic characteristics for the DOI were computed as a weighted average of the socio-economic features of the overlapped block groups with weights being equal to the percentage of the block group area included in the DOI[3].

When two or more TRI sites are in very close proximity (less than 250 meters apart), their DOIs are merged to create a single DOI with multiple TRI sites contained within. Hence, for both data sets, number of TRI sites is a relevant variable for the unit of analysis - the block group or the DOI. This data set permits a comparison of the socio-economic characteristics of geographic areas that are affected by TRI site emissions through uniform proximity to the site with unaffected areas.

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[2] There is no general consensus on the appropriate radius for the buffer. Bryant and Mohai (1992) in their study in the Detroit area used a 1 mile radius. However, their study focused on only a single hazardous materials facility. In this study, the analysis includes multiple sites, all located within the city of Providence, and the level of analysis is the census block group. Most block groups are far smaller than one mile in any orientation. Using a buffer as large as one mile would have nullified the advantages of a finer-grained analysis obtained by working at the block group level.

[3] Using the weighted average approach assumes that all variables at the block group level are uniformly distributed across the block group. The smaller the unit of analysis, block compared to block group compared to census tract, the more reasonable such an assumption is.

VARIABLES

Three kinds of variables are of interest in this study - dependent, independent, and control. The dependent variables[4] represent the sources of hazardous emissions. The independent variables are descriptors of the minority population in the block group or DOI, as the case may be. Control variables represent other socio-economic characteristics that can be expected to correlate significantly with the presence/absence of TRI sites but whose effects should be separated out from the pure relationship of race with hazardous exposure.

As described earlier, the relationship between hazardous exposure and race will be analyzed with two distinct units of analysis - the block group level and the DOI. Hence, each of the following variables was separately operationalized at both the block group level and the DOI level.

Minority Presence

Minority presence was operationalized in multiple ways. The census data provides counts of whites, blacks, American Indians, Asians, and Pacific Islanders. For each block group or DOI, the percentage of non-whites was calculated as an aggregate measure of the proportion of minorities. In addition, black and hispanic populations, the

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[4] Variables are described as independent and dependent on the basis of an implicit causal model, although the methodology does not strictly permit us to test any causal relationship. This is in the same spirit as classification of variables in regression procedures.

significant minorities in Providence, were separately measured both in terms of their count and their proportion.

Hazardous Sites

Exposure to toxic emissions was captured by noting the presence or absence of TRI sites within the block group. This created a dichotomous variable. In addition, the degree of exposure was operationalized in terms of the number of TRI sites within the block group or DOI.

Control Variables

Three control variables were used to distinguish the relationship between hazardous exposure and race from the effects of economic factors. Median per capita income and median housing value were used as indicators of the economic well-being of the block groups' residents. Also, the population density (people per sq. km.) was used as a surrogate for both income and land-use factors.

OVERVIEW OF ANALYSIS

Several statistical techniques are applied in order to examine the influence of race on proximity to polluting facilities. Data sets created using ARC/INFO and ARCVIEW are analyzed using the Statistical Analysis System (SAS) procedures. The analysis can be described as consisting of three phases.

In the descriptive phase, summary statistics and simple bivariate relationships are computed for all the explanatory and dependent variables. This information allows us to get a feel for the data, identify anomalies if any, and also check whether the use of statistical procedures assuming linearity will be valid.

In the second phase, the relationship between race and exposure to toxic emissions is examined using the block group as the unit of analysis. Two separate tests are conducted. First, the presence or absence of TRI sites is used as the classification variable. This provides a comparison of the minority proportion of affected versus unaffected block groups using t-tests.

Next, the presence / absence of TRI sites is used as the dependent variable in a regression-like model. The intent of this analysis is to determine the relationship between the independent variables (population density, income, housing values, and one or more variables representing racial composition) and the dependent variable (presence or absence of TRI facilities in a block group). However, the dependent variable , presence or absence of TRI sites, is a binary variable and its distribution does not in any way resemble a statistical normal distribution. Of the 195 block groups under study, only 21 of them contain at least one TRI site while the balance 174 have no TRI site. Hence, a simple regression model using Ordinary Least Squares is not acceptable. Following the approach adopted by Burke (1993), the presence / absence of TRI sites is therefore modeled as a Logistic regression problem instead and the relationship with explanatory and control variables tested within a general linear model framework.

Several combinations of explanatory variables are evaluated within this model structure. The influence of population density, median per capita income and median housing value is always included in the models. The explanatory variables used as an indication of race /ethnicity vary. A variable reflecting the total Minority Proportion is used in the basic model, while two separate variables reflecting the black and hispanic proportions of each block group are evaluated in a second model.

In the third phase, the analysis approach duplicates that of the second phase. However, the unit of analysis is the DOI rather than the census block group. A comparison of the results from this phase with those obtained by using the block group as the unit of analysis (second phase) will permit us to detect whether the results of past studies were simply methodological artifacts.

A hypothesis testing framework will be used in this analysis, and individual coefficients will be evaluated at the .05 level of significance for a two-tailed test. This level of significance affords a high degree of confidence that the coefficient of interest is non-zero. Although this framework is technically appropriate for inferring characteristics about the whole population from a sample, it is also commonly used in modeling an entire population, such as in analysis including all U.S. counties.

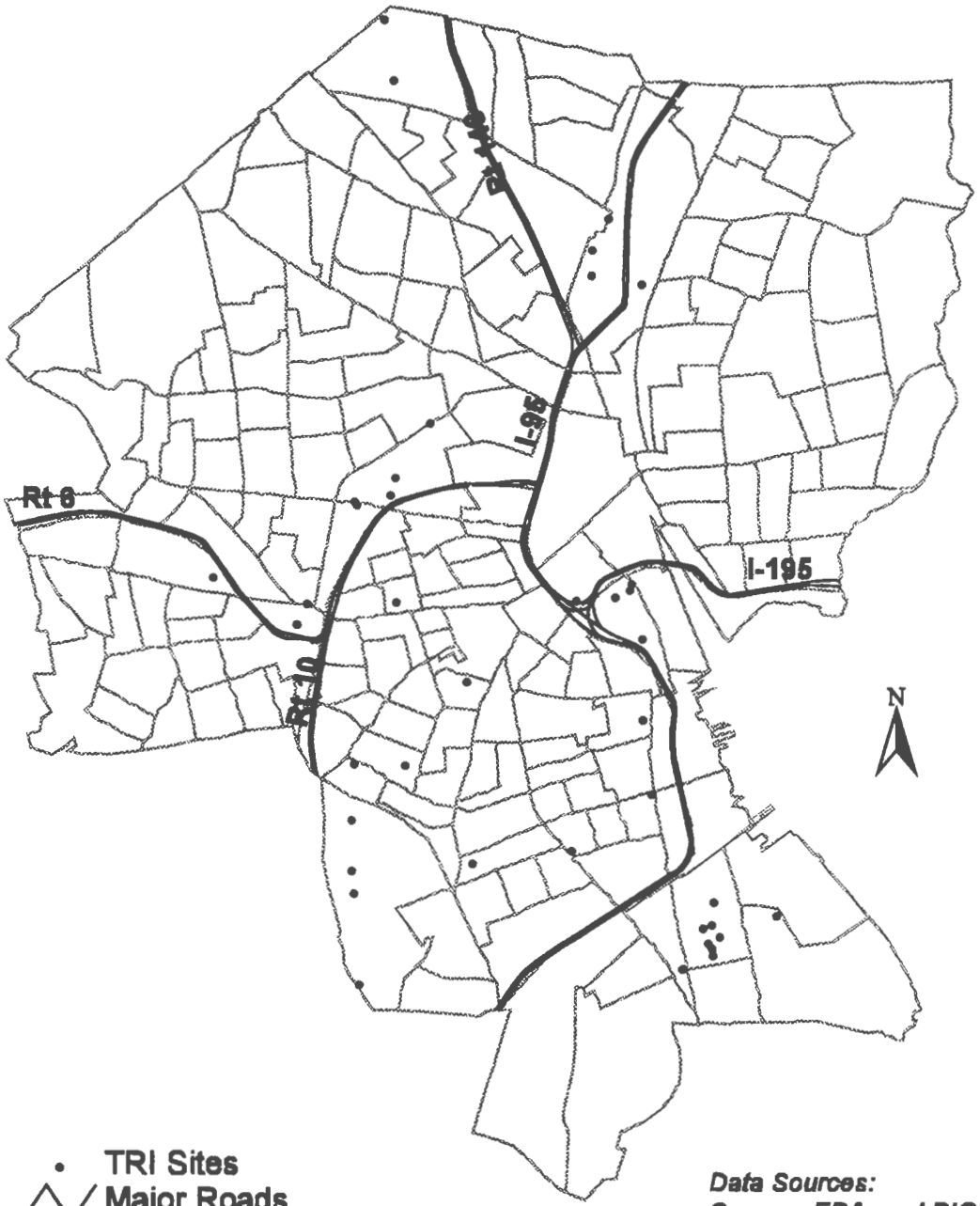
CHAPTER 4: ANALYSIS AND RESULTS

The relationship between racial composition and hazardous exposure was analyzed using multiple approaches. This chapter, first presents a descriptive analysis of all the key variables at the block group level. Next, analyzes the relationship between racial composition and exposure to hazardous materials with the census block group as the unit of analysis. This approach parallels previous studies in that the unit of analysis is a geographic zone determined by criteria independent of the location of TRI sites. The final section, presents the results obtained by using the DOI as the unit of analysis. DOIs were determined by creating a buffer zone of 250 meters around TRI sites using GIS procedures. Unlike census block groups, DOIs are anchored to the existing TRI sites and their utilization as the unit of analysis reflect the unique contribution of this study.

UNIVARIATE ANALYSIS

There are 41 TRI sites located in Providence. The distribution of these sites across the block groups is shown in Figure 2. Two observations can be made about the locations of these sites. First, it appears that the sites are contained in band-like clusters that are adjacent to the major roads. Second, most of the sites are concentrated in the South Providence area.

Location of TRI Sites



- TRI Sites
- Major Roads
- Census Block Groups

0 1 2 3 Kilometers

Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

Figure # 2

Providence has a total population of 160,199 (1990 census), with a majority (about 70 %) being white. The total number of census block groups in the City is 195, out of which five have no population. Summary statistics are shown in Table 1.

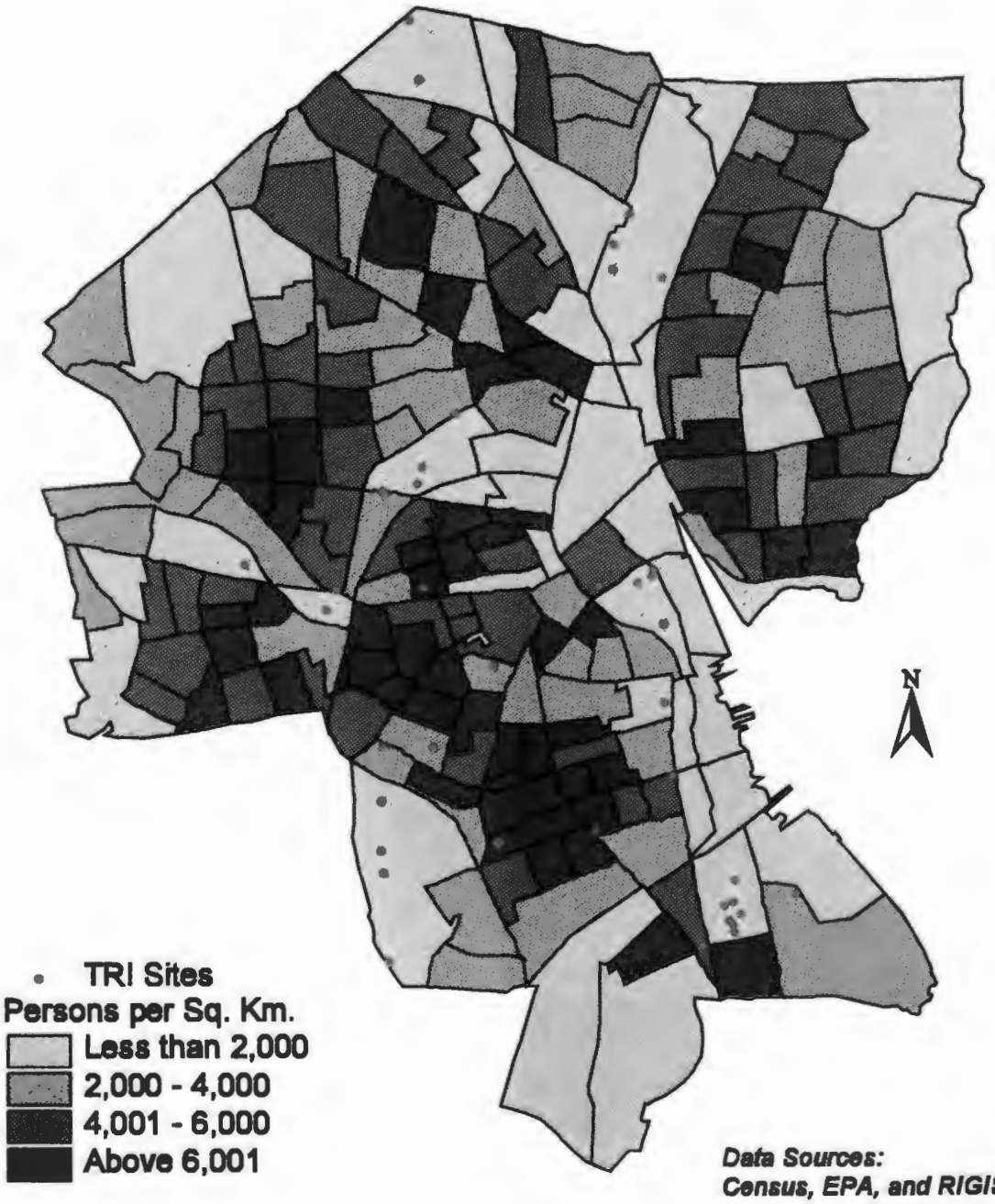
Table 1: Racial Composition by Block Groups

City of Providence (1990)

Variables	Total	Percent
White population	111,921	69.86
Non white population	48,278	30.14
Black population	23,820	14.87
Hispanic population	24,973	15.59
Total Population	160,199	100.00

The total population is distributed over 190 block groups with a mean population of 843 per block group. The most populated block group has 2461 residents, while the least populated block group has only 9 residents, and the median population per block group is 756. In this study, population density of block groups (population/ area in square kilometers) is of greater interest than the absolute population as it removes the effect of the block group area. The average population density for block groups is 4,445 persons per sq. km. Figure 3 displays the variation in density over block groups. Minority population

Population Density

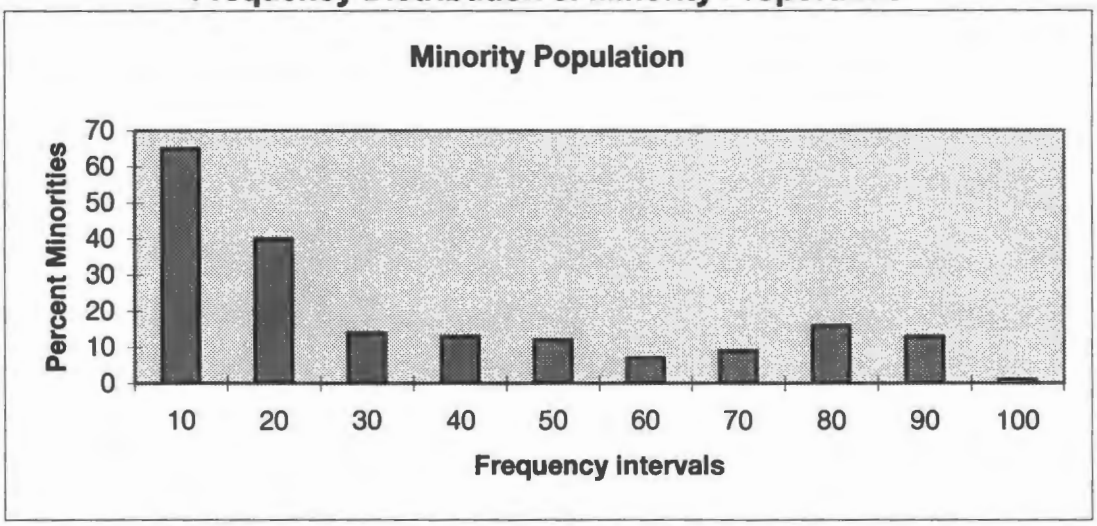


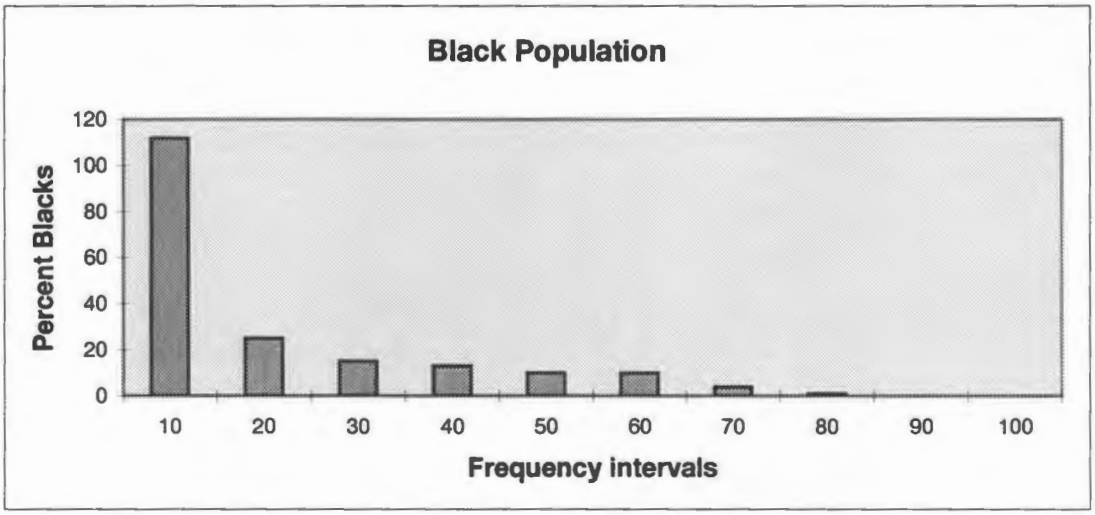
Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

Figure # 3

Frequency Distribution 0f Minority Proportions





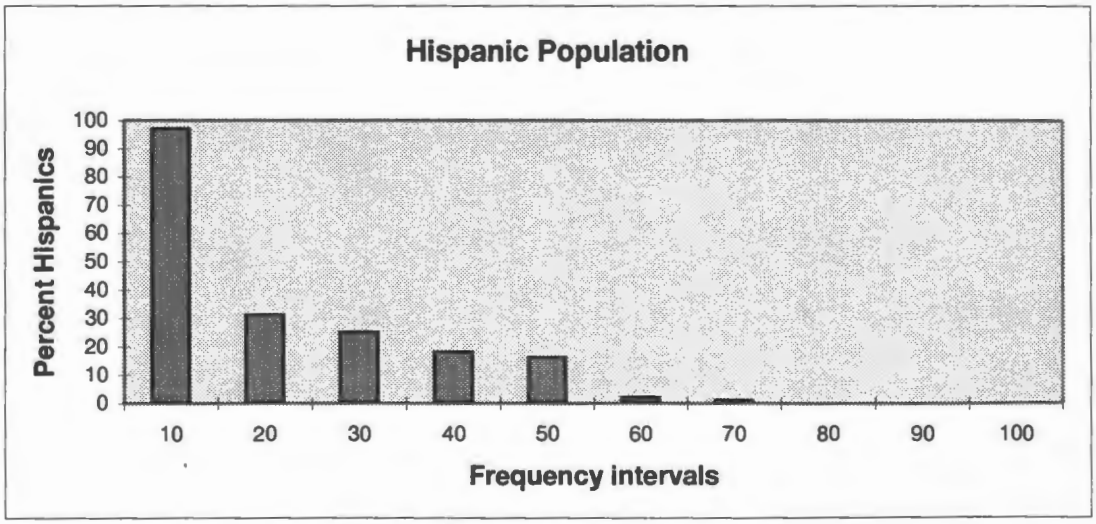


Figure # 4

(non-whites)[5] in block groups varies widely with the inter-quartile range extending from 6.9% to 49.1%. The distribution of minorities across block groups has a bimodal distribution as shown in Figure 4. There are many block groups with under 10% minorities (i.e. largely white dominated block groups), and there is a cluster of block groups with 70% to 80% minority populations. Forty seven of the 190 populated block groups in Providence have a minority population in excess of 50%.

Figure 5 shows the geographic distribution of minorities among the City's block groups. High-minority block groups tend to be clustered together in the South Providence area. A visual examination of the figure indicates that more TRI sites are located in the high-minority areas than in the low-minority areas.

Blacks and hispanics comprise the bulk of the minority population in Providence. The mean proportion of blacks per block group is 15.2% but the median is only 6.5%, indicating that there are many more block groups with low black proportions than block groups with high black proportions (see Figure 4). The high-black proportion block groups are clustered in the South Providence area and generally tend to mirror the distribution of high-minority block groups (see Figure 6).

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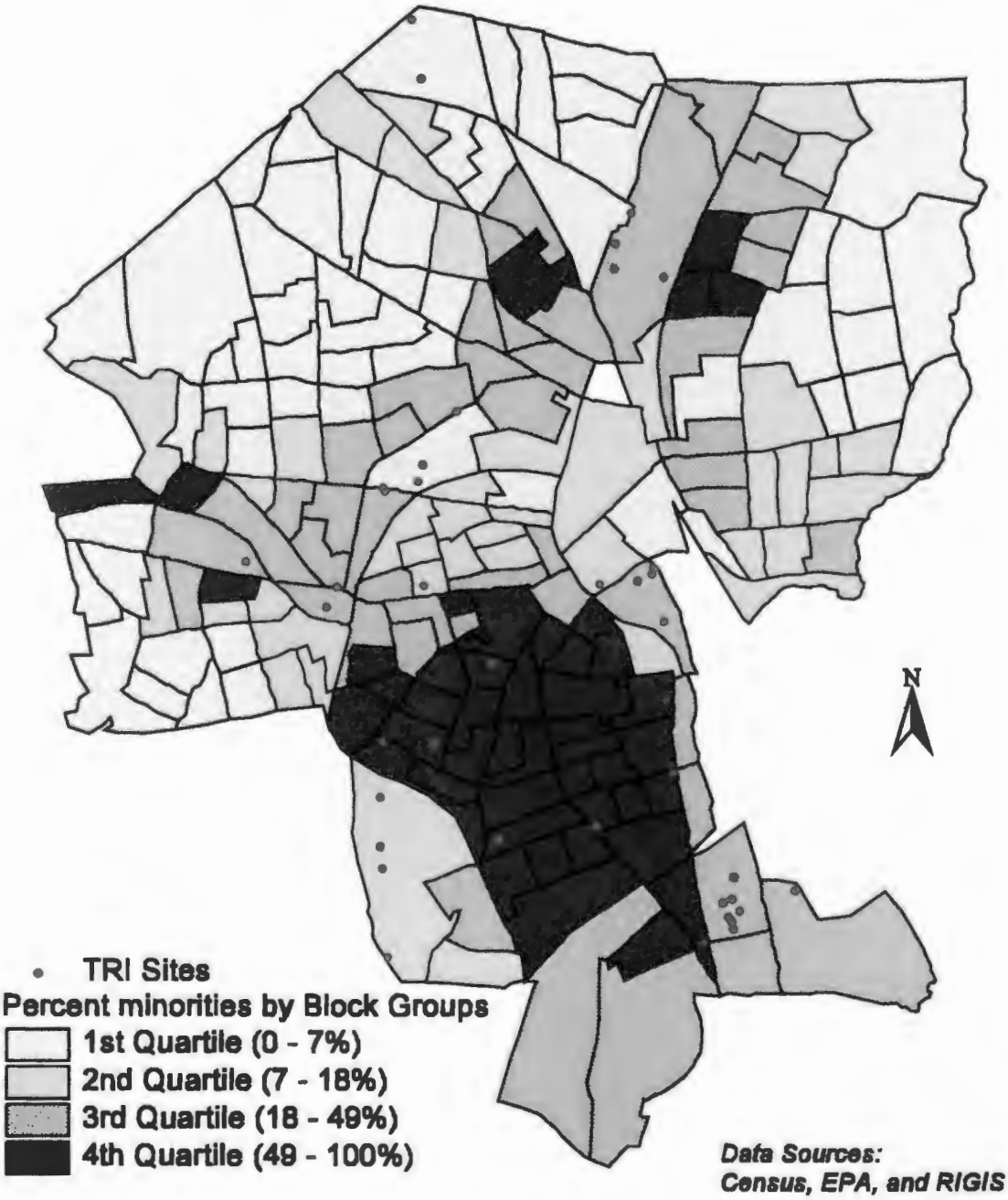
[5] In this report, the term minorities is used to refer to non-white residents.

Spatial Distribution of Minorities

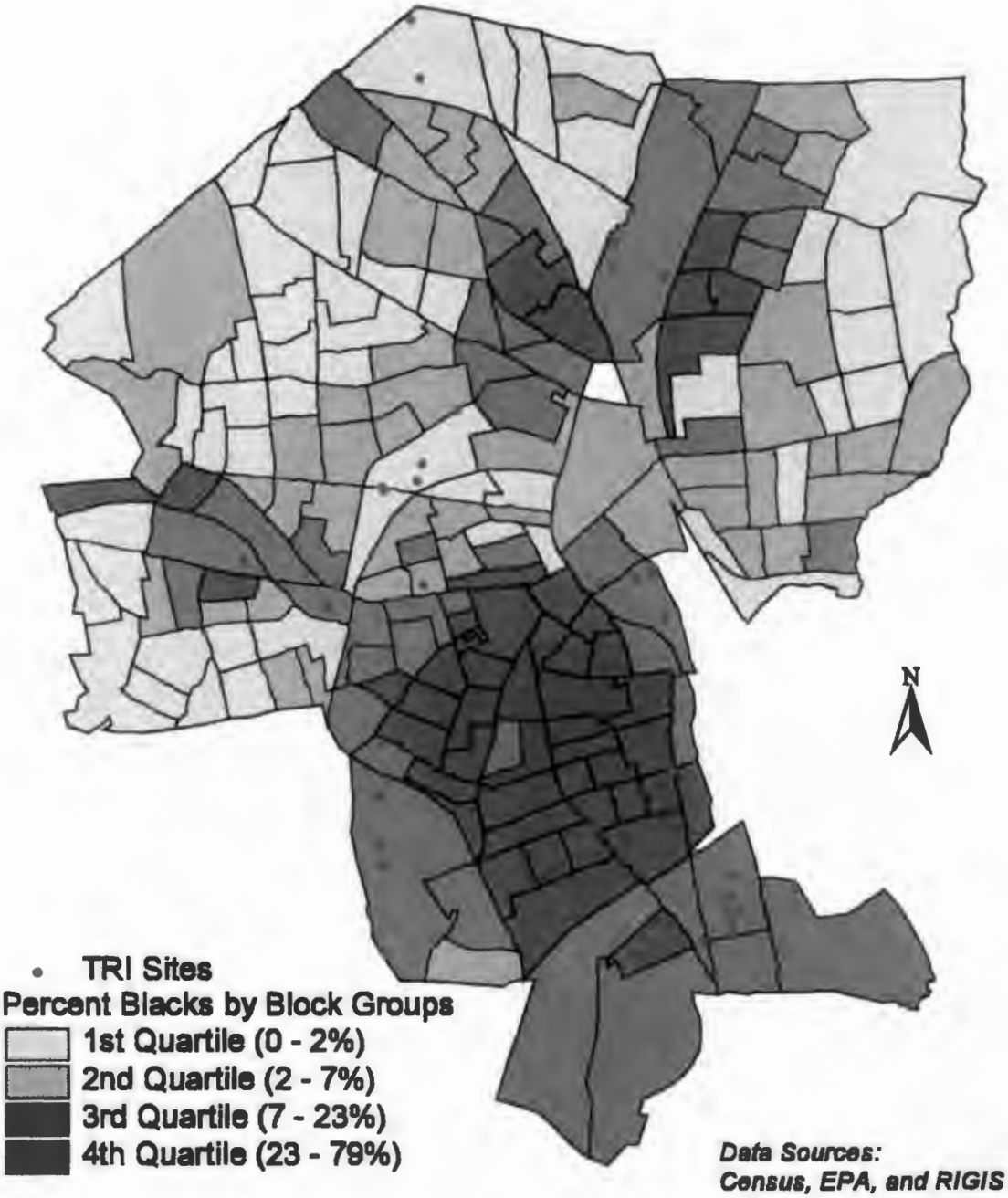


Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

Figure # 5

Spatial Distribution of Blacks

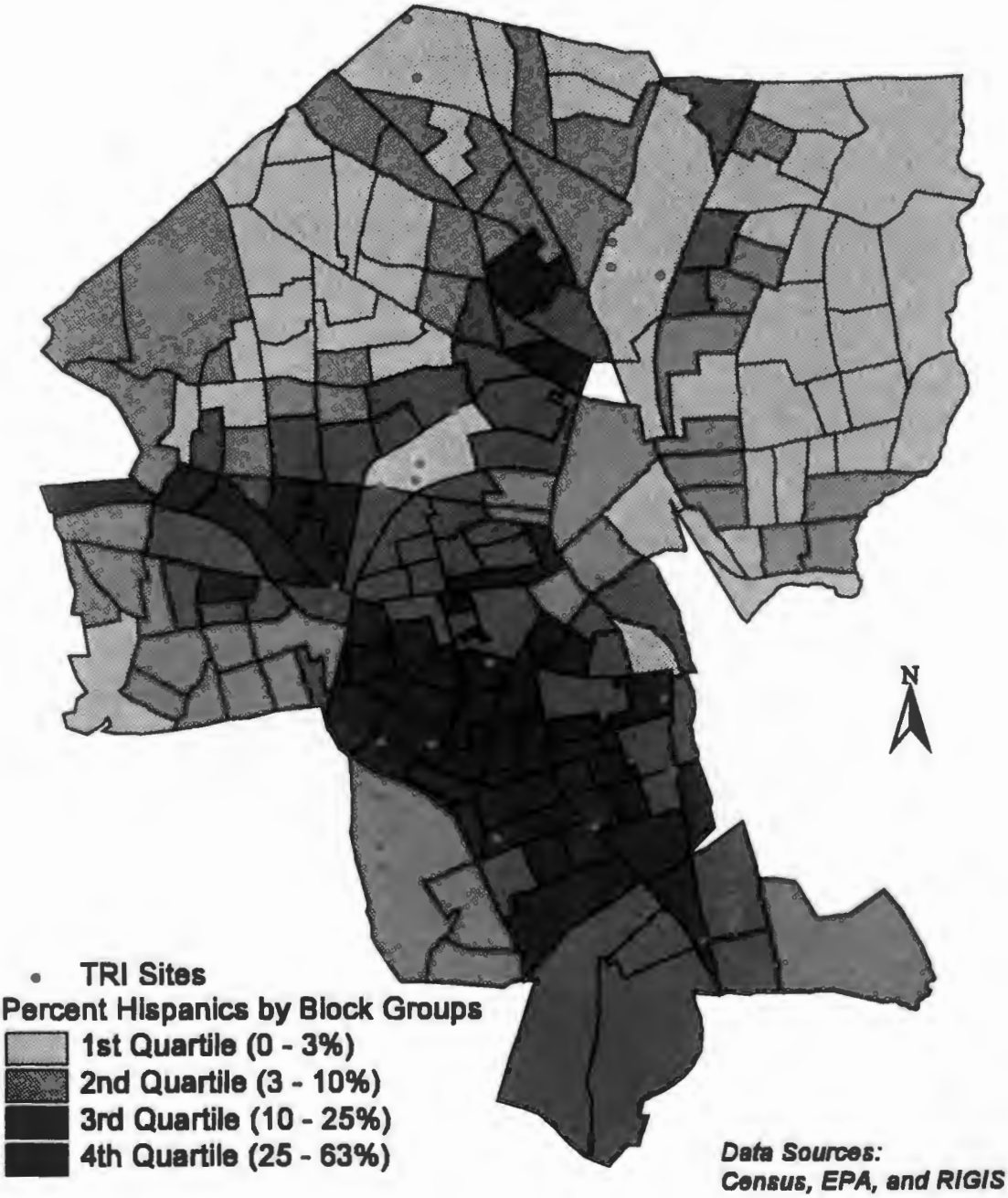


Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

Figure # 6

Spatial Distribution of Hispanics



Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

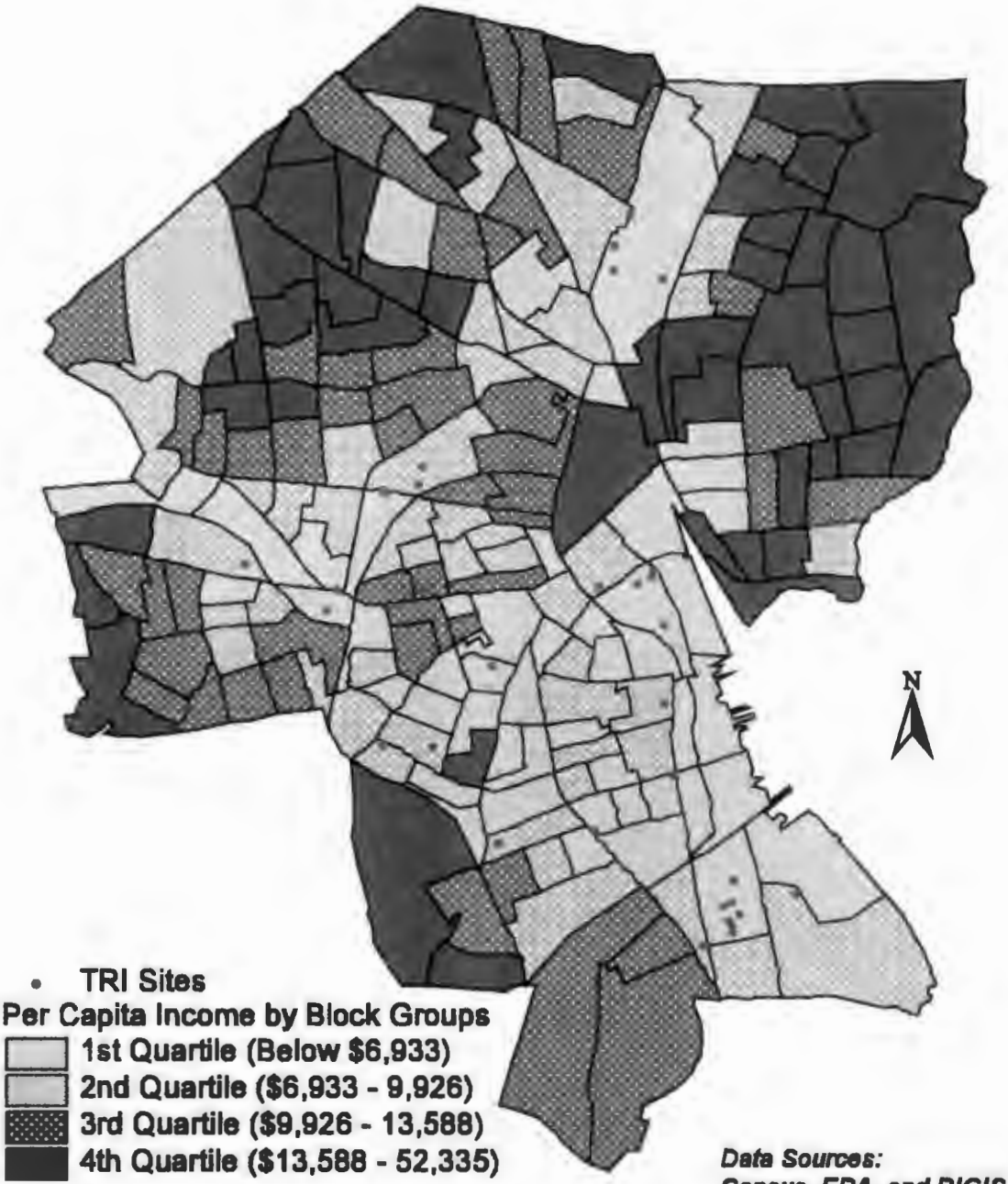
Figure # 7

There are approximately equal numbers of blacks and hispanics in Providence as shown in Table 1. Distribution of hispanics across block groups parallels the distribution of blacks with many low-hispanic block groups (median = 9.6%) but a few with higher hispanic proportions (mean = 16%). Figure 4 shows the frequency distribution of hispanic proportions in block groups, and Figure 7 displays the concentration of hispanics among Providence's block groups.

Once again, the hispanic population appears to be generally located in the vicinity of the South Providence area. By comparing Figures 5, 6, and 7, one can see that there is substantial overlap in the minority, black, and hispanic concentrations. However, a closer examination of Figures 6 and 7 suggests that there are some minority dominated block groups that are either black dominated or hispanic dominated. More importantly, this observation suggests that the relationship of TRI site location with minority presence needs to be studied separately for blacks and hispanics.

As discussed in previous chapters, racial composition of geographic areas tends to be highly correlated with both income and housing values. In order to determine the direct relationship of race with hazardous exposure, it is imperative that effects of income and housing value be isolated. Median per capita income and median home value for block groups were used as the income and housing value indicators for each block group. There is great variation in income within different block groups. The average per capita income is about $10,023 with minimum and maximum being $175 and $52,335 respectively. The average median housing value of owner occupied housing units is $103,400, ranging

Median per Capita Income

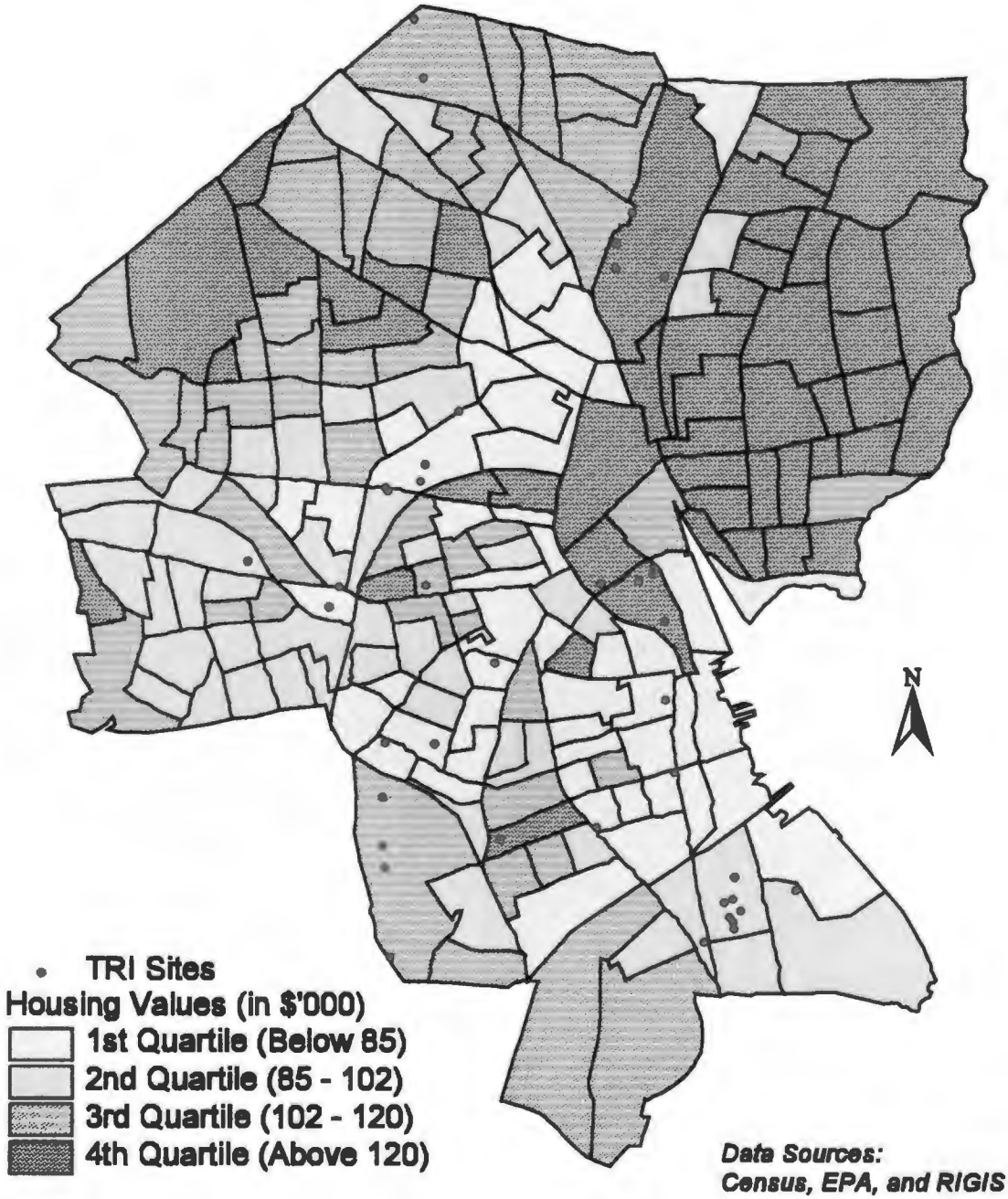


Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

Figure # 8

Median Housing Values



Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

Figure # 9

from $52,500 to $423,400. Figures 8 and 9 show the geographic distribution of income and housing value across all the block groups in the city. As expected, there is a substantial correlation between income and housing value for block groups. More importantly, a comparison of these Figures with Figure 5 shows a clear disparity between the high-minority areas and the high-income/high-value areas. Minority concentrations tend to be in low-income and low-value block groups.

CORRELATION ANALYSIS

Table 2 provides the significant ($p < .05$) bivariate Pearson correlations among all the key variables. The presence / absence of TRI sites (TYES), the main dependent variable, is a bivariate variable and, hence, all correlations with it are biserial correlations. Three conclusions can be drawn regarding its correlations with other variables. First, population and density are negatively correlated with the presence of TRI sites. Second, the greater the income, housing value, and number of white residents of a block group, lower the chances of a TRI site being located in that block group. The significant positive correlations among income, housing value, and number of white residents suggests that these three variables will tend to have a combined effect in most of the analysis. Third, TRI site locations are positively correlated with the proportion of minorities and hispanics, but not blacks.

Table 2: Bivariate Pearson Correlations Among Key Variables
(Only correlations significant at p < 0.05)

	TYES	TNum	DNS	VAL	INC	POP	WH	NWH	BLK	HSP	PNW	PBLK
TNum	0.75											
DNS	-0.20	-0.27										
VAL	-0.12*											
INC	-0.17		-0.26	0.60								
POP	-0.13*	-0.20	0.55									
WH	-0.18	-0.18	0.27	0.24	0.18	0.78						
NWH			0.50	-0.23		0.51						
BLK			0.35	-0.23		0.42		0.93				
HSP			0.52	-0.31		0.45		0.89	0.73			
PNW	0.14		0.26	-0.37				0.77	0.76	0.67		
PBLK			0.14*	-0.33				0.65	0.77	0.47	0.92	
PHSP	0.17		0.28	-0.43				0.61	0.51	0.74	0.83	0.63

*p < 0.1

Terminology:

TYES	Presence of TRI in block group	NWH	Total non whites
TNum	Number of TRI sites	BLK	Total blacks
DNS	Population density	HSP	Total hispanics
VAL	Value of owner occupied units	PNW	Proportion non whites
INC	Per capita income	PBLK	Proportion blacks
POP	Total population	PHSP	Proportion hispanics
WH	Total whites		

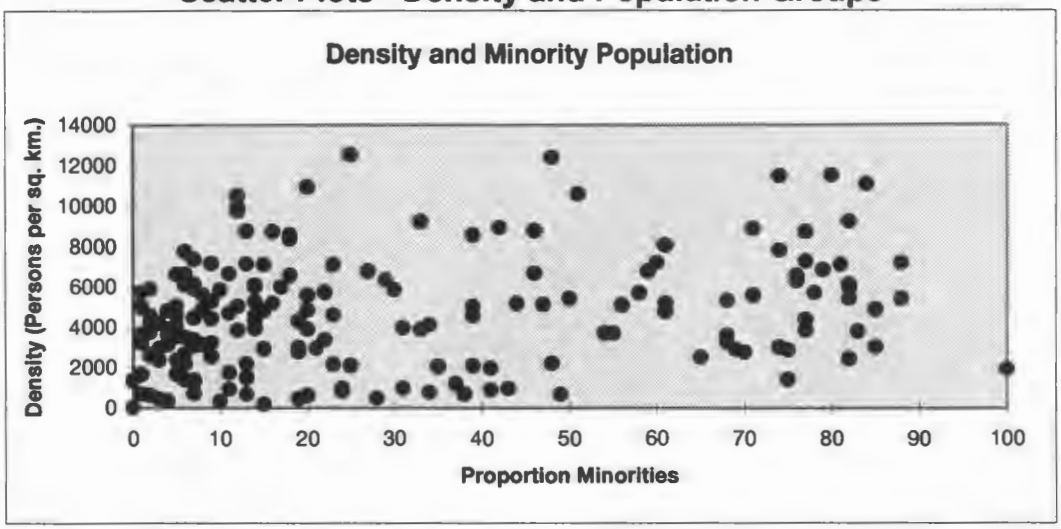
Focusing on the variables capturing racial composition, two observations are noteworthy. First, high-minority block groups tend to have high-black (r = 0.92) and

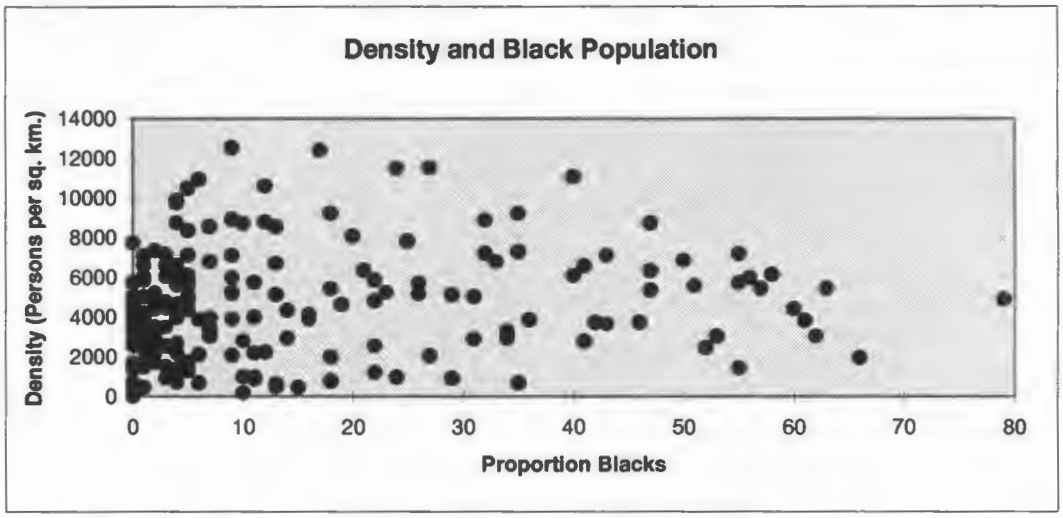
high-hispanic proportions (r = 0.83). However, the correlation between black and hispanic proportion is lower (r = 0.63), although significant. This, in conjunction with the fact that presence of TRI sites is significantly correlated with high-minority and high-hispanic, but not with high-black population proportions, reaffirms the need for separate analysis for blacks and hispanics, as noted previously.

Second, the proportions of minorities, blacks, and hispanics have similar correlations with block group density, income, and housing value. The bivariate scatter plots shown in Figures 10, 11, and 12 provides a graphic depiction of these relationships. Minorities tend to be in block groups with higher density, lower median per capita income, and lower median housing values. Each of these three variables is, in turn, significantly related to the presence / absence of TRI sites. Hence, it is difficult to isolate the relationship between minority proportion of a block group and the presence / absence of a TRI site on the basis of correlation analysis alone. A multivariate procedure such as multiple regression is needed to isolate the effect of minority proportion.

Finally, this study intended to also investigate the relationship between racial composition of block groups and the number of TRI sites in the block group. This analysis would obviously have been appropriate only after establishing a link between racial composition and the presence / absence of TRI sites. However, as shown in Table 2, the number of TRI sites (TNum) is not significantly correlated with any minority population related variables. This may be partly due to the very skewed distribution of number of TRI sites: the 41 TRI sites are spread over 21 block groups with 15 block groups having only one TRI

Scatter Plots - Density and Population Groups





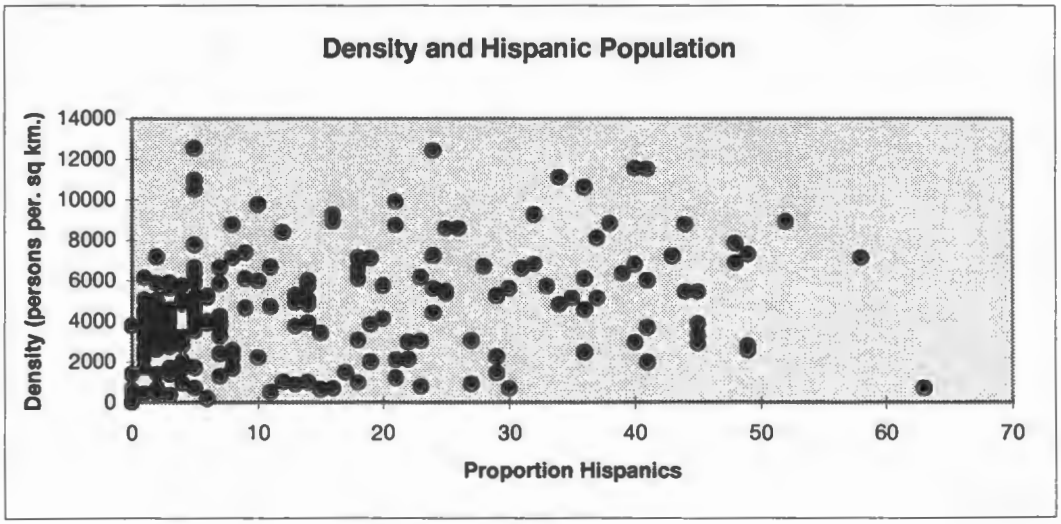
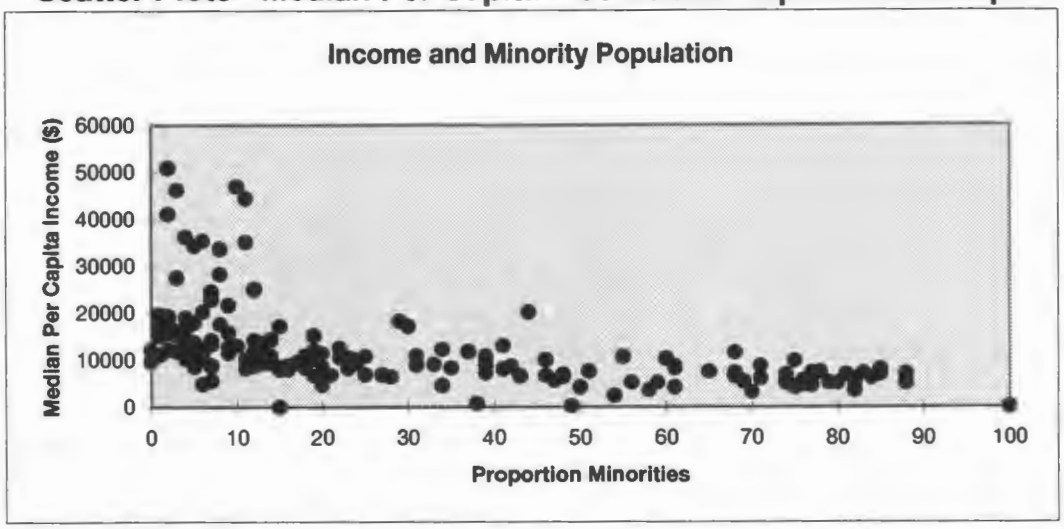
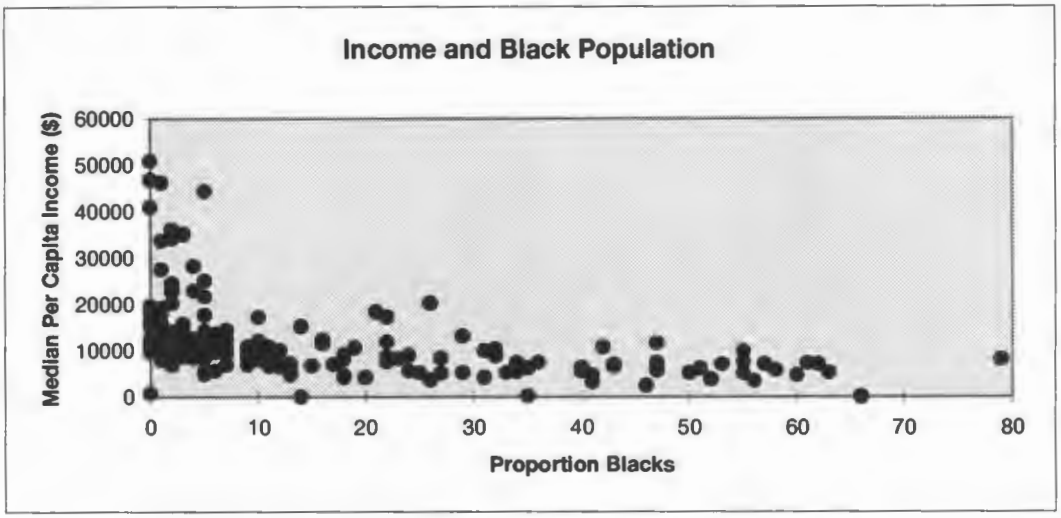


Figure # 10

Scatter Plots - Median Per Capita Income and Population Groups





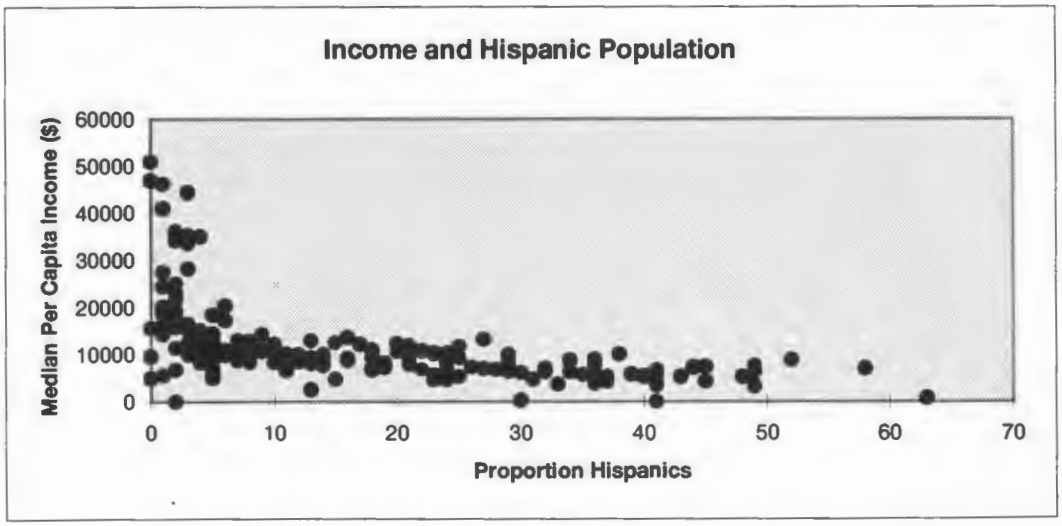
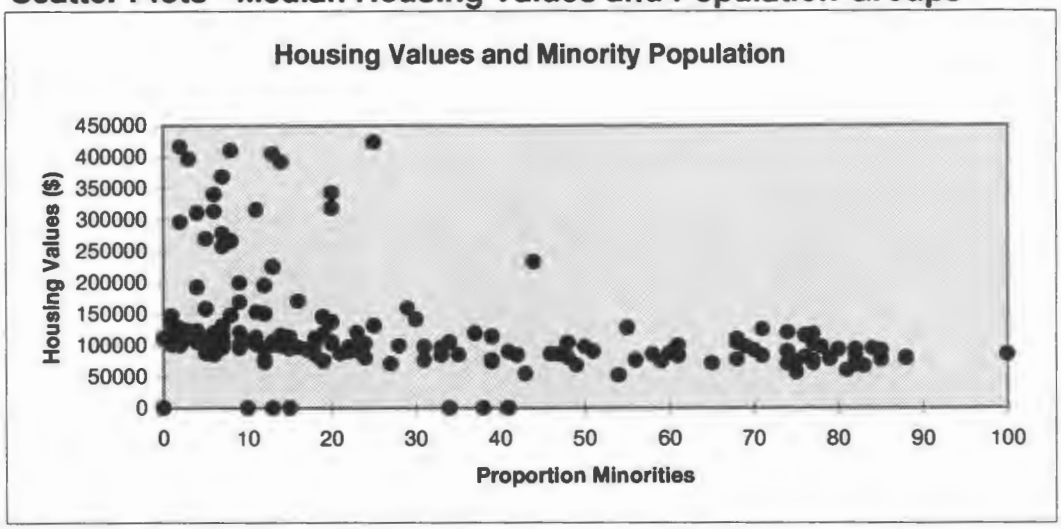
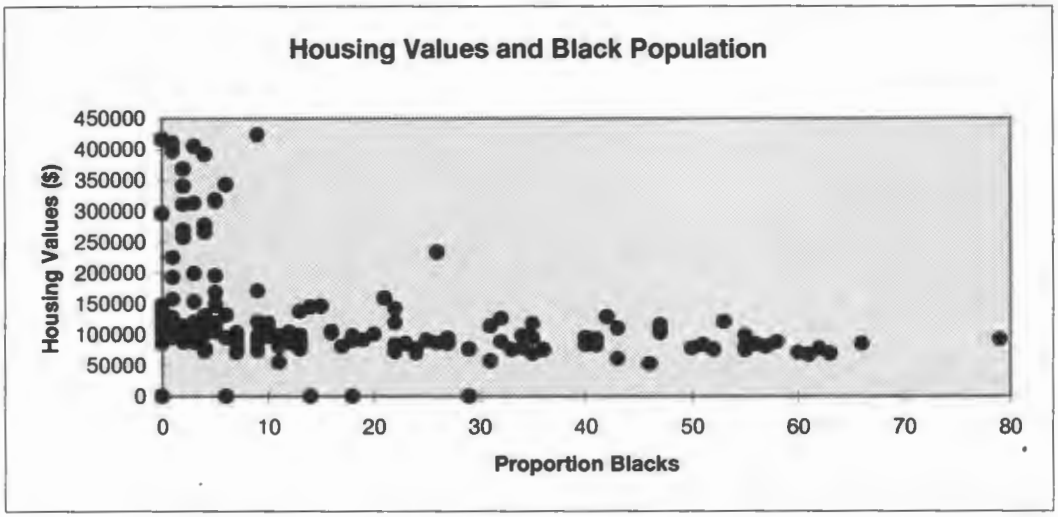


Figure # 11

Scatter Plots - Median Housing Values and Population Groups





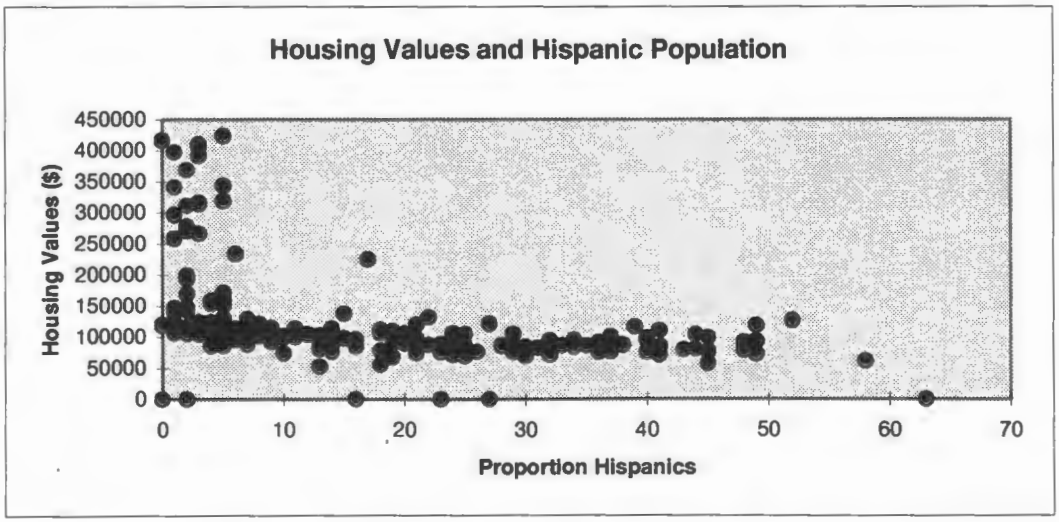


Figure # 12

site, one block group having 3 TRI sites, four having 4 TRI sites, and one having 7 TRI sites.

In conclusion, the correlation analysis suggests that locations of TRI sites are related to the proportions of minority and hispanic population in the affected areas. Further analysis is needed to separate the effect of minority populations from the effects of density, income, and housing value. Also, analysis of the relationship between minority population and number of TRI sites will not be pursued since there were no significant correlations in this category.

COMPARISON OF BLOCK GROUPS WITH AND WITHOUT TRI SITES

In this phase, block groups are identified as either containing at least one TRI site or containing no TRI sites. Comparisons of the two sets of block groups are then undertaken using univariate as well as multivariate procedures.

Univariate Analysis: t-tests

T-tests can provide indications of significant differences between the two sets of block groups. Summary statistics are presented in Table 3 separately for block groups with TRI sites, for those without TRI sites, and for all the block groups with non-zero populations. Results of t-tests for the hypothesis of no difference between the two sets are also provided.

Table 3: Summary Statistics of Key Variables by Block Groups

		Presence of TRI			t-test		
Variables	**Statistic**	**No**	**Yes**	**Overall**	**t**	**df**	**p > |t|**
Population density	Count	169	21	190	2.8	188	0.0056
	Mean	4754	3019	4445			
	Std Dev	2690	2542	2783			
Total population	Count	169	21	190	1.8639	188	0.0639
	Mean	866	659	843			
	Std Dev	471	553	484			
Median housing value (in $)	Count	164	19	183	3.3778	57.8	0.0013
	Mean	131175	99984	127937			
	Std Dev	80532	29473	77365			
Median per capita income (in $)	Count	167	21	188	4.6315	68.2	0.0001
	Mean	12833	8087	12303			
	Std Dev	9226	3369	8890			
White population	Count	169	21	190	2.4881	188	0.0137
	Mean	615	377	589			
	Std Dev	413	409	418			
Black population	Count	169	21	190	-0.2489	188	0.8037
	Mean	124	134	125			
	Std Dev	178	139	174			
Hispanic population	Count	169	21	190	-0.9652	188	0.3357
	Mean	127	163	131			
	Std Dev	154	195	159			
Proportion non-white population	Count	169	21	190	-1.9901	188	0.048
	Mean	0.28	0.41	0.30			
	Std Dev	0.28	0.28	0.28			
Proportion black population	Count	169	21	190	-1.511	188	0.1325
	Mean	0.14	0.21	0.15			
	Std Dev	0.18	0.17	0.18			
Proportion hispanic population	Count	169	21	190	-2.4067	188	0.0171
	Mean	0.15	0.23	0.16			
	Std Dev	0.15	0.17	0.15			

Block groups with TRI sites have a lower population density (mean = 3019 people/sq. km) than those with TRI sites (mean = 4754 people/sq. km), and this difference is significant ($t = 2.8$, $df = 188$, $p < 0.01$). Similarly, the average population tends to be lower in block groups containing TRI sites ($t = 1.86$, $df = 188$, $p < 0.1$).

In terms of income and housing values, block groups with TRI sites have higher median per capita incomes ($t = 4.63$, $df = 68.2$, $p < 0.0001$) and lower median housing values ($t = 3.3778$, $df = 57.8$, $p < 0.05$) than block groups without any TRI sites.

Considering the racial composition of block groups, TRI containing block groups do not differ from block groups with no TRI sites in the absolute number of either black residents or hispanic residents. However, there are significantly fewer white residents in TRI affected block groups ($t = 2.4881$, $df = 188$, $p < 0.05$).

More relevant than the absolute number of residents of any racial category are the proportions of each category in a block group. Overall, TRI affected block groups have a significantly greater proportion of non-white residents ($t = -1.99$, $df = 188$, $p < 0.05$). However, this difference is true only for the proportion of hispanics ($t = -2.41$, $df = 188$, $p < 0.05$) and not for the proportion of black residents.

In conclusion, t-test based analysis suggests that the higher the proportion of hispanics and minorities in a block group per se, the greater is the chance of the block group containing at least one TRI site. However, the presence or absence of TRI sites is also significantly related to the block groups' population density, median per capita income,

and median housing value, which in turn were correlated with minority proportions. Hence, while it cannot be concluded from this analysis that racial inequity exists, there is clear evidence of the possibility and the need to pursue analysis that will yield an estimate of the pure effect of racial composition, isolated from income, density, and housing value.

MULTIVARIATE ANALYSIS - LOGIT

This study initially intended to analyze both the presence/absence of TRI sites and the number of TRI sites as independent variables. However, correlation analysis showed that the number of TRI sites in a block group was not significantly correlated with any independent variables of interest. Hence, this analysis will focus, instead, on the presence/absence of TRI sites in the block group.

Presence/absence of TRI sites is a binary dependent variable and, therefore, not suitable for traditional multiple regression. LOGIT analysis is more suited for the analysis of binary dependent variables and has been used previously in investigations of environmental equity (Burke, 1993). If p is the probability of a TRI site being present, then (1-p) is the probability of a TRI site being absent and (p/(1-p)) becomes the odds ratio of a TRI site being present. In LOGIT modeling, the dependent variable is defined as the natural log of the odds ratio or

$$\text{LOGIT}(p) = \log\left(p / (1-p)\right).$$

The advantage of recasting the binary dependent variable into this form is that while the probability p can only vary between 0 and 1, the LOGIT(p) can vary between minus and plus infinity and is hence more suitable for an assumption of a normal distribution.

The independent variables are still framed in terms of a linear model similar to that in multiple regression. Hence, an example of the model estimated below is:

$$\text{LOGIT}(p) = b0 + b1\,(\text{BGINCOME}) + b2\,(\text{BGDNSITY}) + b3\,(\text{BGTOTPOP})$$

where b0, b1, b2, and b3 are coefficients to be estimated and BGINCOME, BGDNSITY, and BGTOTPOP are block group income, block group density, and block group total population respectively.

The LOGIT model was estimated using the Logistic Procedure in SAS (Version 6) using different combinations of the independent variables for all 195 block groups in the study area[6]. The dependent variable BGTRIYES is a binary variable for which the value 1 indicates at least one TRI site in the block group. The independent variables fall into two classes: (i) indicators of minority residents, and (ii) relevant covariates. Minority population was determined either by considering the proportion of non-whites in the block group (BGPNWH) or the combination of black and hispanic proportions in the block group (BGPBLK and BGPHSP respectively). Covariates were variables that, as per the correlation analysis, were significantly related to both the presence/absence of TRI sites on the one hand and minority population indicators on the other hand. The

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[6] As noted previously, 5 of the block groups had no population. Since each of the LOGIT models estimated used at least one population related independent variable, these 5 block groups consistently had missing data.

covariates included income, housing value, population density, and total population. By incorporating these covariates into the model, this study will be able to identify the uncontaminated link between racial characteristics of the block group and presence/absence of TRI sites.

The first model estimated used BGNWH as the independent variable of interest and all the covariates. The intention here was to allow for any possible effects. Table 4 shows the results of estimation. 182 block groups had non-missing data on these independent variables with 19 of the 21 block groups containing TRI sites included in the estimation. The Log Likelihood ratio (-2LOG L) tests the incremental predictive power of the independent variables over using the intercept alone, and the Score statistic gives a test for the joint significance of the explanatory variables. The model fit very well, as is evident from the highly significant chi-squares for both -2LOG L ($p < 0.001$) and Score ($p < 0.005$). However, among the independent variables in the model, only block group density - BGDNSITY ($p < 0.005$) had a significant effect.

The second model estimated used block group density (BGDNSITY) as the covariate and proportions of blacks (BGPBLK) and hispanics (BGPHSP) as the explanatory variables of interest. As shown in Table 5, once again the model fit extremely well in terms of both Score and -2LOG L ($p < 0.001$). In terms of the independent variables, BGDNSITY was again significantly ($p < 0.001$) related to the probability of a TRI site being present in the block group. The negative sign in its estimated coefficient suggests that as density increases, the probability of a TRI site being present decreases. This is consistent with previous results using correlation analysis and t-tests.

Table 4: Block Groups Based LOGIT Analysis - Model 1

Analysis unit is block groups
Dependent variable: BGTRIYES: Presence of TRI site(s) in block group
Independent variables: BGINCOME, BGVALUE, BGDNSITY, BGPNWH, BGTOTPOP

Response Profile

BGTRIYES	*COUNT*
0	163
1	19
Total	182

(13 observation(s) were deleted due to missing values)

Criteria for Assessing Model Fit

Criterion	Intercept Only	Intercept and Independents	Chi-Square for Independents
-2 LOG L	121.807	100.841	20.966 with 5 df (p=0.0008)
Score	.	.	19.17 with 5 df (p=0.0018)

Analysis of Maximum Likelihood Estimates

Variable	*df*	*Parameter Estimate*	*Standard Error*	*Wald Chi-Square*	*Pr > Chi-Square*	*Standardized Estimate*
INTERCPT	1	-0.0335	1.2085	0.0008	0.9779	.
BGINCOME	1	-0.0001	0.000078	1.6104	0.2044	-0.468432
BGVALUE	1	-0.00000221	0.0000066	0.1098	0.7404	-0.094655
BGDNSITY	1	-413.4	144	8.2407	0.0041	-0.608736
BGTOTPOP	1	0.000239	0.000628	0.1454	0.703	0.06195
BGPNWH	1	1.7053	1.1979	2.0266	0.1546	0.261626

Odds Ratio

Variable	*Odds Ratio*	*Variable Label*
INTERCPT	0.967	Intercept
BGINCOME	1	Median Block group income
BGVALUE	1	Median home value in block group
BGDNSITY	0	Population density of block group
BGTOTPOP	1	Total population of block group
BGPNWH	5.503	Proportion non-whites in block group

Table 5: Block Groups Based LOGIT Analysis - Model 2

Analysis unit is block groups
Dependent variable: BGTRIYES: Presence of TRI site(s) in block group
Independent variables: BGDNSITY, BGPBLK, BGPHSP

Response Profile

BGTRIYES	*COUNT*
0	169
1	21
Total	190

(5 observation(s) were deleted due to missing values)

Criteria for Assessing Model Fit

Criterion	*Intercept Only*	*Intercept and Independents*	*Chi-Square for Independents*
-2 LOG L	132.093	113.127	18.967 with 3 df (p=0.0003)
Score	.	.	18.51 with 3 df (p=0.0003)

Analysis of Maximum Likelihood Estimates

Variable	*df*	*Parameter Estimate*	*Standard Error*	*Wald Chi-Square*	*Pr > Chi-Square*	*Standardized Estimate*
INTERCP	1	-1.5365	0.4816	10.1801	0.0014	.
BGDNSIT	1	-388.4	118.4	10.7648	0.001	-0.583045
BGPBLK	1	0.3545	1.6076	0.0486	0.8255	0.035166
BGPHSP	1	4.6937	1.9407	5.8491	0.0156	0.390586

Odds Ratio

Variable	*Odds Ratio*	*Variable Label*
INTERCP	0.215	Intercept
BGDNSIT	0	Population density of block group
BGPBLK	1.426	Proportion blacks in block group
BGPHSP	109.252	Proportion hispanics in block group

BGPBLK and BGPHSP were the two variables representing proportion of minority residents in the block group. The estimated coefficients suggest that the proportion of blacks in a block group is not related to the absence / presence of a TRI site. However, the proportion of hispanics is significantly related to the odds of a TRI site in the block group ($p < 0.05$). The coefficient for hispanic proportion (4.69) is far greater than that for the black proportion (0.35) although both variables are measured on the same scale.

In conclusion, there is evidence for environmental inequity in Providence in that block groups with a higher proportion of Hispanics, a large minority group in Providence, are more likely to contain at least one TRI site compared with block groups containing smaller proportions of hispanics. This relationship exists over and above the impact of income, housing values, and population density on TRI site locations.

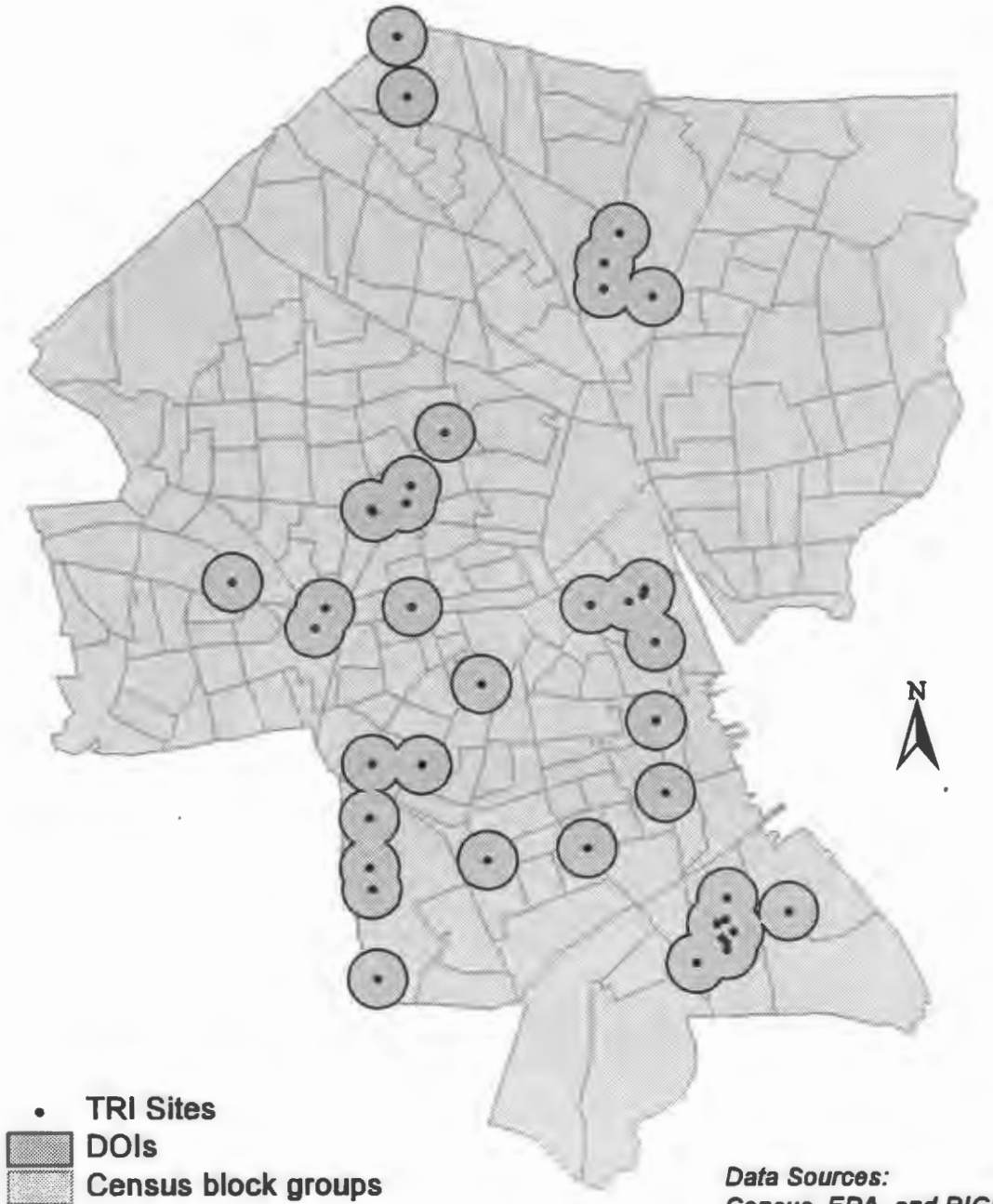
ANALYSIS USING DOMAINS OF INFLUENCE

The approach followed in the previous section parallels past research in that the unit of analysis, the census block group in this case, is defined using criteria external to the location of a TRI site. Hence, an underlying assumption is that all residents within the TRI affected block group, no matter how distant from the actual TRI site, are exposed to the hazardous emissions. Similarly, all residents in an adjacent non-TRI block group are not exposed to the hazardous exposure, no matter how close they actually are to the TRI site. In an effort to minimize the impact of this assumption, smaller geographic units such as block groups were chosen rather than the larger census tracts.

The use of GIS is extremely valuable to identify the area around a TRI site within which residents face exposure to hazardous materials independent of the block group. Contrasting the socio-economic characteristics of residents of a DOI with residents outside the DOI will provide a more meaningful analysis of environmental equity.

Using the polygon over point overlay procedure available in ARC/INFO, a buffer zone of 250 meters radius was created around each of the 41 TRI sites in the City of Providence. As noted earlier, TRI sites in Providence tend to cluster together, resulting in a fairly substantial overlap of the obtained buffer zones. Overlapping buffers were combined into a single DOI, yielding a total of 17 DOIs for the study area (see Figure 13). A series of steps were performed using ARC/INFO to obtain the socio-economic profile of a DOI. First, all the DOIs were intersected with the census block groups to obtain a set of fragmented blocks. Then for each such fragmented block, the population mix was calculated assuming a uniform distribution of the population in the parent block group. Hence, if a DOI included one-fourth of a block group containing 100 hispanic residents, it was assumed that twenty-five of those hispanic residents were in the DOI. The cumulation of such intersection populations was used to derive the racial composition, in absolute numbers and proportions, of each DOI. For computing the DOI income, a weighted average of the block group median incomes reflecting the proportion of DOI a

Domains Of Influence (DOIs)



Data Sources:
Census, EPA, and RIGIS

Map produced by:
Sangeeta Jain
CPAD, URI (1995)

Figure # 13

area common to the block group was used. Income was the only covariate used in the DOI based analysis.

Two approaches were used to identify the non-DOI areas. First, all block groups that did not contain a TRI site (non-TRI block groups) were classified as the contrast area. In this approach, the contrast area remains the same as that used in the previous analysis of TRI affected versus non-TRI block groups. However, it is important to note that the DOI can actually include sections of block groups that did not contain a TRI site but were adjacent to other block groups that did. Hence, there can be common elements in the DOI and the non-TRI block groups, thus resulting in a diminishing of the contrast potential.

In the second approach, the contrast set was defined as all block groups that did not overlap with the DOI (non-DOI block groups) and, hence, had no common elements with the DOI. This results in a cleaner contrast.

DESCRIPTIVE ANALYSIS

Table 6 provides descriptive statistics and t-test based contrasts for comparing DOIs with non-TRI block groups. DOIs have significantly lower median per capita income ($p < 0.005$) and numbers of white residents ($p < 0.05$). DOIs also have more total minorities and more blacks, but the difference is only significant at the 0.10 level. With respect to hispanics, although DOIs on average have more hispanics per DOI (mean =

Table 6: DOIs Contrasted With Non-TRI Blocks

Variables	Statistic	Non-TRI block group	Domain of Influence	t-tests		
				t	df	Prob> |t|
Total population	Count	169	17	0.6967	184	0.4869
	Mean	866	781			
	Std Dev	471	546			
Median per income	Count	169	17	3.0446	36.2	0.0043
	Mean	12833	9128			
	Std Dev	9227	4063			
White population	Count	169	17	2.2156	184	0.0279
	Mean	615	387			
	Std Dev	414	291			
Non-white population	Count	169	17	-1.7782	184	0.077
	Mean	251	394			
	Std Dev	307	401			
Black population	Count	169	17	-1.6933	184	0.0921
	Mean	124	202			
	Std Dev	178	203			
Hispanic population	Count	169	17	-1.4707	17.5	0.1591
	Mean	128	210			
	Std Dev	154	227			
Proportion white population	Count	169	17	1.889	184	0.0605
	Mean	0.72	0.58			
	Std Dev	0.28	0.27			
Proportion non-white population	Count	169	17	-1.8889	184	0.0605
	Mean	0.28	0.42			
	Std Dev	0.28	0.27			
Proportion black population	Count	169	17	-1.7316	184	0.085
	Mean	0.14	0.22			
	Std Dev	0.18	0.18			
Proportion hispanic population	Count	169	17	-1.6962	184	0.0915
	Mean	0.15	0.21			
	Std Dev	0.15	0.14			

210) than non-TRI block groups (mean = 128), the difference is not statistically significant due to the high variance in hispanic population among the DOIs. Focusing on the racial composition in terms of proportion of each race, DOIs have greater proportions of minorities, blacks, and hispanics than non-TRI block groups although, once again, the differences are statistically significant at only the 0.10 level. The lower significance levels could be attributed to the fact that DOIs and non-TRI block groups contain some common elements thus dampening the contrast.

Table 7 shows the results of comparing DOIs with non-DOI block groups. In this case there are no common elements. All the comparisons are now much sharper. DOIs have significantly lower incomes and proportions of white residents. They also have more minority, black, and hispanic residents. In terms of the racial mix of population, DOIs have a significantly greater proportion of minorities, both blacks and hispanics. These differences are extremely significant ($p < 0.005$).

In conclusion, results based on DOIs echo the results reported in the previous section using TRI affected block groups as the unit of analysis. In general, proportions of minorities are greater in the vicinity of TRI sites than in areas distant from the TRI sites. The t-tests focused on a single variable at a time and do not, therefore, take into account correlations among the socio-economic variables. Once again, LOGIT analysis was used to identify the pure relationships between minority residents and exposure to environmental hazards.

Table 7: DOIs Contrasted With Non-DOI Block Groups

Variables	Statistic	Non-DOI block group	Domain of Influence	t-tests		
				t	df	Prob> |t|
Total population	Count	116	17	0.8226	131	0.4122
	Mean	882	781			
	Std Dev	461	546			
Median per capita income	Count	116	17	4.0737	48.5	0.0002
	Mean	14545	9128			
	Std Dev	9617	4063			
White population	Count	116	17	2.9594	131	0.0037
	Mean	696	387			
	Std Dev	415	291			
Non-white population	Count	116	17	-2.079	17.9	0.0523
	Mean	186	394			
	Std Dev	251	401			
Black population	Count	116	17	-2.233	18.3	0.0383
	Mean	88	202			
	Std Dev	140	203			
Hispanic population	Count	116	17	-2.0764	17.6	0.0528
	Mean	93	210			
	Std Dev	131	227			
Proportion white population	Count	116	17	3.3734	131	0.001
	Mean	0.79	0.58			
	Std Dev	0.24	0.27			
Proportion non-white population	Count	116	17	-3.3733	131	0.001
	Mean	0.20	0.42			
	Std Dev	0.24	0.27			
Proportion black population	Count	116	17	-3.1935	131	0.0018
	Mean	0.10	0.22			
	Std Dev	0.15	0.18			
Proportion hispanic population	Count	116	17	-3.054	131	0.0027
	Mean	0.11	0.21			
	Std Dev	0.13	0.14			

Multivariate Analysis - LOGIT

LOGIT modeling was used to estimate the unique relationship between race and hazardous exposure. Once again, all DOIs were contrasted separately with all non-TRI block groups and with all non-DOI block groups. In the first case, this amounted to comparing the 17 DOIs with 171 non-TRI block groups[7]. In the second case the 17 DOIs were compared to the 116 block groups that did not overlap with a DOI, independent of whether they contained a TRI site or not. The dependent variable was a binary variable with a value of 1 if the area under consideration was a DOI and 0 otherwise.

In contrasting DOIs with non-TRI block groups, various LOGIT models with different combinations of the independent variables were estimated. None of these models fit the data with an acceptable level of significance. This finding prompts the conclusion that racial composition does not adequately distinguish between TRI affected areas (DOIs) and unaffected areas (non-TRI blocks). However, as mentioned earlier, there are some non-TRI block groups that are included in both comparison sets by virtue of their adjacency to block groups containing TRI sites, and hence, in the resulting DOI.

In the next step, DOIs were contrasted with all block groups that did not overlap with a DOI (non-DOI block groups). In a spatial sense, this represents a cleaner comparison of residents living in the vicinity of TRI sites with those living further away. Table 8 contains the LOGIT results of the first model using income, total population,

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[7] 21 of the 195 block groups in Providence have TRI sites.

Table 8: DOIs and Non-TRI Block Groups- LOGIT Analysis

Analysis unit is DOIs and block groups
Dependent variable: BUFFYES: Is analysis area a DOI or a non-TRI lock group
Independent variables: BGINCOME, BGPNWH, BGTOTPOP

Response Profile

BGTRIYES	*COUNT*
0	116
1	17
Total	182

(1 observation(s) were deleted due to missing values)

Criteria for Assessing Model Fit

Criterion	Intercept Only	Intercept and Independents	Chi-Square for Independents
-2 LOG L	101.671	89.403	12.268 with 3 df (p=0.0065)
Score	.	.	12.836 with 3 df (p=0.0050)

Analysis of Maximum Likelihood Estimates

Variable	df	Parameter Estimate	Standard Error	Wald Chi-Square	Pr > Chi-Square	Standardized Estimate
INTERCPT	1	-1.0427	1.0961	0.9051	0.3414	.
BGINCOME	1	-0.00008	0.000065	1.3636	0.2429	-0.389171
BGPNWH	1	1.9055	1.1536	2.7283	0.0986	0.263395
BGTOTPOP	1	-0.0007	0.000623	1.2554	0.2625	-0.181605

Odds Ratio

Variable	Odds Ratio	Variable Label
INTERCPT	0.352	Intercept
BGINCOME	1	Median block group income
BGPNWH	6.723	Proportion non-whites in block group
BGTOTPOP	0.999	Total population of block group

and proportion of minorities as the independent variables. This time the LOGIT model fit the data significantly well as indicated by the log likelihood ratio (Chi-Square = 12.268, df = 3, $p < 0.01$) and the Score statistic (Chi-Square = 12.836, df = 3, $p < 0.005$).

On examining the relative influence of the independent variables, this study found that proportion of minority population in an analysis area had a marginally significant influence ($p < 0.1$) on the odds of the area being in the close vicinity of a TRI site, or in a TRI site's DOI.

Next, the relative influence of black and hispanic proportions along with income and total population as covariates was estimated. Table 9 provides the results. Once again the model fit significantly well as seen in the log likelihood ratio and score statistics. However, none of the independent variables had a significant effect.

In conclusion, based on the contrast of DOIs with non-DOI areas, one can suggest that minority proportion in an area is positively related to the likelihood of hazardous exposure, but one can not draw the same conclusion for greater levels of specificity - proportions of blacks and proportions of hispanics in an area.

The next chapter, discusses the findings of this study, the limitations within which the results must be viewed, public policy implications of these results, and avenues for further research in the area.

Table 9: DOIs and Non-DOI Block Groups-LOGIT Analysis

Analysis unit is DOIs and block groups
Dependent variable: BUFFYES: Is analysis area a DOI or a non-DOI block group
Independent variables: BGINCOME, BGTOTPOP, BGPBLK, BGPHSP

Response Profile

BGTRIYES	*COUNT*
0	116
1	17
Total	182

(1 observation(s) were deleted due to missing values)

Criteria for Assessing Model Fit

Criterion	*Intercept Only*	*Intercept and Independents*	*Chi-Square for Independents*
-2 LOG L	101.671	89.598	12.073 with 4 df (p=0.0168)
Score	.	.	12.786 with 4 df (p=0.0124)

Analysis of Maximum Likelihood Estimates

Variable	*df*	*Parameter Estimate*	*Standard Error*	*Wald Chi-Square*	*Pr > Chi-Square*	*Standardized Estimate*
INTERCPT	1	-1.0449	1.1625	0.808	0.3687	.
BGINCOME	1	-0.00008	0.000069	1.2654	0.2606	-0.395647
BGTOTPOP	1	-0.00062	0.000618	0.9972	0.318	-0.160593
BGPBLK	1	1.9619	1.779	1.2162	0.2701	0.168247
BGPHSP	1	1.4033	2.3362	0.3608	0.5481	0.106128

Odds Ratio

Variable	*Odds Ratio*	*Variable Label*
INTERCPT	0.352	Intercept
BGINCOME	1	Median block group income
BGTOTPOP	0.999	Total population of block group
BGPBLK	7.113	Proportion blacks in block group
BGPHSP	4.069	Proportion hispanics in block group

CHAPTER 5: DISCUSSION AND CONCLUSIONS

DISCUSSION

Every method of analysis used yielded a strong relationship between the proportion of minorities and presence of hazardous sites. This pattern is present in simple correlations and in more sophisticated multivariate procedures. Clearly, there is reason to be concerned about environmental inequity in Providence. Further, as was anticipated, racial categories are closely interlinked with economic indicators. In fact, relationships that were present in simple bivariate analysis often vanished when analyzed within a multivariate framework. The multivariate logistics regression analysis showed that racial composition of the area is related to hazardous exposure independent of the residents' economic characteristics.

Of equal, if not greater, interest is the uneven impact on hispanics compared to blacks. Relative to hispanics, blacks appear to be more integrated with the majority white residents in terms of residential location. This results in hispanics being at greater risk of hazardous exposure than blacks. The uneven impact strongly suggests that, in future, research focus should be defined not at macro groupings such as minorities but rather at more specific racial categories such as hispanic and south-east Asians. Given recent immigration trends in the Providence area, it is not inconceivable that a study ten years from today will find south-east Asians at even greater risk than hispanics.

Finally, the difference in findings that result from changing the unit of analysis - census block group versus DOI - is an important reminder of the analysis' sensitivity to spatial units. With no objective standard to use as a reference, it is difficult to compare the validity of block group based versus domain of influence based findings. The guiding factor then has to be the researcher's theoretical underpinnings for choosing one unit over the other. This study argues in favor of using the domain of influence. In fact, it is recommend that the domain of influence unit be improved for further studies by permitting non-uniform shapes that more closely reflect actual hazardous impact of the enclosed sites. GIS approaches give us the power to minimize approximations and one should exploit this potential more extensively. Even though the results from block group analysis are not directly comparable with the DOI based findings, consistency across the approaches lends further credence to the presence of environmental inequity in Providence.

LIMITATIONS

Certain limitations must be borne in mind as one considers the results of this study. Most importantly, the data used in this study represent a snap-shot in time and, hence, while they permit investigation of association they can not be used to draw causal inferences. Longitudinal study of key areas, such as South Providence neighborhoods, is needed to distinguish between the case of deciding to locate a TRI site in high-minority areas in anticipation of low resistance versus the case of minority residents

migrating toward TRI site vicinities in search of jobs and residential facilities that the majority white population considers undesirable.

The analysis presented in this report applies only to toxic release sites reported under TRI data base, and only to Providence, and is not generalizable beyond this case study. Many other environmental hazards exist within Providence, which were not included in this analysis. Environmental hazards such as landfills and conventional air pollutants from automobiles and industrial emissions have not been considered.

POLICY IMPLICATIONS

The bivariate analysis employed in this analysis, including the correlation analysis and LOGIT models, confirmed the strong correlation between income and minority population. There is a clear pattern showing that greater the proportion of minorities in a block group, the poorer the block group tends to be. To understand whether race or income has a more important effect on the distribution of environmental hazards may be less relevant than understanding the underlying causes that lead to it, and addressing and remedying the situation.

The findings of this report have relevance for potential policies aimed at addressing the disproportionately high minority residents in close proximity to TRI sites. Until very recently, there were no public policies in place that required monitoring equity in the distribution of environmental quality. While there are many, and increasingly more,

policies to help control pollution, there is at the same time very little knowledge of the equity consequences of such control measures.

Risk-based approaches, which focus on areas of high pollution and identify the greatest risk to the population generally treat all residents equally. Even if such policies are eventually successful in limiting the extent of pollution, there success will be constrained by their lack of focus on socio-economic characteristics of affected populations. In most cases, such as with South Providence in this study, a closer examination would show that residents of such affected areas are generally racial minorities with lower incomes. To be truly effective, policies on environmental protection must address both priority setting and socio-economic descriptors of the residents and do so independently of political interests.

These patterns also have important implications because of the distribution of the costs and benefits of these facilities. The benefits in terms of product-value generated at these sites may be benefiting the individuals around the world but the burden of pollution related health is borne by the adjacent residents of these sites. This study confirms that in the Providence area, residents adjacent to hazardous sites are more likely to be hispanics. Racism remains a major social problem in this country, as so the degradation of the environment Minority groups are under represented on the local, state, and federal regulatory boards that determine and / or approve the location of hazardous waste sites. Also very few minority citizens occupy leadership positions among mainstream green organizations. Clearly, this imbalance between the impacted and the ones with the voice needs to be urgently addressed.

And, finally, the quality of environmental education is poor in general, and even worse in inner-city schools. Environmental education should be improved in both primary and secondary schools as a means of improving environmental awareness and of improving people's ability to address environmental concerns within their communities. These education projects should be targeted to minority population groups.

FURTHER RESEARCH

This research examined the relationship between the population and TRI facility occurrence within census block groups and their DOI, defined as a buffer of a quarter mile around the site. This analysis could be expanded in three ways:

1) Within this analysis, all TRI facilities were treated as equivalent. The analysis could be enhanced by evaluating the relative risk posed by individual facilities in terms of type and volume (or overall toxicity) of emissions.

2) Additionally, other sources of pollution could be included in order to get a broader picture of environmental equity in Providence. Sources such as incinerators, municipal and hazardous waste landfills, and Superfund sites could be included, in addition to information on concentrations of conventional pollutants.

3) Finally, another extension could be an in depth neighborhood analysis, especially South Providence area. A longitudinal research of the history of the neighborhood may yield more insightful findings.

APPENDIX

LIST OF ALL THE TRI SITES IN PROVIDENCE

No.	Name of the Facility	Street Address	City	State	Zip
1	Alan Jewelry Co.	1280 Eddy St.	Providence	RI	02905
2	Anson Inc.	100 Dupont Dr.	Providence	RI	02907
3	Antonelli Plating Co.	50 Valley St.	Providence	RI	02909
4	Arconium Specialty Alloys	400 Harris Ave.	Providence	RI	02909
5	Armbrust Chain Co.	735 Allens Ave.	Providence	RI	02905
6	B. B. Greenberg Co.	333 W. River St.	Providence	RI	02904
7	Darmet Corp.	960 Broad St.	Providence	RI	02905
8	Eastern Color & Chemical Co.	35 Livingston St.	Providence	RI	02904
9	Eastern Wire Prods. Co.	498 Kinsley Ave.	Providence	RI	02909
10	Electrolizing Inc.	10 Houghton St.	Providence	RI	02904
11	Esposito Jewelry Inc.	225 Dupont Dr.	Providence	RI	02907
12	Excell Mfg. Co.	200 Chestnut St.	Providence	RI	02903
13	Federal Prods. Corp.	1139 Eddy St.	Providence	RI	02940
14	Ferguson Perforating & Wire Co. Inc.	130-140 Ernest St.	Providence	RI	02905
15	Ge Co. Providence Base Plant	586 Atwells Ave.	Providence	RI	02909
16	George Mann & Co. Inc.	Harborside Blvd.	Providence	RI	02905
17	H & H Prods. Co. Inc.	148 W. River St.	Providence	RI	02904
18	International Etching Inc.	7 Ninigret Ave.	Providence	RI	02907
19	Interplex Metals	45 Salem St.	Providence	RI	02907
20	Klitzner Ind. Inc.	44 Warren St.	Providence	RI	02901
21	Mainelli Tool & Die Inc.	30 Houghton St.	Providence	RI	02904
22	Microfin Corp.	555 Valley St.	Providence	RI	02908

23	Monarch Metal Finishing Co. Inc.	189 Georgia Ave.	Providence	RI	02905
24	National Plating Corp.	946 Eddy St.	Providence	RI	02905
25	Oster Alloys	50 Sims Ave.	Providence	RI	02909
26	Patton-Macguyer Inc.	17 Virginia Ave.	Providence	RI	02905
27	Pilgrim Screw Corp.	120 Sprague St.	Providence	RI	02907
28	Providence Chain Co.	225 Carolina Ave.	Providence	RI	02905
29	Quality Spraying & Stenciling Co.	150 Park Ln.	Providence	RI	02907
30	Quebecor Printing Providence Inc.	99 W. River St.	Providence	RI	02904
31	Rau Fastener Inc.	102 Westfield St.	Providence	RI	02907
32	Regal Plating Co. Inc.	85 S. St.	Providence	RI	02903
33	Ribco Mfg. Inc.	192 Georgia Ave.	Providence	RI	02905
34	Rolo Mfg. Co. Inc.	274 Pine St.	Providence	RI	02903
35	Spectrum Coatings Labs. Inc. Inc.	217 Chapman St.	Providence	RI	02905
36	Technic Inc.	1 Spectacle St.	Cranston	RI	02910
37	Textron Inc. Speidel Div.	70 Ship St.	Providence	RI	02903
38	Uncas Mfg. Co.	623 Atwells Ave.	Providence	RI	02909
39	Universal Engravers	695 Eddy St.	Providence	RI	02903
40	Victory Finishing Tech. Inc. Inc.	145 Globe St.	Providence	RI	02903
41	Victory Pearl Inc.	50 Agnes St.	Providence	RI	02909

Source: EPA's Toxic Release Inventory, 1992

BIBLIOGRAPHY

Adams, John, 1992. "The Mainstream Environmental Movement". *EPA Journal*, 18,1:25-27.

Adeola, Francis. 1994. "Environmental hazards, health, and racial inequity in hazardous waste distribution". *Environment and Behavior*, 26, January:99-126.

Anderson, J.E. 1986. "U.S. Population distribution and the Location of Hazardous Waste Sites." Paper presented at the *Population Association of America Annual Meetings, April 1986.*

Anderton, Douglas L., Aderson, Andy B., Oakes, John Michael. 1994. "Environmental Equity: the demographics of dumping". *Demography*, 31, May:229-43.

Anselin, Luc, 1990. "Some robust approaches to testing and estimation in spatial econometrics". *Regional Science and Urban Economics*. 4,2:141-163.

Asch, P. and J. J. Seneca. 1978. "Some evidence on the distribution of Air Quality". *Land Economics*. 54: 278-97.

Bryant, Bunyan and Paul Mohai, 1992. *Race and the Incidence of Environmental Hazards - A Time for Discourse*. Westview Press, Boulder, CO.

Bullard, Robert D., 1990. *Dumping in Dixie: race, class, and environmental quality*, Westview, Press, Boulder, CO.

Burke, Lauretta M., 1993. "Race and Environmental Equity: A Geographic Analysis in Los Angeles". *Geo Info Systems*, 3,9:44-50.

Camia, Catalina. 1993. "Poor minorities want voice in environmental choices". *Congressional Quaterly Weekly report*, 51, August 21:2257-60.

Council on Environmental Quality (CEQ), 1971. *The Second Annual Report of the Council on Environmental Quality*, U.S. Government Printing Office, Washington, DC.

Dear, Michael J., 1992. "Understanding and overcoming the NIMBY syndrome", *Journal of the American Planning Association*, 58,3:288-299.

Gaffney, Vincent; Stanic, Zoran. 1993. "GIS approaches to regional analysis". *American Journal of Archaeology*, 97, October:799-800.

Garson, David G.;Robert S. Biggs. 1992. *Analytical mapping and geographic databases.* Sage Publications, California.

Godsil, Rachel D., 1991. "Remedying environmental racism", *Michigan Law Review*, 90,2:394-427.

Goodchild, Michael.1991. *GIS:principles and applications.* Taylor and Francis, London & New York.

Groothuis, Peter A.;Miller, Gail.1994. "Locating hazardous waste facilities: the influence of NIMBY beliefs". *The American Journal of Economics and Sociology*, 53, July:335-46.

Haining, Robert, P., 1990. *Spatial Data Analysis in the Social and Environmental Sciences*, Cambridge University Press, New York.

Helman Michael.1990 " From 'not in my backyard! to 'not in anybody's backyard!: grassroots challenge to hazardous waste facility siting". *Journal of American Planning Association*, 56, Summer:359-62.

Hird, John A.1993. "Environmental policy and equity: the case of Superfund". *Journal of Policy and Management*, 12, Spring:323-43.

Hutchings, Vicky. 1994. "Green guage (racism plays a key role in who gets toxic waste dumped on them, a report from the U.S.)". *New Statesman & Society*, 7, March 11:31.

Johnson, J.T. 1994. "Tired of pushing pins into maps? Let GIS do it". *The Quill* (Chicago, IL), v82, March:14.

Lavelle, Marianne, 1992. "Residents Want Justice, the EPA Offers Equity", *The National Law Journal*, v15, n3:S12.

Les, Worrall. 1990. *Geographic information systems: developments and applications.* Belhaven Press, New York.

Maguire, David J.;Michael F. Goodchild, and David W. Rhind. 1991. *Geographical information systems: priciples and applications.* Wiley, New York.

Mohai, Paul. 1990. "Black Environmentalism". *Social Science Quarterly*, v71, December:744-65.

Mohai, Paul and B. Bryant, 1992a. "Environmental Racism: Reviewing the Evidence". In Bunyan Bryant and P. Mohai, eds., *Race and the Incidence of Environmental Hazards - A Time for Discourse.* Westview Press, Boulder, CO.

Mohai, Paul and B. Bryant, 1992b. "The Michigan Conference: A turning Point", *EPA Journal*, v18, n1:9:10.

Mohai, Paul and B. Bryant, 1992c. "Race, Poverty and the Environment", *EPA Journal*, v18, n1:6-8.

Morell, Robert, 1987. *"Siting and the Politics of Equity" in Resolving Locational Conflict.* Center for Urban Policy Research, New Brunswick, NJ.

Novick, Michae. 1992. "The Watchdog", *EPA Journal*, v18, n1:51-52.

Reas, Judith. 1991. "Equity and environmental policy". *Geography*, v76, October:292-303.

Reilly, William K., 1992. "Environmental Equity: EPA's Position", *EPA Journal*, v18, n1:18--22.

Rosen, Ruth. 1994. "Who gets polluted? the movement for environmental justice". *Dissent*, 41, Spring:223-30.

Satchell, Michael, 1992. "A whiff of discrimination?", *U.S. News & World Report*, 112,17:34-35.

Schor, Juliet B. 1991. "Global equity and environmental crisis: an argument for reducing working hours in the North". *World Development, January*:73-84.

United Church of Christ Commission for Racial Justice. 1987. *Toxic Wastes and Race in the United States: A National Report on the Racial and Socio-Economic Characteristics of Communities Surrounding Hazardous Waste Sites.* New York: United Church of Christ.

U.S. General Accounting Office. 1983. *Siting of Hazardous Waste Landfills and Their Correlation with the Racial and Socio-economic Status of Surrounding Communities*. Washington, DC: U.S. General Accounting Office.

Wilson, Albert, R., 1991. *Environmental Risk: Identification and Management*, Lewis Publishers, Chelsea, MI.

Wrigley, Neil, 1985. *Categorical Data Analysis for geographers and environmental scientists*. Longman, London & New York.

Zimmerman, K. 1986. "Distributional Considerations and the Environmental Policy Process." In A. Schnaiberg, K. Zimmerman and N. Watts. eds., *Distributional Conflicts in Environmental-Resource Policy*. New York: St. Martin's Press.