6-2008

Analysis of Spatial Distribution of Hazardous Wastes in Semcog Region, Michigan

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ANALYSIS OF SPATIAL DISTRIBUTION OF HAZARDOUS WASTES IN SEMCOG REGION, MICHIGAN

by

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A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
requirements for the
Degree of Master of Arts
Department of Geography

Western Michigan University
Kalamazoo, Michigan
June 2008

ACKNOWLEDGEMENTS

I would like to extend my greatest appreciation to Dr. Chansheng He for all his support, help during the two years in Western Michigan University. Also I would like to thank Dr. Kathleen Baker and Dr. Charles Emerson for their valuable reviews and constructive comments to this thesis. Since as everybody knows, to edit writings by a person not using his/her native language means much more work than that by native language, I appreciate Dr. Baker's great patience on my poor English language skills.

I would like to express my most hearty thanks to Dr. Gregory Veeck and my previous Advisor Dr. Shuwen Niu for their extreme kindness and generosity and insightful guidance to my research.

Special acknowledgement would be given to Teresa Bertossi for her encouragements and help in my life in the US.

Finally, I wish to express my gratitude to my husband Chen Nan, my parents, and my brother for their endless love, and I also give many thanks to my friends in the Geographic Department for supporting me along the way. Thank you all, once again.

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This research is devoted to an increasingly recognized issue: environmental injustice, that is, the distribution of environmental risks and/ hazards are disproportionably distributed in the space in terms of the effects on the victims. Specifically, this thesis focuses on an analysis of the spatial distribution of hazardous materials from fixed incidents and the characteristics of neighborhoods living near the incident sites, so as to test the hypothesized relationships that poor people and minority people live near the incident sites. SEMCOG region, Michigan is chosen as the study area due to its frequent occurrence of incidents involving environmental hazards. It is learned from the literature on environmental injustice that there are several different units of analysis and methods being used, since the issue of environmental injustice is well known, this research tries to approach the issue of environmental injustice in a different way. In order to testify whether the unit of analysis plays a role in the findings on environmental injustice, this research extends the unit of analysis from census tract to county subdivision level (city, township). The results show that poor people and minority people tend to live near the environmental hazards, and the unit of analysis does not play significant role.

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CHAPTER I

INTRODUCTION

During the last decade, attention to the impact of environmental pollution on particular groups of our society has been steadily growing. Organizations working for environmental justice in the United States include: Center for health, Environmental and Justice, and the Coalition Against Environmental Racism (U.S. Department of Justice). In response to public concerns on their health and living conditions, the U.S. Environmental Protection Agency established the Office of Environmental Justice in 1992(U.S. Environmental Protection Agency, 2007) to provide the framework for protecting communities with poorest health, greatest concentration of environmental pollutants or least economic development from additional sources of pollution. Concerns that minority populations and/or low-income populations bear a disproportionate amount of adverse health and environmental effects led President Clinton to issue Executive Order 12898 in 1994, focusing Federal agency attention on these issues (Federal Register, 1994). Since then, environmental justice (EJ) activism has penetrated many U.S. states to varying degrees, and some forms of EJ have become institutionalized. As of 1999, North Carolina, Georgia, Alabama, Louisiana, Michigan, New York and Arkansas had passed legislation to achieve environmental justice (Turner, 2002). All these actions resulted from the environmental justice movement, which was launched in response to environmental inequalities, threats to public health, unfair treatment to minorities and people in poverty. What is sad about this is that many times these kinds of unfair treatment happened without the victims' knowledge of the health threats lying ahead. According to the EPA's first report on trends reflecting environmental facts that may affect the health and well-being of children in the United States, Some environmentally-related health risks are persistent among certain groups of children, with race and poverty playing a disproportionate role (U.S. EPA, 2008). Now with the environmental justice movement, a grassroots movement actively fights against it (Goldman, 1996).

Cases of inequitable impact of environmental hazards on poor and minorities are well documented. For instance, minority children have been proven to suffer disproportionately from lead poisoning (Maantary, 2002). As a neurotoxin that causes a spectrum of symptoms depending on the blood lead level concentration, lead exposure provides one example of environmental inequity. Researchers found an inverse relation between blood lead concentrations and all cognitive function scores, a result that was seen in math and reading scores for concentrations as low as 2.5 ug/dL. Another type of toxic substance disproportionably concentrated in the environments where poor people and minority children live is PCBs, which are a class of organic compounds that are banned due to their persistent toxicity (Canfield, et al., 2003). Toxic substances from spills or emissions can potentially result in serious public health consequences for workers and the general public nearby. There is evidence suggesting that respiration illnesses are the most commonly reported injuries resulting from them, though the overall health impact could depend on the location, the substance released, and the atmospheric conditions during the release (Margai, 2001). To date many race and income based studies conducted during the last decade have shown the existence of disproportionate environmental impacts, whereas many other researchers have tried to prove its influence of analysis choices/assumption by arguing that the analysis method applied is problematic or the selection of unit of analysis results in great variation in the findings (Been, 1995; Mohai, 1996; Pulido, 1996).

When putting the problem in the context of Michigan with regards to its demographic characteristics and the distribution of environmental hazards, the southeast Michigan region has high concentrations of minority and high occurrence of incidents involving environmental hazards. Among all the 83 counties, Wayne County holds the largest number of minority residents (U.S. Bureau of the Census, 2000). According to the environmental data from U.S. Environmental Protection Agency (U.S. EPA), it also hosts the most incidents involving hazardous materials.

In order to get a bigger picture and less skewed result, SEMCOG region, which is an extension of Wayne county is chosen as a favorable study area instead of merely Wayne county for the study of the well-being of the minorities and/or poor people in relation to the incidents. SEMCOG is the abbreviation of Southeastern Michigan Council of Governments. As a community development and planning organization, SEMCOG makes the policy decision to make sure that regional policies reflect the common interests and concerns of the member communities, the areas that SEMCOG help the member communities with include transportation, environment, regional growth, and education, the goal is to promote more efficient government. Although SEMCOG will make the final regional decision to the best interest of the region, it also supports the local-level decision making process. By and large SEMCOG plays a role of balancing the regional coordinated development.

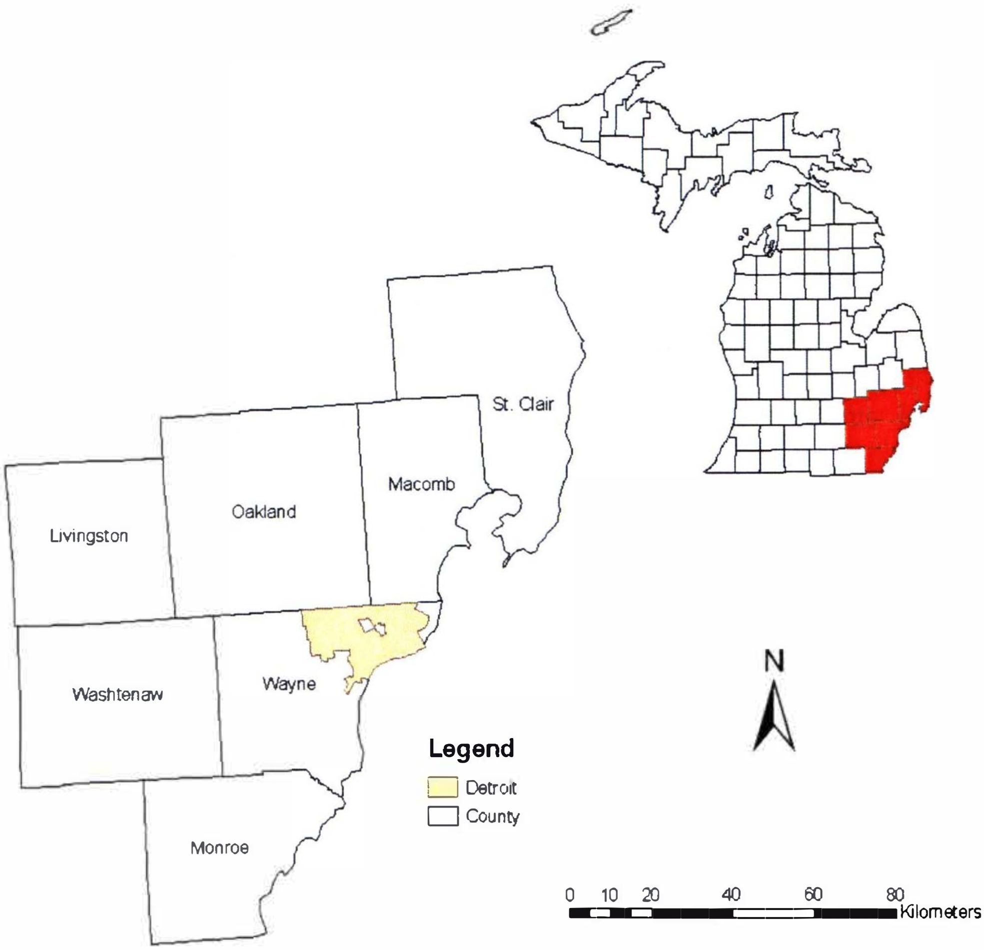

Figure 1: Location of SEMCOG region, MI

The specific research of this paper is devoted to examining the increasingly focused issue: environmental injustice, to be more specific, whether or not the distribution of environmental risks and hazards are disproportionably distributed in space in terms of their effects on the victims. Since people in poverty and minorities as disadvantaged ones are more susceptible to various hazards incurred on them than those advantaged individuals, it is worthwhile for academic communities to pay more attention to the well-being of these groups and speak for them. This paper would first test the hypothesis that the affected neighborhoods from accidents involving environmentally hazardous substances are characterized by lower economic status and a higher proportion of minority residents, and more importantly, it would explore different approaches to the issue of environmental injustice to see if the unit of analysis plays a role in the findings.

Previous studies at a national scale revealed a strong regional pattern in the distribution of hazardous material within the northeastern United States (Cutter & Tiefenbacher 1991; Cutter & Ji 1997), which means that the location of hazardous accidents is not evenly distributed among different communities. At this point, it is easy for one to question that it is not sufficient to be considered as environmental injustice just by the accidents' spatial distribution pattern by any means, since one can briefly reach the conclusion that it comes as no surprise that areas with lower transportation connectivity and less industrial development would be less likely to experience those accidents. In light of this, the focus of this research is not just on showing the spatial distribution of incidents involving environmental hazards is uneven, but rather on investigating the disparity of socioeconomic characteristics between the immediate proximity of the hazardous accidents and areas further away. Moreover, it will go further to see the effects of unit of analysis in the findings.

As far as the occurrence of incidents in Michigan is concerned, for the years 2004 through 2006, out of 499 fixed incidents associated with hazardous materials, the SEMCOG region accounts for 40 % of all incidents. The reason why this happened can in part be attributed to the higher transportation connectivity and greater number of industrial sites in this area. The Detroit Metropolitan area, as the major industrial region of the State, includes not only the heavy concentration of auto-related plants in Wayne, Oakland, and Macomb counties, but also major steel, chemical, and pharmaceutical industries (U.S. EPA). Various employment opportunities stemming from industrial development there have drawn a significant population from around the nation or even the world to this "magnet" to pursue their careers.

As a result of intense industrial production and some associated service industries, inevitably numerous incidences have happened there and mountains of wastes have accumulated. Some of them may not produce immediate and/or visible environmental consequences, due to what can be called "lag effect", which is a term borrowed from other disciplines as economics, politics, and ecology, meaning that one variable is correlated with the values of another variable at a later time rather than immediately. Some do instantly cause various health problems: in health synchs we usually use the term chronic for long effects and acute for short term effects. Breathing petroleum vapors can cause nervous system effects (such as headache, nausea, and dizziness) and respiratory irritation. Very high exposure can even cause coma and death.

According to New York Government report (New York Government, 2007) oil spills from leaking underground storage tanks at homes and gas stations are the largest single threat to groundwater quality in the United States today. An estimated 1.2 million tanks nationwide, many of which were installed prior to new regulations in 1988, are a big concern because tanks corrode quickly when buried unprotected in the soil. Spills during product delivery, and piping failures, have already caused more than 400,000 confirmed underground storage tank leaks nationwide. As a result, the polluted groundwater becomes a leading carrier of toxic substances which further affect a variety of lives (New York Government, 2007). Speaking of incidents involving hazardous materials, chances are they might happen naturally or accidentally, which makes it difficult to discuss environmental injustice. In order to minimize the accidental factors, incidents chosen for this research are focused on fixed type and incidents of natural phenomenon are eliminated. Other types of incidents such as pipeline, aircraft, and mobile are all excluded. The causes of these incidents might be dumping, equipment failure, explosion, or operator error, etc.

In the literature review in the next chapter, it is noted that a great deal of caution should be taken when dealing with the unit of analysis since different units of analysis may produce a dramatic variation in the findings, as such, this paper would use two different units of analysis on the same study area. It starts out with census tracts as the unit of analysis, and then as an examination of the role that unit of analysis plays, the unit of analysis is extended to a bigger entity as sub-county (city & township) level for analysis.

The Study Area

As it can be seen from figure 1, the SEMCOG region is located in southeast Michigan. It encompasses approximately 4643 square miles, and is made up of 89 cities, including the largest city of Detroit, known as the world's traditional automotive center. Within SEMCOG region are Livingston, Macomb, Monroe, Oakland, St. Clair, Washtenaw, and Wayne Counties (figure1). Due to the coordinated efforts, these counties share some policies and characteristics to ensure the mutual needs are met.

Of the 205 civil divisions located within the SEMCOG region limit, the largest and most dominant is the city of Detroit, which is also the largest city in Michigan and the tenth largest in the nation. Detroit is located in the northeast section of Wayne County (figure1), and the Counties of Wayne, Oakland, and Macomb form the core of the Detroit area. Wayne County is the industrial center with vehicle manufacturing industry being the dominant industry and the home to numerous multinational corporations. Although the automobile industry has mostly moved outward to developing countries, pollution coming along the production process of the automobile persists, leaving people surrounding still suffering (Wayne County Government, 2007).

Over the last few decades, SEMCOG region has experienced severe environmental problems with industrial development, especially the development of automobile industry in the City of Detroit. Today stigmas of closed plants and contaminated property, along with illegal dumps and closed landfills, scatter the older urban communities of the region. According to news report, Michigan is ranked as one of the worst States in terms of air pollution while Wayne County is known as one of the dirtiest counties in Michigan.

Problem Statements

Some drawbacks have been noted in areas related to the spatial units of analysis, improper definition of research concepts, the time frame, and the use of few or no statistical methods to confirm the presence or absence of environmental inequalities (Godman, 1996). In light of these challenges, this study seeks to extend the scale of time and space for a more complete understanding of environmental injustice. This study is in favor of the sites of incidents defined as fixed instead of mobile that involve hazardous materials, and these releases can potentially cause serious public health consequences for workers and the general public. The premised of this research is that people who live in close vicinity of the environmental incidents are affected most by hazards and that everyone in that vicinity is equally likely to be affected with no regard to the age.

A review of the literature review shows that researchers usually categorize the vicinity of the fixed facilities as high impact zone, and those far away as low impact zone with a buffer distance. The mostly used buffer distance is 1 mile, the buffer zone is circled around the fixed facility point by a radius of 1 mile. Since the buffer distance of 1 mile is still arbitrary and can't be adequately justified in this research, it is advised to explore different ways to approach the issue of environmental injustice. A new design is as follows: First define the poor zone versus rich zone and minority zone versus white zone based on the demographic characteristics, then use the *Near*

Analysis command within ArcGis to calculate the distance between the centroids of tracts/county subdivisions and the nearest incidents. Lastly, control for the categorization and test for the difference of mean distance between the respective groups.

According to the definition in the GIS environment, the centroid is a polygon's mean center which is based on the weighted average of its X and Y coordinates. Visual basic codes are used to calculate the X and Y coordinates which is the basis for creating the centroid point layer.

This study is based on the assumption that the health impact and environmental burden of populations living near the accidents involving hazardous materials suffer more from the accidents than those further away. Margai (2001) defined the immediately adjacent areas from the accidents are as the high impact zones, whereas the areas further away from the accidents are defined as low impact zones. This research instead defines the social economic characteristics first, and then compares the distance difference. Drawing from the literature on environmental injustice, the conclusion on the existence of environmental injustice is largely a binary answer, which is not reliable or complete. Since different units of analysis may produce totally different findings, the unit of analysis should be paid more attention to when making conclusions.

For the study area, the SEMCOG region is categorized into two different groups by poverty status and race respectively, a white zone is those tracts/county subdivision whose ratio of white population is greater than 0.6, the rest hence is a minority zone, and a poor zone is those tracts/county subdivisions whose ratio of poor people is greater than 0.6, the rest is accordingly rich zone. The primary purpose of this study is to determine whether minority and poor persons tend to live near the incidents involving environmental hazards, and furthermore, if the findings still hold true when they are based on the different unit of analysis on different scale. If the hypothesis is tested true, then the poor and minorities bear environmental burden in a disproportional way and environmental injustice exists.

Objectives of the Study

The objectives of this study are to:

a) Verify the distributional environmental injustice based on environmental hazard locations both geographically and statistically.

b) Explore different methodologies to approach the issue of environmental injustice.

c) Examine the effects of different units of analysis.

The fight against environmental injustice has been going on for decades, this research is based on previous work while trying to make use of the geographical techniques. Minority zone and poor zone will be identified by demographical characteristics, these groups should be paid more attention to, especially for the sake of the vulnerable populations such as young children and the elderly within these zones. Although right now there is no universal methodology applicable for the research of environmental injustice, it is still worthwhile to explore different ways to see the potential factors that affect the findings.

CHAPTER II

LITERATURE REVIEW

The issue of environmental injustice is well-known, although there is barely consensus on the definition, categorization, and the choice of unit of analysis. Studies on distributional environmental injustice largely center on the location of the unwanted fixed facilities or the toxicity and transfer of environmental hazards from incidents using one single unit of analysis rather than using multi-units (Brulle, 2003; Cutter, 1996; & Been, 1995). One research by Margai (2001) on environmental inequity is accomplished by using the incidents from both fixed facilities and transportation. What is not plausible about this practice is that it involves accidental factors of the incidents, which is uncontrollable and hence unaccountable when analyzing the existence of environmental inequity. To improve on the selection of incidents, this study focuses merely on the fixed incidents within the SEMCOG region as the study area to test for the existence of the hypothesis that higher percentage of minorities and lower economic status people tend to live closer to the environmentally dirty areas than other groups of people. What is distinct about this research is that it will extend the unit of analysis from census tract to Sub-county (township, city) to see if the conclusions will still hold true, if not, this study examines how the scale of study impacts the findings.

The groundbreaking environmental justice study, "Toxic wastes and race in the United States: A national report on the racial and social-economic characteristics of communities with hazardous waste sites" was produced in 1987 under the support of the United Church of Christ's Commission for Racial Justice, and is deemed as the earliest work on environmental injustice. The report presented maps of the locations of the country's hazardous waste facilities along with characteristics of the nearest populations (by ZIP code), using indicators such as race, ethnicity, and income, it concluded that more than half of all blacks and Hispanics in the United States lived in communities having at least one closed or abandoned hazardous waste dump site.

After that, studies on EJ have grown dramatically with the environmental activism or environmental injustice movement, meanwhile, academic confusion inevitably entailed. In addition to the research methods and the units of analysis, the definition of environmental injustice has different versions and meanings.

Definition of Environmental Injustice

Looking into the research on environmental injustice, one can easily come across another term called *environmental racism* being used frequently in the literature, and many times it is used along with the term *environmental justice* interchangeably, researchers do so with little attention to how to define these concepts. Drawing from Pellow (2001), environmental racism is part of environmental injustice (an environmental injustice occurs when a particular social group – not necessarily a racial/ethnic group – is burdened with environmental hazards), but it is more specifically focused on race-based differential enforcement of environmental rules and regulations without regard to the economic status. What is even more confusing is that *environmental inequity* also appears from time to time in the environmental literature. Pellow (2001) argues that "environmental inequity focuses on broader dimensions of the intersection between the environmental quality and social hierarchies. Environmental inequity addresses more structural questions that focus on social inequity (the unequal distribution of power and resources in society) and environmental burdens. That is, environmental inequity includes any form of environmental hazards that burden a particular group.

Maantary (2002) defined environmental injustice as "disproportionate exposure of communities of color and poor people to pollution, and its concomitant effects on health and environment, as well as unequal environmental protection and environmental quality provided through laws regulations, governmental programs, enforcement, and policies." This definition incorporates the concepts of both distributional and procedural justice.

According to the U.S. EPA, environmental justice is "the fair treatment for people of all races, cultures, and incomes, regarding the development of environmental laws, regulations, and policies. Fair treatment, in regards to environmental injustice, means, no person or group should bear a greater share of negative environmental impacts that result from environmental programs" (U.S. Environmental Protection Agency, 2007).

Cutter (1995) defines environmental justice as equal access to a clean environment and equal protection from possible environmental harm irrespective of race, income, class, or any other differentiating feature of socioeconomic status. For this study, environmental inequity and environmental injustice are used without differentiation to the distributional disparity of environmental hazards.

Although there are different perspectives in existence on the definition of environmental justice, they all share a common critical element, that is, every being deserves the right to clean environment, with no regard to its status, whether it be socially or economically.

Categories of Environmental Injustice

As Turner (2002) noted, environmental justice activists and academics have drawn from three broad categories: distributional justice, procedural justice, and entitlements. Distributional justice refers to distribution of harms (and benefit) over a population. For this standard to be met, the distribution of harms should not be more prevalent for any identifiable subgroup than another. Procedural justice focuses on the process through which environmental decisions are made. If decisions are made through a fair and open process, they may be considered just regardless of their distributional impact. Entitlements approach seeks to ensure that individuals (and communities) have effective access to and control over environmental goods and services necessary to their well-being.

Much of the distributional environmental injustice research focuses on the static investigation into the siting of industrial facility and the origins of pollution (Margai, 2001; Glickman, 1995), that is, it is only concerned with whether the neighborhood consists of high proportion of poor people or minorities at the specific time of research, rather than how the siting and the settlement of population interact with each other. For instance, if the residents settled around the industrial sites after it was established, then it is hard to tell if the environmental injustice exists there. The uncertainty of who came first, the noxious facilities or the people, is better to be explored through historical documents to get a full understanding of the issue. If it could be shown that the minority population came to the area after the facilities was in places to live then it might be that there are no other affordable places to live and they are forced to turn to the low quality neighborhood. One reason for this failure is because of the availability of data and the difficulty of analysis, so researches choose to explore the issue in a static manner. In order to reduce the bias resulting from deficiency records and extend the time frame, this research will use the data multiple years (2004 to 2006) for analysis.

The Geographic Unit of Analysis

Accurate estimation of human exposure to hazards across all levels of geographic aggregation is constrained by the paucity of suitable monitoring methods, proper measurement, and validated model for predicting exposure to populations of interest (Maantay, 2002). While it is highly beneficial to have some sound methodologies to measure environmental injustice, either to guide the decision making process or reduce the existing unequal distribution of environmental resources or hazards, it is not always easy to develop a universal one to do that. First of all, along with the limitation of the data sources there are many potential indicators of environmental injustice to choose from. The selection of appropriate indicators is dependent on the situation and the focus of the research. Another challenge here is that of interpreting the disparity relationship of the environmental conditions and the social and economic status with each methodology: why poor people minorities end up living in poor environmental conditions?

When dealing with the spatial aggregation of data, there is a so-called "modifiable areal unit" (MAUP) problem involved (Openshaw, 1983). Since the choice of the unit affects the comparability of studies and the strength of the statistical associations, MAUP is both a geographic and statistical problem that results from arbitrarily choosing of geographic boundaries or other parameters when making social and economic measurement. As environmental injustice is inherently a spatial problem, the MAUP makes it difficult to conduct research on environmental injustice. Choices of data aggregation include census tracts, zip codes, states, counties, cities, blocks, or block groups. Depending on the study scale and the capacity of the analytical method, the research can make different choices. Currently there are wide variations in the units of analysis used to test the environmental injustice hypothesis. The majority of studies have used administrative units such as counties, census tracts, census block groups, zip code areas, and buffer areas using GIS. The findings of some environmental injustice have been diametrically opposed to those of others just because of different geographic unit of analysis being used (Maantay, 2002; Williams, 1999). The contradictory findings confirm that the unit of analysis is a key factor to be considered in the study of environmental justice.

"The choice of unit of analysis can affect even the most basic findings of an environmental equity study. Had we used only block groups to define 'community' we would have found contrary to expectations that in the Toxics Release Inventory (TRI) communities the proportion of blacks and minorities is slightly lower than in non-TRI communities. Similar results come out for census tracts. This pattern is reversed, however, when we look at the proportions for the combined half-mile radius circles around TRI facilities vs. the areas beyond the circles. We also see that the proportion of blacks and minorities is substantially higher in municipalities with TRI facilities than those without such facilities" (Maantay, 2002).

Researchers have noted that, in general, data aggregated at high levels of governmental unit (county, or city, for instance) will be less reliable as indicators of disproportionate burdens, and less accurate in identifying the affected populations, than data aggregated by smaller units such as census block groups or blocks (Maantay, 2002; Bowen, 1995; Brulle, 2006). The reason for this trend is that there is so much variation in demographics and facility location within the larger geographic units, impact and burden are impossible to determine, and smaller units of analysis require more modest assumptions about causal and statistical variations in local phenomena. Bowen (1995) concluded that the issue of environmental equity is not amenable to county- level analysis. Analysis using smaller spatial units is more appropriate. Glickman (1995) found that the use of block groups gave the greatest number of potentially misleading results because of its lack of homogeneity in his study which employed a proximity method to assess the impact of the offending facilities on health of the people nearby.

Studies of distributional environmental injustice analyze the characteristics of the population potentially exposed to a type of hazard. Exposure is often defined as whether the population is within the same zip code, census tract, county, or municipal boundary as the hazard. This has the obvious drawback that the definition of proximity to hazard is too constrained to the predefined geographic boundary rather than the actual distance. So "the unit of analysis chosen may bear little relationship to the actual community affected and may severely distort the outcome of an equity analysis" (Glickman, 1995), which is true in some cases, for example, one might live near a hazard but right across the county line that encompasses the hazard, but s/he would not be considered to be impacted by the hazard for the purpose of the analysis, it also can be that one might live far away from a hazard but is within the county that encompass the hazard, and s/he still would be considered to be impacted by the hazard. This becomes less of a concern for the finer geographic levels of analysis if the analysis is solely based on the shared geographic boundary. Meanwhile, if the units of analysis are too small, say blocks, it will make the analysis too heavy to handle and some statistics are hardly available. Census tracts and counties are the most commonly used units of analysis because of the ease of use and availability of the data from the U.S. Census Bureau (Canfield, 2003). In summary, oftentimes the choice of units of analysis is constrained by the availability and ease of use of data.

Researchers have begun to seek ways to determine what constitutes the most appropriate units of analysis for these kinds of studies. However, many studies use only one single unit of analysis, such as census tracts, zip codes, or counties to examine the problem at a specific scale (United Church of Christ's Commission for

Racial Justice, 1987; Zimmerman, 1993). This study would use different aggregation on the same study area to test for the environmental injustice.

As an improvement over the common selection of analysis unit, some researchers use the actual proximity to the hazard to assess the population at risk by constructing buffer zones of specific distances around the hazard, capturing the demographic data for the entire population within the buffer regardless of what political district they are in. the buffer zones are usually established as circles with a radius of one-half mile or one mile (Cutter, 1996). Margai (2001) used atmospheric dispersion modeling method to delineate impact zones and find 1.4 mile an optimum radius with his study on two counties in New York. This method is risk-based measure and requires extensive information such as atmospheric conditions at the time of accident, air temperature, wind speed and direction, relative humidity, cloud cover, and some substance related information. It can be categorized into advanced proximity-based assessment method (Buzzelli,M. etc., 2003), except that it creates the buffer zones based on modeling the specific air conditions and the toxicity of substance released. In summary, the user-created zones serve as the unit of analysis.

Based on the already established single administrative unit as the unit of analysis, some researchers have noticed their common character and introduced a new conceptual unit called "community" (Taquino, et al. 2002; Williams, 1999). It is established by virtue of social and economic relationships among people living in geographic proximity to one another and by the relationship between people and the physical environment in which their daily needs are served. This is a flexibly constructed unit of analysis which reduces some unreasonable compromises caused by the data availability and ease of use, the advantage of it is that it is based on the primary investigation of the characteristics of its neighborhoods.

The Analytical Methods in the Study of Environmental Injustice

Looking into the studies on the environmental justice, Geographic Information Systems (GIS) have proven their great potential especially in mapping and storing huge amount of information on the environmental issues (Menis, 2002; Buzzelli, 2003; Maantay, 2002). As one of most commonly known applications, GIS is used to map environmental injustice to visually demonstrate the disproportionate spatial distribution of hazard, and more importantly it offers a unique, flexible way to examine the effects caused by using different units of analysis and devise more appropriate units of analysis. Many geostatistical functions have been incorporated into GIS software packages or are available as extensions. For instance, the Spatial Analyst extension is available for both ArcMap and ArcView 3.x software. Moreover, users can program an interface within GIS for their own specific purpose. Many function used to be done in special statistical software package now can be accomplished within GIS software, these include Inverse Distance Weighting and

Spline methods of spatial interpolation on point data, all these together add much values to GIS (McMaster, 1997).

One shortcoming noticed in Margai's study (2001) which also uses the accident data with environmental hazards is that of duplicate use of census data for both high impact zones and low impact zones. The author created buffer zones around the accidents using a radius of 1.4 miles based on the Areal Location of Hazardous Atmospheres (ALOHA) program, and labels those tracts within the buffer zones as high impact zones, whereas those outside of the buffer zones low impact zones. Since some census tracts are intersected by the buffer boundaries, the census data for those particular tracts are used twice, once for high impact zones and the other for low impact zones. So when using the statistical method to compare those two groups, it obviously skews the indication of the census data.

When dealing with the boundary sections. Areally weighted interpolation methods are widely used when the boundary needs to be split. Since the assumption that the population is evenly distributed in reality is not always true, the assumption will be imposed twice when it were used, once for target group, the other for total population, causing much more ambiguity because of the boundary problem. But within GIS environment, if the research is concerned about the ratio of one group to the total population instead of the actual population in the split sections, *Spatial Query* within ArcGis can be applied to get around the problem and identify areas within a certain distance. Some researchers create a buffer area with an established distance, in reality the hard part with the process is how to justify the distance being used, it is not surprising to see different distances used in different researches, with the scale, the focus, or the indicators of the researches being often times different. But once the buffer distance is established, the next part can easily turn to *Spatial Query* which is one option of the selection methods. The outcome is that units whose centroids are within the established distance are isolated from those outside the buffer distance, and all units is still whole ones.

CHAPTER III

DATA AND ANALYSIS DESIGN

Environmental Data

To keep the research problem consistent and minimize certain accidental factors, such as incidents from road, air, and water transportation, this research will confine the environmental hazards to those ending up in fixed locations, that is, the fixed incident sites involving environmental hazards in relation to the neighboring demographic characteristics. This study will use location data associated with fixed incidents and eliminate those non-locating fixed data.

The environmental data on incidents involving hazardous substances were obtained from the "Emergency Response Notification System" (ERNS). The ERNS is a national database used to store information on releases of oil and hazardous substances, extremely detailed information regarding the incidental releases of both fixed and mobile facilities are recorded in this database. This includes description of accident, type of accident, accident cause, date and time of incident, incident location description, location address, nearest city from the incident, location state, location county, and location zip code, etc. The ERNS database is managed by the United States Environmental Protection Agency (EPA). As with most self reported data, there are some concerns with reported reliability, particularly with underreporting of the occurrence and severity of the accidents (Margai, 2001). As such, this study will not deal with the severity of the incidents, instead it will base the analysis on the proximity to the occurrence. The ERNS records suggest that the SEMCOG region is the heaviest bearer of the accidents among all counties in the State of Michigan. In the year 2006 alone, SEMCOG accounted for more than a quarter of the total accidents.

In order to get more samples, the environmental data for the most recent years 2004, 2005, and 2006 are combined to extend the time frame instead of using data for a single year. Since the major concern of this research is about the incidents' location and the well being of the neighborhood, incidents' sites for several different years are used for analysis rather than randomly choosing one year. What follows are a few descriptions about some incidents: "The caller stated that the hydro electro generating unit leaked material; A vehicle struck a pole mounted transformer causing a release onto the pavement and into a storm drain; The caller stated that due to a storm, a pole with a transformer on it fell down. The contents of the transformer discharged from it; Caller stated a thermometer somehow got broken and the materials have released onto the bed; Caller stated that a valve on a pipe at an asphalt facility released onto the ground and into a pond due to unknown causes." (U.S. EPA, 2007)

Demographic Data

The U.S. census data are used for demographic analysis. Such data are available at various spatial resolutions, from blocks all the way up to counties. Collected every ten years, the most recent census data is available for the year 2000. For this paper, the demographic data is acquired from US Bureau of Census at census tract level and county subdivisions (U.S. Bureau of Census 2000). Race, economic status, as the most commonly used indicators in the study of environmental injustice, are the parameters chosen for the analysis. Specific variables were drawn from existing environmental studies to measure the economic conditions and racial make-up of the neighborhood of interest.

Since there are many factors that may influence the real economic status, say, the size of the household, the source of income, the age structure of the household, education, etc. it hardly can construct a comprehensive indicator to fully tell the real economic status. Finally the total population for whom poverty status is determined was chosen as the indicator of the economic status, since it is indicative of the poverty status and is easily available for both census tract and county subdivision level. Besides, the median household income is not useful when the mean household income is not available as comparative variable to determine if it is a poor tract/county subdivision or not. The ultimate selection of the variables is as:

P006002: Total population: White alone

P006001: Total Population: Total

P087002: Population for whom poverty status is determined: below poverty line: Total

Selection of the Unit of Analysis

Since the accidents normally did not occur at the center of census tract or county subdivision, choosing single geographic divisions that encompass the accidents may be misleading or even produce totally wrong results. Furthermore, "the census units are often bounded by very real geographical features, such as roads, rails, and rivers and socio-demographic characteristics of these units may change substantially on crossing these boundaries" (Glickman, 1995). In addition, the geocoding process is a rough estimate with some matches being not a 100 percent success or the match score is extremely low, so it is not a bad idea to create a buffer zone centered on the rough location of the accidents to measure the environmental risk. But when using buffer distance, it is hard to find a optimum and justifiable distance. So it is advised not to use the buffer distance to categorize the groups, instead use the social-economic status to categorize the groups first and then compare the difference of mean distances between the units and nearest incidents.

Based on the reviews of the literature on environmental injustice and data availability, the choice of unit of analysis and scale plays a critical role in the environmental injustice study, as such, for this research census tract and county subdivision (city, township) will be used as units of analysis. The reason why county subdivision is also chosen as the unit of analysis is that county subdivision is an alternative unit on regional scale to represent the geographic entities. The sizes of both of the units vary widely depending on the density of population, and some tracts and county subdivisions share boundaries especially for those less densely populated regions, but the average size of tract is smaller than county subdivision.

Geographic Analysis

1) Locating incidents involving environmental hazards (Geocoding Process)

Geocoding is accomplished in the ArcMap environment. The street addresses of the accidents come with each record of the report. These data are aggregated for the years from 2004 to 2006 so as to create more point features for analysis. Each record was identified by the sequence number assigned to the accidents chronologically. It is no surprise that there are cases where different sequence numbers share the same address but represent different accidents, so one point feature on the created map may represent several incidents which is unreadable from the map, hence there are fewer points appearing on the map than the real number.

The first step of the geocoding process is to create an "Address Locator" previously known as "Geocoding Service". There are a number of different styles available to choose for the "Address Locator" depending on the address element (zip code, street name, street number, city, State, etc.) available and the accuracy needed for the problem at hand. For this research "US Streets with zone" was chose given the attributes stored in the road layer as the reference layer here which is obtained from the Michigan Geographic Data Library.

There were more than 240 fixed incidents associated with environmental hazards for SEMCOG region over the three years (2004 - 2006), with some addresses missing from the record. Upon data cleanup for geocoding, there were 198 records left with addresses associated, among which there were 167 unique addresses. In order to maintain the original record information, no screen analysis was performed to keep one single record for each address. However, when looking at the geocoding results, this may have caused inaccurate report since one address might be counted several times. Furthermore, due to inaccurate address information provided in the environmental database, the success rate was not very high. There were some addresses that seemed identical but spelled differently, which caused misleading result, for example, "1300 S. FORT ST, Detroit, MI, 48217" and "1300 South FORT ST, Detroit, MI, 48217" most likely refer to the same location, but due to their different prefixes, the ArcMap identifies them as the different locations, as a result, the former is matched with one hundred percent success while the latter is unmatched. Both are identical, representing one single point on the map. The unmatched one could be neglected to keep the matched one, but if one incident occurred only once on a specific location and the address was misspelled, it was attempted to be matched manually. Ultimately there was literally a 74% success rate of match with the bottom score of 66%, the number of events matched is 147 (figure2).

As an exploration of the distribution of the poor people, the density of poor is also mapped out. When computing the population density for which the poverty status is determined for the county subdivisions, it is possible that some abnormally big numbers will come up, e.g. 20,000 persons per square km, which is misleading, the reason why this happens is that there might be several polygons belonging to one certain city or township in the census boundary layer. When the demographic data were joined, each of these polygons had one identical total population but different individual area. When doing the sheer mathematical computations, the results were wrong. To correct this error, the area of these pieces for each city or township is summarized by the county Federal Information Processing Standard code and total area of each entity is assigned to them, so each different pieces of one geographic entity has an identical density value for the whole administrative unit.

Originally the minority groups chosen for this research included Black or African American, American Indian and Alaska native, and Asian, the operational variable were the housing units occupied by the selected groups, and these three groups were summed up to represent the minority. Since the biggest minority Hispanics and some others were missing, the primary design was clearly problematic. To correct the problem, the minority is now defined as all groups other than whites as a whole. The population of minority is obtained from the subtraction of whites from the total population. To see the distribution of the poor people, both the density and ratio of population for whom the poverty status is determined were calculated and analyzed.

2) Overlaying

Upon the completion of Geocoding process, geographic boundary layer with the population information associated were overlaid under the incidents point layer. Next step was to categorize the neighborhood into two different groups by different indicators. When the majority of the population is composed of whites, e.g. the ratio of white to the total population is more than 0.6, the area was treated as the white zone, and the rest was treated as minority zone in the study. When the comparison is performed, it was found out that there were an overwhelming big proportion of tracts/county subdivisions that had whites more than half of the total population. To make the classification more conservative, white zone is now defined as those that the proportion of population of white to total population is no less than 0.6, and accordingly, the rest is minority zone. Similarly, rich zone is defined as that whose proportion of the population above poverty status to the total population is no less than 0.6.

Statistical Analysis

The final step is statistical test, which is accomplished by merging the demographic data using census tract identification code and county subdivision identification code to the geographic boundaries at both the census tract and county subdivision within ArcGis environment. White zone versus minority zone, and poor zone versus rich zone are first identified, and then its associated attribute database file is exported for statistical analysis.

For this research it is intended to compare the statistical significance of a hypothesized difference between the means of the selected variables of the two groups. With this distance-based approach, the population information is used for categorization, since the population information is determined it is used as a controllable variable, based on the categorization by population the distance between the centroids and the nearest incidents is the ultimate parameter to compare, accordingly groups 1 and 2 represent minority zone versus white zone or poor zone versus rich zone. Since those geographic boundary areas (census tracts and county subdivisions) are independent entities and samples are big enough, an independent sample t test is performed in using statistical software package.

CHAPTER IV

RESULTS AND DISCUSSION

Results

From the geocoding result, it is clear that there is a quite distinct cluster around the Detroit area in terms of incidents point. Visually both census tract and county subdivision based maps show similar patterns. Minority groups tend to have a closer proximity around the incidents, which contrasts to the pattern of the whites. Also as expected, the ratio of population for whom the poverty status is determined to the total population is higher around the incidents (figure4, 5), as the darker color represents higher values while lighter color represents lower values.

It should be noted that the points on the maps show the distribution of the incidents that happened in the years from 2004 through 2006 in SEMCOG region, Michigan, this is accomplished through Geocoding procedure within ArcGIS. A questionable point here is that it does not accurately portray the real number of the incidents because some points on the map may represent several incidents. Overlaid with the census tracts (1399 in total), the incidents' distribution can be analyzed in relation to the census tracts, this is done in the statistical analysis section with the help of SPSS.

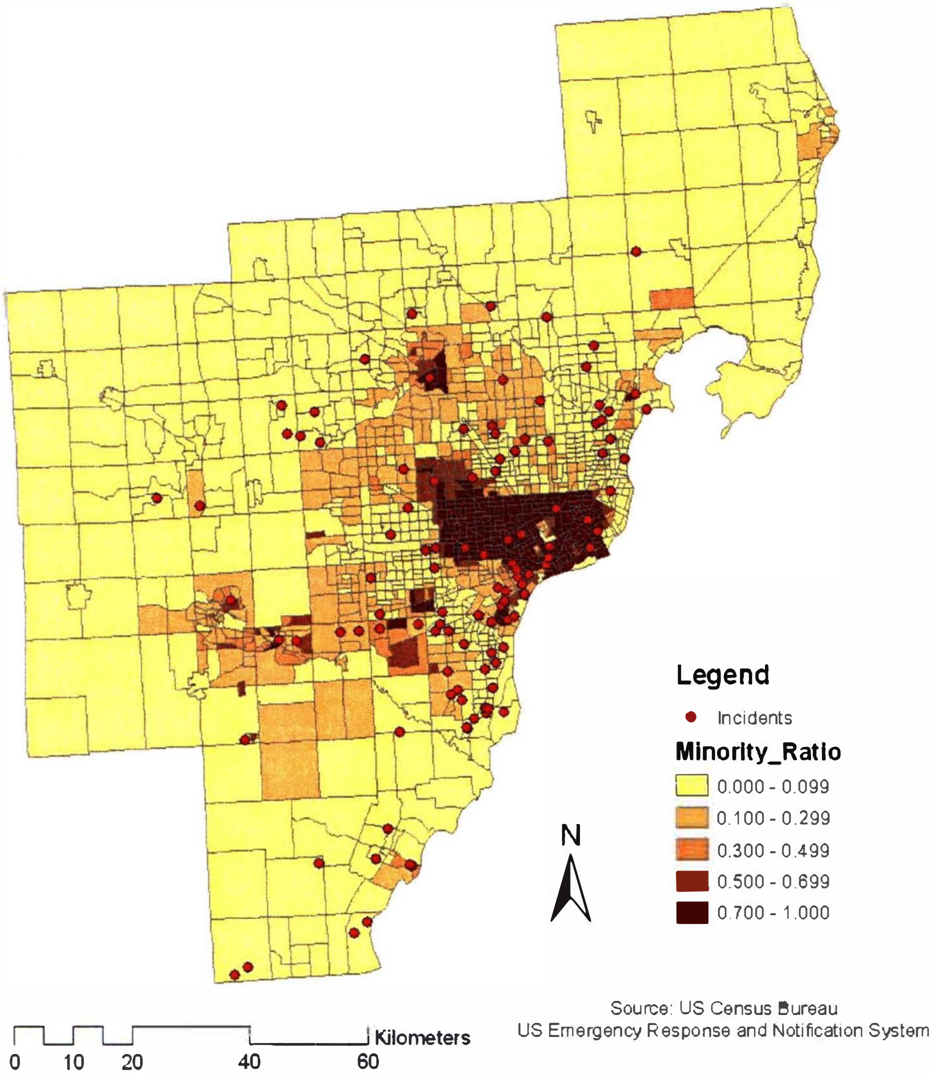

Figure 2: Census tract based ratio of minorities in SEMCOG region: 1999

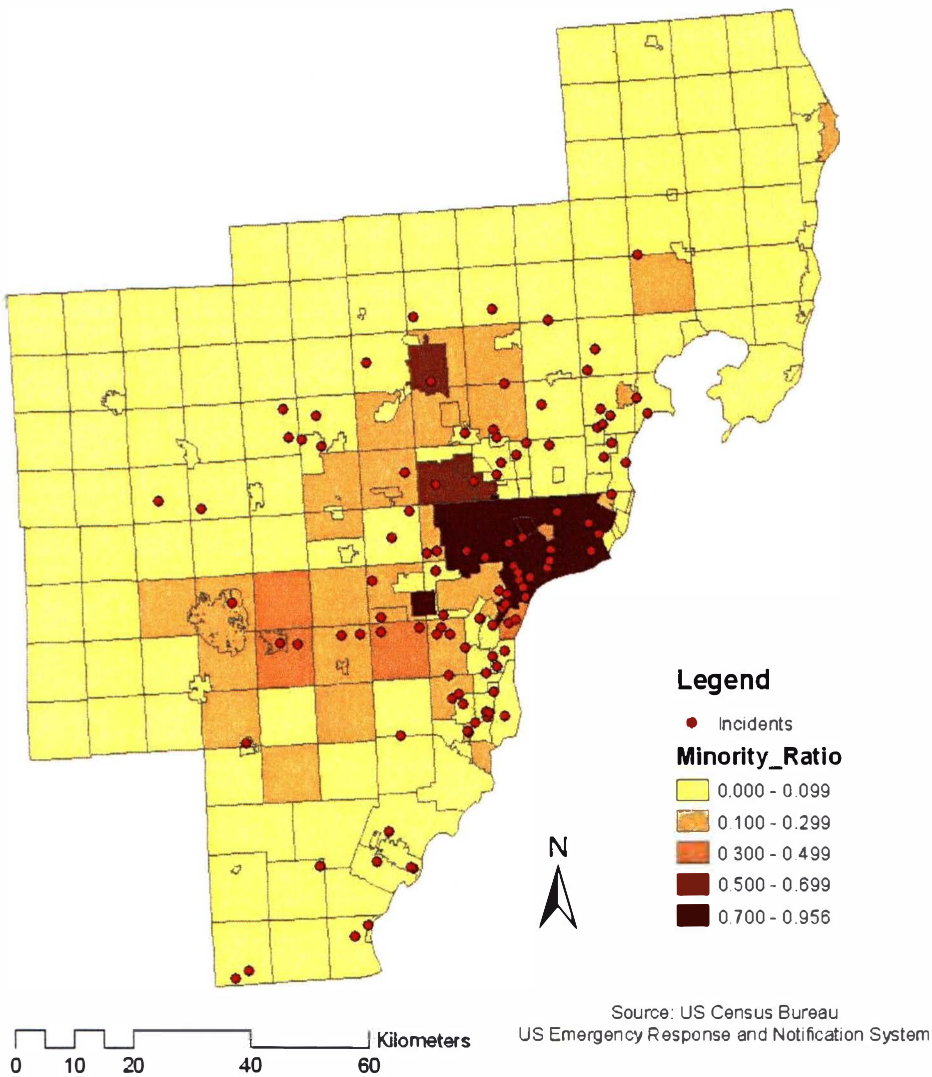

Figure 3: County subdivision based ratio of minorities in SEMCOG region: 1999

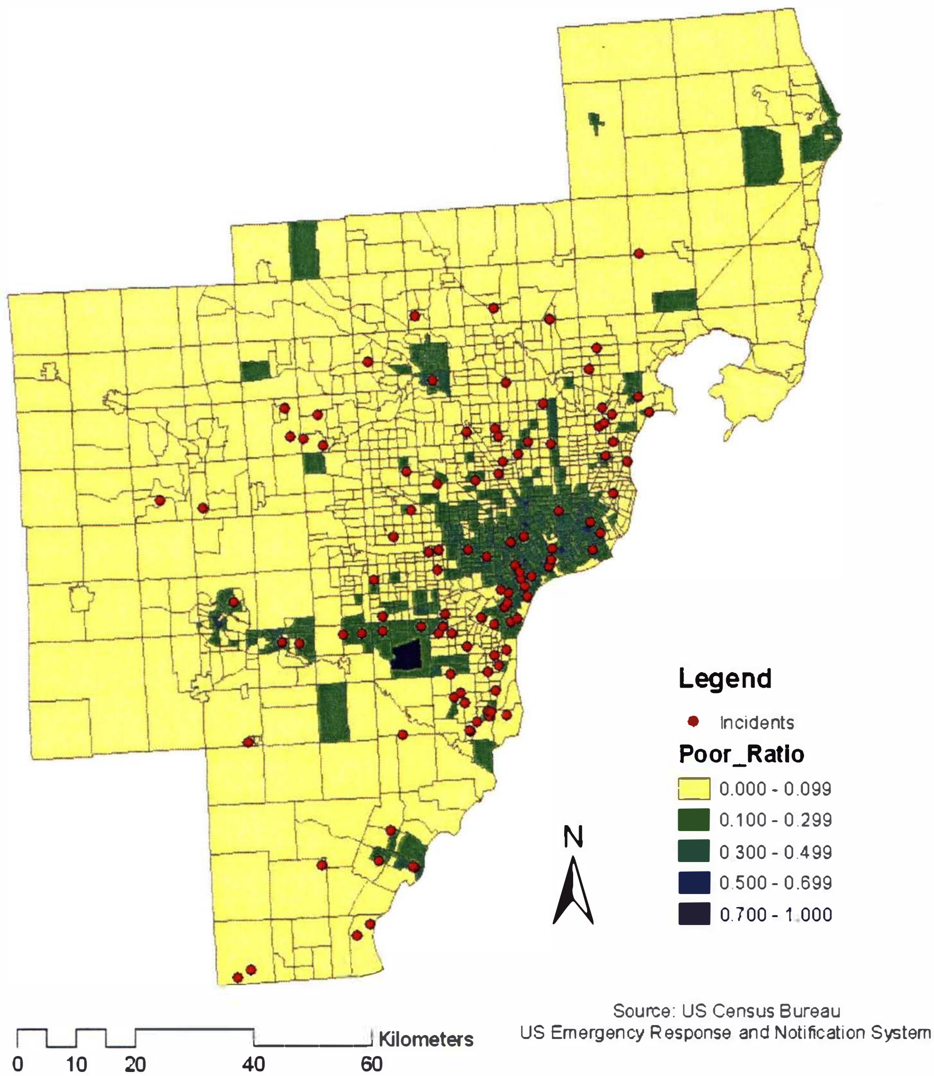

Figure 4: Census tract based ratio of poor population in SEMCOG region: 1999

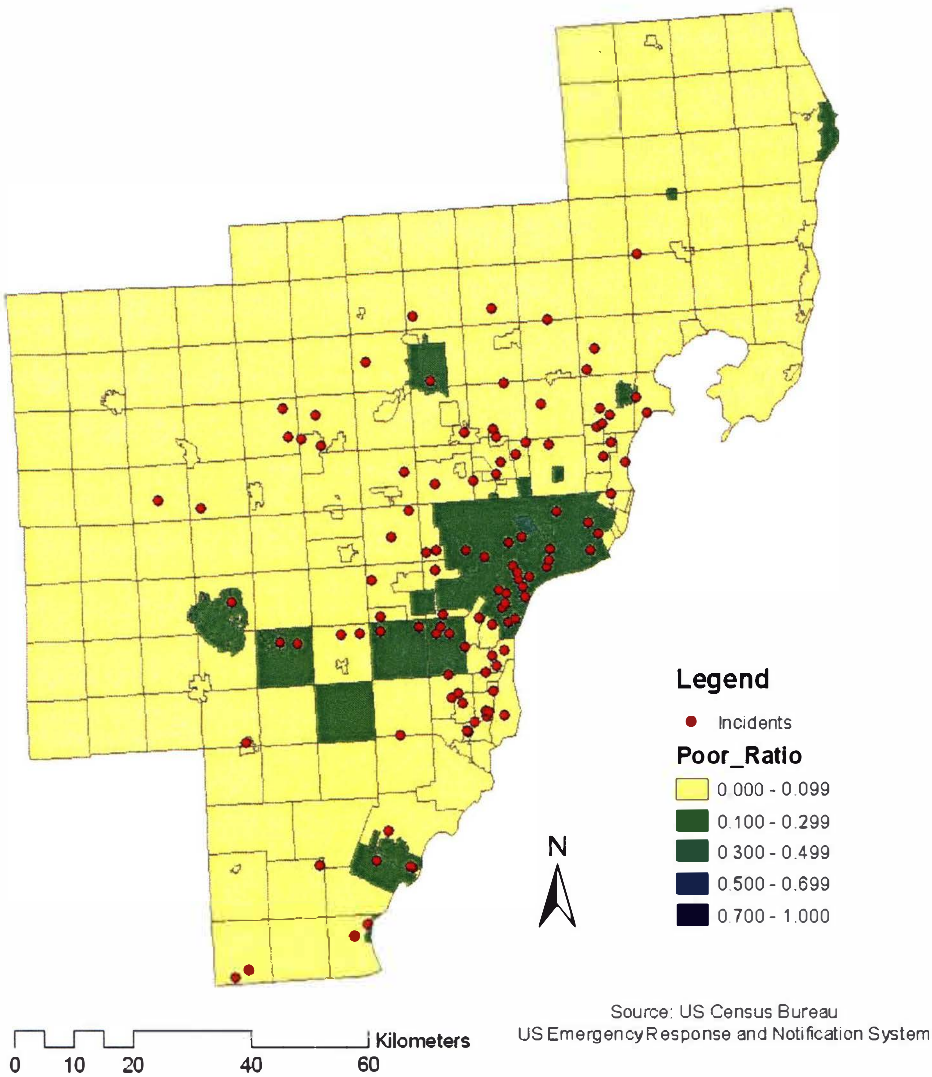

Figure 5: County subdivision based ratio of poor population in SEMCOG region: 1999

Output of the independent sample t tests for both census tract and county subdivision shows that the mean distance of the centroids of the tracts/county subdivisions from the nearest incidents within minority zone is significantly smaller as opposed to white zone, which means minority people tend to live near the incidents involving environmental hazards (Table 1). As shown in Table 1, the column significance indicates a consistently high level of confidence. With poor zone versus rich zone, the significance level is also as high, and the overall mean distance of the centroids from the nearest incidents within poor zone is less than that in the rich zone.

Tablel. Comparison of mean distance from the centroids to the nearest incidents between the categorized groups

Unit	*Type*	*N*	*Mean distance (m)*	*Mean Difference (m)*	*Sig.*	*t*
Census Tract	Poor	57	2231	-2917	0.000	-3.337
	Rich	1342	5148			
	Minority	402	2579	-3438	0.000	-9.353
	White	997	6017			
County Subdivision	Poor	11	3547	-5889	0.032	-2.078
	Rich	276	9436			
	Minority	20	3140	-6524	0.000	-3.061
	White	267	9664			

Note: census tract based analysis and county subdivision based analysis are performed separately

As can be seen in Table 1, the unit of analysis does not play a significant role in the results of analysis in this study when the operational analysis variable is based on distance. The poor zone versus rich zone is determined by the ratio of rich population instead of density of poor population, the significance level of both census tract and county subdivision based analysis exceeds 95 percent, reaching nearly 100 percent except the poor vs. rich at the county subdivision level. Overall the racial and economic indicators demonstrate a consistent pattern as expected (with the confidence interval being 95%, Sig. <0.05), the computed distance is significantly less within the minority and poor zones than in the white zone and rich zone at both census tract and county subdivision levels. The results show that there is a trend that social-economically disadvantaged people tend to live near the environmentally unfriendly sites.

CHAPTER V

SUMMARY AND RECOMMENDATIONS

A growing number of studies have been conducted on the issue of environmental injustice, focusing on either the procedural aspect, or entitlement, or the spatial distribution. This study analyzes the spatial distribution of accidents involving hazardous material release relative to the demographic characteristics of the residents nearby. The accident information for this study was acquired from the United States Emergency Response Notification System database for years 2004 - 2006 while the population and housing data were from the 2000 Census at both census tract and county subdivision levels for the southeast region of Michigan.

Although all these incidents are unintentional, the consequences warrant human beings to take action to minimize the chances of incidents and value every life. This study explored the existence of environmental injustice from a geographic perspective. It integrates both spatial analysis anf statistical techniques to analyze the proximity of residents to the environmental hazardous incidents at both the census tract and county subdivision levels. The results show the trend that minority people and poor people tend to live near the environmentally undesirable sites. Actions need to be taken to help these people to enjoy equal rights to clean environment.

Since the environmental injustice is a big social issue, it is hard to reach consistence in the conclusions as there are wide variations in the choice of units, research methods, indicators, data source, direction of research, and historical background (why and how did the phenomenon happen), due to the time and resource constraints, this study has not thoroughly investigated the interactive mechanism between environmental injustice and other factors such as industrial development, immigration/migration, and urban planning.

The research did not explore the actual health impacts of these environmental hazards from the incidents either because when dealing with the distance, the toxicity and its duration varies with the substances released. Another limitation is that this research did not select specific groups such as children and women for more comprehensive analysis. There are still more vulnerable groups other than the poor and minorities who may also be disproportionately at risk, such as children and the elderly that are not addressed in this study.

Recommendations

As to the economic indicator, the density of poor people might a better indicator to categorize the neighborhood as it is normalized by the area. If the poor zone versus rich zone is categorized by population density, the results might enforce the findings: the mean distance of the centroids in the poor zone from the nearest incidents tend to be shorter as shown in figures 6 & 7. Further research requires incorporating other relevant information, such as amount and toxicity of toxic releases, into GIS-based research with spatial data. Since environmental injustice does not occur in a short period of time, the historical factors may account more for its present pattern. An exploration of residential and occupational segregation and education background might help interpret the disparity relationship of the environmental conditions and the social and economic status: why do poor people and minorities end up living in poor environmental conditions?

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