Influence of the Palisades Nuclear Power Plant on Residential Housing Prices

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INFLUENCE OF THE PALISADES NUCLEAR POWER PLANT ON RESIDENTIAL HOUSING PRICES

by

Nicole N. Blodgett

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

Western Michigan University Kalamazoo, Michigan December 2004
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Nicole N. Blodgett
INFLUENCE OF THE PALISADES NUCLEAR POWER PLANT ON RESIDENTIAL HOUSING PRICES

Nicole N. Blodgett, M.A.
Western Michigan University, 2004

The controversy over the influence of nuclear power plants on property values is a continual debate among communities (Clark et al. 1997). I will be looking at a sample of 400 residential houses within a twelve-mile radius of the Palisades Nuclear Power Plant in Covert, Michigan to see how the location of the plant influences the home sale price. Several structural, neighborhood, and demographic characteristics were compiled for the analysis. In addition to these characteristics, distance to the plant, a visibility component, and a dummy variable to indicate all properties within a quarter mile from the Lake Michigan shoreline were also included in the dataset.

Variogram models, kriging models, and hedonic regression models will be used to assess the data. These methodologies will help determine what factors influence the sale price of residential properties surrounding the Palisades nuclear power plant.
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CHAPTER I

INTRODUCTION

The Palisades nuclear power plant is located in Covert, Michigan on the shoreline of Lake Michigan. Several popular tourist destinations, historic areas, small businesses, and medium-size manufacturing facilities surround the plant. The area has a diversified economic base, which also includes agriculture, wineries, and a variety of service industries. These diverse land uses and economic activities provide an attraction for real estate and an opportunity to assess the property values within a twelve-mile radius of the Palisades nuclear power plant to determine possible effects of the power plant on property values.

Previous research shows that disamenities, such as nuclear power plants, can negatively affect surrounding property values (Folland and Hough 2000; Bloomquist 1974; Hamilton and Schwann 1995). A disamenity is defined as an aspect of a property that decreases its value. It is a feature of a property that would make a home and or land less desirable and unattractive. Perceptions of features surrounding a property can also become disamenities. A nuclear power plant is often thought of as a disamenity.
because of the negative opinions associated with the facility that include pollution and possible health impacts.

Studies have also looked specifically at the consequences of negative and positive perceptions of nuclear power plants (Clark et al. 1997; Galster 1986; Trolley 2000). Those who hold a negative perception of the plant may be fearful because of the potential danger the plant holds. If one believes that nuclear power plants are unsafe or unpleasant to look at, it will ultimately affect the sale price of a house if potential buyers believe there are risks associated with the plant.

There are also positive influences that are associated with nuclear power plants. Nuclear power plants employ many people in the community. For example, the Palisades nuclear power plant employs over 650 people (Nuclear Management Company 2002). Employees of the plant are often less fearful of the potential dangers because they are more informed on how the plant operates and of the safety issues involved. Employees of the plant may also want to live near their workplace to ensure a shorter commute time (Kivimaki and Kalimo 1993). Consequently the number of people the plant employs not only contributes to the local economy, but also may increase the real estate prices in the areas
immediately surrounded by the plant. Additionally, nuclear power plants provide a clean and reliable source of electricity.

The controversy over the influence of nuclear power plants on property values is a continual debate among communities. As mentioned above, Clark et al. (1997) and Kivimaki and Kalimo (1993) present opposing viewpoints with Folland and Hough (2000) and Galster (1986) on this issue. Clark and Kivimaki and Kalimo both found evidence that a nuclear power plant does not influence property values. Kivimaki and Kalimo found accessibility for employees who work at a nuclear power plant to be valuable amenity. While Folland and Hough and Galster both found evidence that nuclear power plants do have a negative impact on the property values. Folland and Hough and Galster both found land depreciates in value upon the announcement of the installation of a plant.

Other disamenities such as hazardous storage facilities, electric utility lines, and airport noise have also been used to determine how certain land uses have influenced property values (Zeiss 1998; Kiel 1995; Bloomquist 1974; Espey and Lopez 2000). Many generalizations can be made about property values that are located near a major disamenity. For a more refined answer
over the controversy each community must be evaluated separately. This study evaluates the community surrounding the Palisades nuclear power plant and explores the relationship between proximity to a potential hazard and housing prices for the real estate market in Southwest Michigan.

The focus of this thesis is to examine the relationship between the location of the Palisades nuclear power plant and the influence it may have on the sale price of residential homes. The objective of this research is to synthesize and analyze previous research efforts and incorporate geographic techniques to determine if the proximity to a nuclear power plant affects property values.

This study is empirical by nature and is not meant to resolve any specific real estate issues located in Southwest Michigan. Several methods will be employed to determine if proximity to the nuclear power plant has a negative, positive, or no influence on the sale price of a house. The study does not include primary research on the specific perceptions of the surrounding communities involved in this study. I will use previous research on perceptions of nuclear power plants to inform this current analysis.
Data used in this analysis were gathered via the internet during a one-day period to eliminate any changes in the market conditions. Only houses that were for sale were included in this study and used as observations. Sale price, street address, and several structural characteristics were gathered. Structural characteristics included: number of bedrooms, number of bathrooms, square footage of the house, and lot size. In addition to the structural characteristics, demographics were also collected at U.S. census block group level to be incorporated in the analysis. Data at the block group level will eliminate generalizations about larger tract level areas and pull out distinct characteristics for each particular area. Three additional variables were calculated in ArcGIS: distance to the Palisades nuclear power plant, a visibility factor (can one see the plant from a particular location), and a dummy variable to indicate all properties within a quarter mile of the Lake Michigan shoreline, all were coded as a presence/absence variable.

These variables will be used to determine if proximity to the nuclear power plant affects the sale price of the home. Even though there have been several studies similar to this research, there is still no clear answer to this
question. Previous research leads me to believe that residential sale values will be directly related to the distance from the nuclear power plant (Polland and Hough 2000; Galster 1986; Trolley 2000; and Kiel 1995). The closer you are to the plant, the sale price for a home will be lower and the further away you are from the plant the sale price for a home will be higher, assuming the same type of home on the same type of property.

Although I expect there to be a negative relationship between sale price and distance, I believe there will be a small price influence in the surrounding areas due to the plant’s start date in 1971. There has been no life threatening accidents at the Palisades nuclear power plant. Residents in the surrounding areas may feel more comfortable with safety issues in Southwest Michigan as opposed to locations where there have been major accidents with a nuclear power plant. Three decades have passed since the plant was built, which has given time for the residents who do not want to live near a nuclear power plant the opportunity to move away; those who have moved in after the start date were well aware of the implications and potential risk associated with nuclear power plants. While time and positive perception of the plant’s safety may result in no influence on residential home sale price,
the plant does not provide an aesthetic view. Despite these factors, noticeable pattern of price change moving outward, or further away, from the nuclear power plant is expected.

The methodologies that will be used include variogram models, kriging, and the hedonic price method (multiple regression model). Several software packages will be used in this thesis, including ArcInfo™, Microsoft Excel™, and SPSS™. Through the use of the above mentioned methods and software packages, the following research questions will be answered:

1. Does proximity to the Palisades nuclear power plant affect the sale price of a residential home?

2. Does visibility of the Palisades nuclear power plant affect the sale price of a residential home?

3. What factors influence the sale price of a residential property in a twelve-mile radius of the Palisades nuclear power plant?

The hedonic price analysis will be used to test the hypothesis that residential home sale price will be directly related to the visibility of the plant and to estimate the cost that a disamenity has on property values. The plant is not pleasing in appearance and may be considered as an “eyesore” or a disruption to the environment. The containment building where the reactor is stored is tall and can be seen by many local residents.
The smoke pouring out of it is unattractive and provides a constant reminder to people of its existence. I expect the results to show that homes with a view of plant have lower home sale price than the homes that are not within view of the plant’s containment building.

This study will provide further evidence on the effects of disamenities, such as a nuclear power plant, on home sale prices of residential homes in close proximity to these types of plants, by adding valuable information for similar studies in the future. This research will provide a concrete example for planners who are faced with locations where a nuclear power plant are located. The results will also help planners develop long-term and short-term plans for land use, growth, and revitalization for urban and rural communities because they will have a better understanding of the real estate market. It will also help the planners assist the local governments when making decisions on economic and environmental issues.

Lastly, this research will provide information for localities where a nuclear facility, hazardous waste site, or similar facilities are proposed. This research and results would present evidence on the effects of disamenities on future developments.
CHAPTER II

PREVIOUS LITERATURE

Land Use Models

Models of city structure have been used since the 1920s to understand patterns of urban land use for various regions. Land use describes how space is organized to meet the needs of society. Examples of different types of land use include regions used for business, industry, manufacturing, housing, and other services. Rural areas may be used for farming, orchards, ranching, or for preservation.

Both urban and rural areas include residential land. Urban areas and the bordering communities typically have higher population and more housing than rural areas. There are three well-known urban land use models used in geography. All cities are different and because of this a single model cannot fully explain the patterns of land use for all cities. These models have been redefined because of developing societies and changing landscapes; the models also reflect the impact of transportation improvements from streetcars to automobiles and highways. The three models are: the concentric zone model, the sector model, and the
multiple nuclei model. These three models represent the initial research on land use types in cities and the relationship with property values.

The concentric zone model, otherwise known as the Burgess model, was the first of the three models to be developed in the early 1900’s (Park, Burgess, and McKenzie 1925). This model describes land around the central business district (CBD) with a series of concentric rings (Taaffe et al. 1996) that describe different land uses (Figure 1). The inner ring is the CBD, the second ring includes factories and industries, the third ring represents low-class residential, the fourth ring identifies middle-class residential areas, and the outer fifth ring includes the high-class residential areas.

Not only did Earnest Burgess classify the types of land use around the central business district, more importantly he discovered a correlation between socio-economic status of households and the distance from the CBD. In general, higher income residents live at further distances from the CBD than the lower income residents. This model details how and why the low socio-economic status housing will be located near the heart of the city.

As population increases, the city grows and pushes outward
and the wealthy residents move further away from the CBD to better quality housing areas.

![Concentric Ring Model](image)

**Figure 1: Concentric Ring Model**

The Hoyt model was developed after the concentric zone model (Hoyt 1939). This model builds on the concentric zone model and incorporates the impacts of transportation systems and the accessibility for the residents of a particular area (Taaffe et al. 1996). The model includes a CBD with sectors that radiate out from the center (Figure 2). These sectors follow major transportation routes including highways, railways, seaports, subway systems, and trolley routes. This model theorizes that better accessibility to transportation systems will attract higher income residents and reflect higher land values. Lower
income residential sectors will form around the each of the different industrial and manufacturing sectors (Taaffe et al. 1996). Smell, noise, pollution, and less attractive buildings make these areas less desirable locations in comparison to area located further away from the factories and industries sectors.

![Sector Model](image)

Figure 2: Sector Model
Source: Taaffe et al. 1996

The multiple nuclei model was created after both the concentric zone model and the sector model because not all cities fit the spatial patterns of the previous land use models. The multiple nuclei model reflects the impact that highways have on urban areas. This model still used the CBD as the center of the model, but Harris and Ullman (1945) realized that many cities had grown to a point where
small non-central business districts were being formed (Figure 3). These small business districts were being considered small subsidiaries that surrounded larger cities. Wholesale and light manufacturing districts were found near major transportation routes while heavy manufacturing districts were located on the outskirts of the city. This model locates low-income residential areas (lower quality housing) in the less desirable locations and high-income residential areas (higher quality housing) in the more attractive and desirable places to live (Taaffe et al. 1996).

Figure 3: Multiple Nuclei Model
Source: Taaffe et al. 1996

More recent urban land use models include: polycentric and edge cities models. Polycentric land use models describe how cities are developing with more than one
central point to a city; the many different land use types in a city have their own central point. Edge cities are suburban districts. As higher income residents have moved away from inner city areas, they have also moved away from important amenities. Edge cities have moved their marketplaces to where they live, creating several self-sufficient districts outside of the CBD.

Public Perceptions and Housing Values

In general, land use values are related to the type of district or residential area. However, property values can be influenced by several external factors as well, such as neighborhood characteristics, environment and surroundings, and physical attributes of the property. Not only are property values influenced by external factors, but personal perception can also play an important role in shaping the market value of a property.

Location is a factor that can both lower or raise the value of property depending on the perception associated with the location and what the location may or may not provide. For example, if a property is located near major highways or shopping centers, it may raise the property value because people value convenience and accessibility. On the flip side, if a property is located near a structure
that is perceived negatively, such as a smoke stack pouring out black smoke, property values may be lowered because people do not want to live in areas that are not pleasing in appearance or ambiance. Grimston (2002) uncovered many public perceptions and opinions on nuclear power and nuclear facilities and how the public is involved. Several additional studies have been conducted to determine if negative imagery, perceived risk, and personal perception have a significant effect on residential property values (Bloomquist 1974; Hamilton and Schwann 1995; Clark et al. 1997; Metz and Clark 1997; Folland and Hough 2000).

Hamilton and Schwann (1995) and Bloomquist (1974) both found significant impacts on housing values within close proximity to a disamenity, such as coal-fired plant or high voltage electric transmission lines. In addition, Folland and Hough (2000) conclude that negative perception of nuclear risk causes a reduction in agriculture land prices. Clark et al. (1997) and Metz and Clark (1997), however, both evaluated two nuclear power plants in California and found no significant evidence of negative effects when residential homes are located near a nuclear plant facility or one decision on nuclear storage sites.
Nuclear Technology

There are over 100 nuclear power plants in the United States located in 31 states (Nuclear Regulatory Commission 2004). The plants supply the United States with electricity, but people have differing views regarding whether or not nuclear power should be used. The opinions of the general public influence the housing market in the areas surrounding a nuclear power plant. The below literature will discuss why nuclear technology is a controversial topic and why there are many different views.

There are several factors that may influence one’s perceptions of nuclear power plants (Grimston 2002). The perception of risk is often high after an accident, when the problems that did or can occur are publicly displayed in the media. People are more aware of the implications and undesirable effects of a major accident if they have previously been involved with one. One’s perception of risk may be minimal if they are more familiar with nuclear technology or if they have lived near a nuclear power plant that has encountered very little problems or accidents over the years.

Social and political factors can also influence these perceptions. One may be less fearful if (s) he either
works or has a family member who works at a nuclear power plant because one depends on the plant’s productivity and safety for their income (Grimston 2002). Political figures with strong personal views of nuclear power and the associated risks can easily persuade others to believe the same.

Grimston (2002) also examined why the public may be fearful of a nuclear power plant. He uncovered several reasons, which included secrecy, recent terrorist attacks, and previous accidents. Many people are unaware how nuclear power plants work. Further, when there are problems and accidents, details are hardly disclosed to the public, so the public has remained largely uninformed. Since the attacks on the World Trade Center and the Pentagon in 2001, there has been much talk about the abilities of terrorists and possible attacks on nuclear power plants in the United States. The Nuclear Regulatory Commission (NRC), the Federal Bureau of Investigation (FBI), and other government organizations have had several meetings and press conferences to discuss the United States susceptibility of terrorist attacks on our nuclear power plants.

The NRC has expressed its concern for highly populated areas where nuclear power plants are located and the need for better security and contingency plans. In an October
2001 brief, Tiwari (2001) from the Nuclear and Security Program examined the safety of our nuclear power plants in the United States. Tiwari expressed concern regarding the vulnerability of our nuclear plants because “experts consider U.S. nuclear reactors to be high-value targets for a terrorist determined to inflict large scale death and destruction in the county” (Tiwari 2001). Nuclear power plants are attractive targets for terrorist because the plants have emergency plans for accidents and unintentional mishaps, but terrorists could inflict intelligent attacks. These intelligent attacks are well planned and could not only cause destruction at the power site, which could result in mass casualties, but also planned attacks on the emergency planning efforts.

The concern for possible attacks on nuclear power plants in the U.S. has been an unsettling issue that dates back well before the attacks on September 11, 2001. In 1991, nearly half of the nuclear power plants failed a simulated security test by the NRC to resist a small terrorist attack (Orrik 1991). After the attacks in 2001, the NRC stated that the plants could resist a commercial jetliner. However, after more investigation it was revealed the scenario had never been considered and therefore there was never a contingency plan created for such attacks on a
nuclear power plant (Tiwari 2001). This information leads one to believe that an attack on a plant would leave us in a vulnerable state that we would be unable to handle. This uneasy feeling of vulnerability to attack a nuclear power plant is a major driving force pushing the public to be fearful. Tiwari concluded that since we are not properly prepared for such a catastrophic attack, we need to create short-term and long-term solutions to strengthen our security measures (Tiwari 2001).

Amenities vs. Disamenities

There are several factors that affect the market value of residential property, and ultimately the asking price, of a home. These factors include the location, the characteristics of the property itself, the condition of the home, the values of comparable properties, the market conditions, and the wealth of the economy. Locational and spatial influences may be the most significant factors. When looking for a home or property to buy, proximity to community amenities, the quality and consistency of neighborhood planning, future development plans, and local zoning are all important issues that will attract people to a particular area. There are also many factors that will be considered as annoyances or disamenities to prospective
buyers, such as unattractive buildings, power lines, noxious facilities, loud or continuous noises (from an airport or major highway for example), unpleasant smells, or difficult access to community amenities.

Hedonic modeling can help to determine and interpret the economic effect resulting from negative perception related to property characteristics. Hedonic modeling is a method used to estimate the value of a good by looking at a group of related attributes. It is usually calibrated using a regression model. Studies have used hedonic modeling to measure how property values are impacted with spatial attributes such as airport noise (Espey and Lopez 2000; Nelson 1979), public school attributes (Clark and Herrin 2000), transmission lines (Hamilton and Schwann 1995), electric utility lines (Bloomquist 1974), noxious facilities (Zeiss 1998; Kiel 1995).

Spatial Influence on Property Values

Much research has been conducted on how spatial attributes impact residential home values in relationship with how close the home is located to the particular influence. Espey and Lopez (2000) conducted research on the impact of airport noise and proximity to the airport on residential property values by using the hedonic price
method. The study area included a 42.9 square mile area around the Reno-Tahoe International airport in the state of Nevada. This study considered how noise compatibility affected the value of residential homes. Results showed that in areas with louder airport noise, measured in decibels, residential homes sold for less than homes that were located in areas that were quieter (Espey and Lopez 2000).

The negative relationship between the airport noise and the property values implies that the airport is a disamenity to the residents who live near it. I would argue that although the airport noise can be an annoyance to some, it could also become an amenity to others. Airports can both hold an amenity and disamenity value on property, which is dependent on a resident’s preference for either quietness or accessibility to a major transportation hub. One could assume that the noise from an airport would be a variable disamenity with the closer the home is to the airport, the greater the level of annoyance. Indeed, as one moves a certain distance away research shows that the noise is less of an annoyance and the airport becomes an amenity because of the ease of access to transportation.

Other factors also influence property values, such as the quality of public schools. In the case of positive
imagery and property values, one would expect that a positive perception would generate higher property values. Numerous studies have determined that public school quality is an important factor in location choice for prospective homebuyers and property values. Clark and Herrin (2000) looked at the impact of public school attributes on home sale prices in California. To determine if there was a significant relationship between sale price of a home and the quality of public schools, a large sample of homes that were sold in Fresno, California during the time period of 1990-1994 was used. Results showed that there is a significant positive relationship. The research results indicated that community or neighborhood characteristics are important attributes that can either raise or lower the sale price of a home. A high quality public school will raise the sale price of a home, while a low quality public school will lower the real sale price of a home.

Various visual externalities have been examined throughout the years to determine the influence they have on property values. Hamilton and Schwann (1995) conducted research on the effects of high voltage electric transmission lines on property values. Transmission lines are not only unpleasant to look at, especially if attached to a house, but studies show that people are also fearful
of the potential health and safety risks in involved (Priestley and Evans 1990). The results from Hamilton and Schwann revealed that there is a small negative impact on property values when high voltage electric transmission lines are within 200 meters of the house (Kroll and Priestley 1991). Hamilton and Schwann (1995) also concluded that there is a negative impact; properties adjacent to such a power line lose 6.3 percent of their value due to the proximity and visual impact. The impact may be small because construction firms take into consideration the negative effect it may have on property values. To reduce the undesirable visual impacts from the transmission lines, they will try to orient the houses to face the opposite direction or change the layout of the subdivisions to make the lots more appealing. In some cases, they will compensate the homeowners for being near the lines.

Bloomquist (1974) also found disamenities negatively impact property values. In this research a small clean electric utility plant located in a residential area provides electricity to the surrounding community, but those living within a two-mile radius thought of the plant as a nuisance and wanted to be compensated for unwanted effects. This electric utility plant contributed to a
significant decline in the property values within close
proximity to the plant. Total Possible damages for the
community could have accrued to the amounts of $200,000,
but other elements ran as high as $17 million. More
specifically, each property could lose 0.9 per cent of its
value for every 10 percent closer to the plant (Bloomquist
1974).

Zeiss (1998) and Kiel (1995) measured the effect
noxious facilities have on property values. Zeiss analyzed
69 property value studies to determine what facilities had
significant negative impacts on property values. Results
from the research indicates significant negative impacts on
property values at 20 percent of the sites for nuclear
power plants, 35 percent of the sites for hazardous and
municipal solid waste facilities, 88 percent of the sites
for waster quality impacts, 100 percent of the sites for
visibility of noxious facilities, and 40 percent of the
sites for electrical plants and lines.

Kiel examined the effect two Superfund sites have on
the city of Woburn, Massachusetts. This study looked at
the impact of the Environmental Protection Agency (EPA)
announcements and efforts to clean the sites. Data
obtained for this study included years prior to the
announcements and through the final agreements. Results
show announcements to clean the sites had little influence on the public’s perception; residents did not believe the cleanup process would be successful. Therefore Kiel found evidence that information on hazardous waste sites does influence property values.

Nuclear Power Plants Impact on Property Values

There have been many studies that focus on the impact of nuclear power plant on residential property values (Clark et al. 1997; Metz 1994; Metz and Clark 1997; Folland and Hough 2000; Gamble and Downing 1982; Glaster 1986; Nelson 1981; Kivimaki and Kalimo 1993; Trolley 2000; McClelland et al. 1990). These cases will be discussed briefly in the following paragraphs.

A nuclear power plant could affect the sale price of a home negatively, positively, or have no effect. Many studies have shown that there is negative imagery associated with nuclear power plants because of potential risks, unpleasantness of visual effects, noise, and many other reasons discussed throughout this paper. The negative imagery is attributed to the perceptions of individuals relating to the previous appearance of the community. Individuals may be fearful of living close to nuclear technologies and the community may be fearful that
nuclear facilities could possibly have a negative effect on the economy (Clark et al. 1997).

On the other hand, nuclear power plants can also possess positive imagery with respect to residential housing prices and to the local community. Those working at the plant may be less fearful and may actually want to live near the facilities for shorter commute times to work (Kivimaki and Kalimo 1993). Nuclear facilities may also be financially beneficial to the residents who own property in close proximity to a plant by lowering their property tax (Metz 1994).

The effect nuclear facilities have on property values is a controversial issue because of conflicting negative and positive attitudes associated with the nuclear technology. Folland and Hough (2000) and McClelland et al. (1990) both conclude that living in close proximity to a nuclear facility will significantly affect property values. However, Clark et al. (1997), Metz and Clark (1997), and Gamble and Downing (1982) conclude that living in close proximity to a nuclear facility does not significantly impact property values. Galster (1986) would argue that nuclear power plants have no long-term effect on property values, but have short-run effects on housing prices.
Folland and Hough (2000) disagree with those who have concluded that nuclear power plants have no impact on residential property values (Gamble and Downing 1982; Clark et al. 1997; Metz and Clark 1997). Folland and Hough found that these researchers make a generalization about all areas. In previous studies, researchers used only a limited number of cases, which resulted in location specific findings, but did not provide an overall answer that would explain the issue for all residential areas that were located near a nuclear power plant. Consequently, the results of prior studies may be true for a particular area, but not everywhere. Folland and Hough used 494 market areas, which included data for the years 1945, 1950, 1954, 1959, 1964, 1969, 1974, 1978, 1982, 1987, and 1992. Their in-depth research reveals that there is a strong negative nuclear externality. A negative externality occurs when a individual or business cause uncompensated cost to the economy. Furthermore, the research concluded that public perception of nuclear risk creates a reduction in land prices, especially with older reactors.

Similar to Folland and Hough, Galster's (1986) research contradicts the research of Gamble and Downing (1982), Nelson (1981), and Clark et al. (1997) and reveals that there was no statistically significant evidence that
property values were negatively affected after the 1979 Three Mile accident. Galster argued that there is a difference when you look at the short-term considerations. The studies by Gamble and Downing (1982) and Nelson (1981) looked exclusively at long-term outcomes. Short-term and long-term impacts depend on the following: "(1) the extent of the externality; (2) the nature and distribution of household preference; and (3) the degree of household mobility" (Galster 1986). However, when taking a short-term perspective, the results conclude that there is significant evidence that property values are negatively affected.

Galster employed the theory of reequilibrium to understand why Gamble and Downing and Nelson found no effect. According to this research, the over-riding issue to consider is the initial date when a plant was introduced to an area. At this point in time, those who oppose nuclear power, those who are fearful of living near a plant because of the potential risks, or those who believe their market value will depreciate because they are located in the zone of externalities will try to sell right away. Those who are indifferent to the presence of a new plant will outbid those who are not indifferent and will think they are getting a "wonderful deal" for the property. Over
time, all people who do not want to live in close proximity will move out of the zone of externalities, leaving only those who are indifferent inside the zone.

During this process the surrounding areas of a nuclear power plant will eventually reach a state of reequilibrium where the price gradient is not different throughout the community. In conclusion, Galster reveals that although there may be no significant long-term effects on property values, one must look at the initial introduction of the plants to find the short-term implications. In the cases of both Gamble and Downing and Nelson, their research took place a decade after the start up date of a plant, where market values had enough time to adjust the price differentials. The short-term impacts for the investigation were purely theoretical.

Some communities have been faced with a possibility of a nuclear facility being built in their neighborhoods. Many of those communities have fought to keep the structures out of their area. In a recent case, Trolley (2000) discloses the reasons why a proposed facility would be detrimental to property values. Trolley is one of the nation’s leading experts in urban and environmental economics and conducted an economic and environmental analysis for Libertyville, Illinois. His research was
conducted to determine how much effect the proposed Indeck nuclear facility would have on the property values.

Trolley discusses the factors that cause the facility to be a disamenity: visual effects, noise, effect on the reputation of an area, attraction of future undesirable land use if a disamenity is added, application to zoning, and inability to completely eliminate effects on residential neighborhoods. These factors all contribute to the overall cost the proposed facility would have on the community. Trolley used Bloomquist’s (1974) results to estimate the effects of the Indeck facility. In the event that the facility was located in Libertyville, there could be a total property value loss of $12.7 million and tax revenue losses of $3.8 to $44 million (Trolley 2000).

Hedonic Modeling

Several of the studies discussed above have used the hedonic approach to estimate the relationship between a specific disamenity and property values. A hedonic model estimate the price of a property based on the external characteristics of the property and on the characteristics of surrounding neighborhoods. The hedonic method dates back to the beginning of the twentieth century and the research of Hass in 1922 and Wallace in 1926 to estimate
the value of a good (Hidano 2002). In 1938 Andrew Court used the hedonic method to estimate the price of an automobile after the Great Depression. Court proved that the price of an automobile greatly declined after the depression (Hidano 2002). The hedonic method has also been used to establish estimates for price indexes for example, for a car or computer (Griliches 1971), housing prices (Bailey et al. 1963), and land prices (Hidano 2002). Although the hedonic method was established in the early twentieth century, it was not until the 1970’s that the flexibility of approach was recognized. Griliches (1971) and Rosen’s (1974) research established the theoretical model of housing markets and the foundation for implicit values of attributes for a good. This foundation follows the belief that the sale of a house is based on the house’s attributes and the willingness of a person to pay for these attributes. A person will be willing to pay more for a house based on characteristics they value, such as a location far away from potential hazards, aesthetic views, and structural attributes of the home.

Gamble and Downing (1982) used the hedonic price method to determine the effects of nuclear power plants on residential property values. Their study used a sample of 540 observations for four nuclear power plants. In their
multiple regression equation, independent variables included: year of construction, lot depth, corner lot, view, condition of the house, area of each floor, finished basement, attached or detached garage, fireplace, bedrooms, lot area, water frontage, distance to plant, and plant visible. The dependent variable was the actual market price of the residential property.

Hamilton and Schwann (1995) used separate regression models for three different distance zones to determine if high voltage lines affect property value. Independent values used in their model were tower visibility, distance from tower, and the joint effect at 100 meters and 200 meters. These variables were used to help identify variations in the dependent variable, property value.

Metz and Clark (1997) used the hedonic model to examine the effects of property values on the decisions to move spent nuclear fuel from wet storage to dry-cask storage. Clark et al. (1997) used the hedonic model to examine the influences nuclear power plants have on property values. In both studies, the dependent variable was the real sale price of the residential home, which was a function of variables in four categories: structural, neighborhood, nuclear, and time (Metz and Clark 1997) and structural, neighborhood, city, and year (Clark et al.
Attributes for the structural category were: age of house, number of bedrooms, central air conditioning, fireplace, number of full and half bathrooms, size of lot, and number of stories. Neighborhood characteristics included: nearest ozone monitor, proximity to airport, interstate, and railroad, and race and ethnic variables.

In addition to the hedonic method, Metz and Clark (1997) also used a number of geostatistical tools to create an interpolated surface of the real sale price of the residential property. This surface was used to reveal any price patterns of the residential homes surrounding the two plants under investigation in their study. Creating a surface helps to visually display any patterns the data may hold. It reveals where clusters of houses that have similar sale prices are located in relationship to the location of the nuclear power plant. Both of these methods, the hedonic regression method and geostatistical methods are used in the current study.
CHAPTER III

STUDY AREA

The Palisades nuclear power plant is located in Van Buren County, Michigan. The site is located south of the town of South Haven on the eastern shore of Lake Michigan. The study area expands twelve miles outward from this location. The majority of the study area is found in Van Buren County but it also encompasses portions of Allegan County to the north and Berrien County to the south (Figure 4).

![Study Area Map]

Figure 4: Study Area- Allegan County, Berrien County, Van Buren County, and the Palisades Nuclear Power Plant

The population of Van Buren County has been increasing steadily during in the past 40 years. In 2000, the
population was 76,263, representing 48.7 percent increase from 1960 (U.S. Census Bureau 2000). Allegan County has experienced a more dramatic increase with a population of 105,665 in 2000; this is a 65 percent change in population since 1960 (U.S. Census Bureau 2000). Berrien County experienced population growth from 1960 to 1980, then a decline in 1990. In the last decade there has been a slight growth with a population increase to 162,453 in 2000 (U.S. Census Bureau 2000). Overall, the study area has experienced population growth. This growth has continued through the introduction and start-up date of the Palisades nuclear power plant in 1971 and is still continuing to grow today.

Major urban areas within the study area include the cities of South Haven, Bangor, Hartford, Coloma, and Watervliet. These five cities plus the small town of Covert, where the nuclear power plant resides, were the primary locations of data collection. Property sales data was collected by the city zip code using two internet web sites, the National Association of Realtors and Southwestern Michigan Region Information Center, to search for property data and therefore descriptive characteristics of the study area are also categorized by zip code. Table 1 reveals the characteristics of properties on the study
area, such as the number of observations (property data) collected, average home sale price, average number of bedrooms, average number of bathrooms, and average square feet of the home for each zip code boundary in the study area.

<table>
<thead>
<tr>
<th>County</th>
<th>Homes Sampled</th>
<th>Average Sale Price</th>
<th>Average # Bedrooms</th>
<th>Average # Bathrooms</th>
<th>Average Square Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bangor</td>
<td>42</td>
<td>$108,407</td>
<td>2.9</td>
<td>1.6</td>
<td>1399</td>
</tr>
<tr>
<td>(49013)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coloma</td>
<td>74</td>
<td>$154,086</td>
<td>3.1</td>
<td>1.8</td>
<td>1442</td>
</tr>
<tr>
<td>(49038)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Covert</td>
<td>8</td>
<td>$227,725</td>
<td>3.5</td>
<td>2.4</td>
<td>1843</td>
</tr>
<tr>
<td>(49043)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hartford</td>
<td>51</td>
<td>$94,654</td>
<td>2.9</td>
<td>1.5</td>
<td>1365</td>
</tr>
<tr>
<td>(49057)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>South Haven</td>
<td>162</td>
<td>$212,004</td>
<td>3.2</td>
<td>1.8</td>
<td>1675</td>
</tr>
<tr>
<td>(49090)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Watervliet</td>
<td>40</td>
<td>$143,226</td>
<td>2.9</td>
<td>1.7</td>
<td>1480</td>
</tr>
<tr>
<td>(49098)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Descriptive Characteristics of Zip Code Boundaries

The shoreline of Lake Michigan attracts many people both in state and out and contributes significantly to the tourism industry of Van Buren County. Many people flock to these areas during the spring, summer, and fall months. Not only is Lake Michigan a great tourist destination for Van Buren County, but the shopping districts, restaurants, historic ports, and quaint towns all contribute to the value of real estate in the area.
The cities of Covert and South Haven have the highest average home sale price in the study area. This is more than likely because these two cities are located near Lake Michigan. The value of real estate along the shoreline is impressive and a valuable commodity in the area. Figure 5 provides a visual display of the patterns of average home sale price for each block group in the study area. In general, higher sale prices are located along the shoreline of Lake Michigan in South Haven, Covert, and Coloma while property values for the rest of the study area are substantially lower. There is one block group in the southern portion of the study areas that has a very high average home sale price because of one very expensive home in that particular block group.

Property Data

Home sale prices were obtained from two internet web sites that serve as public access for property searches - the official site of the National Association of Realtors (www.realtor.com) and Southwestern Michigan Region Information Center (www.SWMRIC.com). These websites were chosen because they supplied a variety of important housing information that could be selected according to certain criteria.
Figure 5: Average Home Sale Price ($) for Each Block Group

A sample of 500 residential properties was gathered on Tuesday May 15, 2004. The 500 properties all were found in the six surrounding zip codes within twelve-miles of the Palisades nuclear power plant: (Covert) 49043, (South Haven) 49090, (Watervliet) 49098, (Bangor) 49013, (Hartford)
49057, and (Coloma) 49038. The data was complied into an Excel\textsuperscript{TM} spreadsheet format included the sale price, property address, city, and zip code. Additional housing characteristics were also collected from the same web sites: number of bedrooms, number of full and half bathrooms, square feet, and lot size.

Geographic Data

Tiger files from the 2000 Census containing the street index for Van Buren, Berrien, and Allegan counties were obtained from the State of Michigan Center for Geographic Information (www.michigan.gov/cgi). Census blocks and zip code boundaries were also obtained from the same website in shapefile format. Several neighborhood characteristics were also gathered at the block level from the U.S. Census Bureau (www.census.gov), including demographic attributes such as total population, urban population, rural population, and median household income. Lastly, supplementary data were collected, such as total housing units and year of structure built. In addition to housing characteristics and demographic information, distance to the nuclear power plant, a visibility component, and a dummy variable to indicate all properties within a quarter
mile from the Lake Michigan shoreline were also added to the dataset.
CHAPTER IV

METHODS

The data for this thesis were obtained from multiple sources: the U.S. Census Bureau, Michigan Center for Geographic Information, the National Association of Realtors, and the Southwestern Michigan Regional Information Center.

GIS Tools

As indicated in Chapter III distance to the nuclear power plant, a visibility component, and a dummy variable to indicate all properties within a quarter mile from the Lake Michigan shoreline were added to the dataset. ArcGIS software was used to generate all of these variables. To get the distance from each property to the nuclear power plant, each home needed to be geocoded.

Geocoding is a process used in ArcGIS to match address data to a street index. Geocoding assigns each observation longitude and latitude coordinates from which the distance is computed. This process gives spatial descriptions and geometry to the data that did not have locational characteristics appointed to them. One of the initial steps in the geocoding process is to define the
appropriate geocoding service. A geocoding service is reference data, typically a street index, that contains both geometry and address information (ESRI 2004). This geocoding service is used to match the non-spatial data to locations in a given street index. When a match is found it assigns the point, geometry and spatial descriptions that are then placed in a new geocode file (ESRI, 2004). Ninety-two percent of the data was matched with at least seventy-five percent accuracy. Eight percent of the observations could not be matched to the street index for several reasons. Since the street index used was from 2000, it was not as up-to-date as the sales data collected for this study. The four-year difference in data sources is one reason several houses were not matched, mostly because the houses were new and the roads and addresses did not exist on the 2000 street index. Errors also existed in the street index itself with road names, zip codes, and street numbers (Clark et al. 1997). Lastly, data mismatches were caused by human error, for example errors generated by typing in the road names or addresses incorrectly. Observations that were not matched with an accuracy of seventy-five percent or higher were dropped from the study.
Next, the distance from each observation to the Palisades nuclear power plant was calculated using an analysis tool in ArcToolbox called point distance. To calculate the distances, a geographic projection and distance units must be set. In this study the digital map was projected in an azimuthal projection and meters were used as distance units. The point distance tool computes the distance from one point feature in a feature classes to all point features in another feature class. The results were displayed in meters in an output table which was later exported to an excel spreadsheet to be used as an independent variable in the regression model for analysis.

In addition to geocoding each property and calculating the distance from each property to the nuclear power plant, a visibility variable was added to each observation. This was accomplished by using a surface analysis tool in the 3D analyst extension in ArcGIS called viewshed. Calculating a viewshed was important because it identifies from which location (homes) on the landscape the containment building of the nuclear power plant is visible. Two components are necessary to create a viewshed. The first is an elevation surface in raster format. The second is at least one observation point (ESRI, 2004).
In this project, digital elevation models (DEM) were acquired for Allegan, Berrien, and Van Buren counties from the Michigan Center for Geographic Information (www.michigan.gov/cgi) in raster format. The observation point was the tallest structure at the Palisades nuclear power plant. According to Mark Savage, a news media contact for the Palisades plant, “The containment building, where the reactor is located, is the tallest structure on site. It is approximately 200 feet” (personal communication with Mark Savage 2004). The viewshed identifies the cells in the raster from which the observation point can be seen, assigning a value of 1 for visible and a value of 0 for not visible (ESRI, 2004).

After the viewshed was created, I was able to identify which houses from which the containment building may be seen. Many researchers have used distance as a factor in determining if living in close proximity to a nuclear power plant will affect the property values, but very few have taken visibility into account. I feel this is an important variable to use. It will allow me to determine what the people living in the houses are looking at and if the view affects property values. If the plant is visible, I would expect the home sale price of the property to be lower
because the location of the home would be a less desirable place to live.

Lastly, a dummy variable was added to each observation to indicate which properties were located within a quarter mile from the Lake Michigan shoreline. Previous researchers have used this variable to measure the effect of waterfront properties (Clark et al. 1997). An analysis tool in ArcToolbox called buffer was used to locate all properties within a quarter miles from the shoreline. After the buffer was created, the selected point features (homes) were assigned a 1 if they were completely contained within the buffer and a 0 if they were not within a quarter mile from the shoreline.

Research Methodology

As stated in the introduction, observations in the study area were gathered during a single day to eliminate changes in market conditions. Market conditions can change from month to month depending on the number of buyers and sellers in the current property market. A home may sell for thousands of dollars more if the current market reflects buyers who want a higher quality home with added amenities and if houses with those characteristics are available for sale. The time of year can also reflect the
market conditions. For example, homes for sale in the spring and summers months that have a pool and or are waterfront properties will be in demand and will sell for a higher price. We can assume that if data are collected on the same day, then the market conditions for each home will be the same in relative terms.

Sale price was chosen for use in the study because it is a good indicator of a house’s actual value. The asking price of a home should closely resemble the market value. Market value can be defined as the value at which the home would sell in a reasonable amount of time (Miles and Wurtzbach 1987). The assessed values were not used because tax information was not readily available and although, “tax assessors are required to assess the values of properties, they are not required to adjust the assessed values of each property to reflect the market value every year” (Romano 2004). Sale prices will reflect what similar houses in the areas have been sold for, which would have taken into account the location and view of the nuclear power plant.

Home sale price was gathered from the six surrounding zip codes around the Palisades nuclear power plant. A twelve-mile radius was created extending out from the plant. Any homes that lay outside of the twelve-mile
radius were eliminated from the study. A total of 460 observations were left after the geocoding process, but 43 homes were located beyond the twelve-mile radius from the plant and were also eliminated from the study.

The twelve-mile radius used in this study was based roughly on the ten-mile emergency-planning zone set in place by the Nuclear Regulatory Commission (NRC) and Environmental Protection Agency (EPA). Federal Law requires all nuclear facilities to have an emergency response plan to protect the health and safety of the public. There are ten and fifty-mile emergency planning zones (EPZ) designated for areas that are located near a nuclear facility. Residents located in the ten-mile EPZ are in the most danger of the release of radioactive material from the reactor. Residents located beyond the ten-mile radius would have limited exposure to radiation. The ten-mile zone was extended to twelve-miles because the city of Bangor and Hartford were located just outside the ten-mile zone. I felt it was important to include these two cities in the study because there were many houses for sale in both of these areas, which would contribute valuable information for analysis in this study.
Modeling Spatial Dependence

There are three types of data that are used for the statistical analysis in this research, areal data is used in the spatial regression model, discrete (point) data is used for point pattern analysis, and continuous data is used in geostatistical analysis. Point pattern analysis is used when interested only in location. Geostatistical methods use continuous data because one is interested in location in conjunction with another attribute (price). The type of data used in this study represents a continuous process (housing values). With continuous data, attributes of the observations are spatially continuous throughout the region of the study area. Variograms and kriging models are both examples of geostatistical methods used in the analysis for continuous data because traditional regression models cannot incorporate the spatial qualities of the data.

A variogram is a graphical display of spatial dependence plotted against distance. In short, a variogram shows the change in spatial dependence that occurs with a change in distance. More specifically it describes the surface’s roughness (Barnes 2004) and identifies, over what range spatial autocorrelation exists in the data. Below
are examples of a variogram models (Figure 6 and 7) and its three corresponding components: sill, range, and nugget. The sill is where the semi-variance (the difference between pairs of observations) levels off. The range is the lag distance of where the variogram levels off; where all succeeding values are independent of each other. Any points beyond the sill and range of a variogram represent spatial independence. The nugget represents the spatially uncorrelated semi-variance or possibly measurement error; it is where the model meets the y-intercept.

Figure 6: Components of a Variogram

Figure 7: Variogram Model
Source: Golden Software, Inc. Tutorial 2004

More importantly, a distinction should be made between the empirical variogram from the data and the variety of possible theoretical variograms that can be used to “fit”
the data. Major theoretical variograms models include the gaussian model, the spherical model, and the exponential model (Bailey and Gatrell 1995). The shape of the curve for each model is different. A theoretical variogram model that has a similar or matching shape of the curve to the empirical data is selected to “fit” the data to a variogram model (Barnes 2004).

The variogram is used as the basis for the kriging model. The kriging model uses the estimates of spatial dependence from the variogram to interpolate values for points (observations) where data was not collected. There are several kriging models: simple, ordinary, and universal. Universal kriging is an extension of ordinary kriging and was used in this study. Universal kriging incorporates the trend component into the model; this is comparable to removing the trend in a regression model and using the residuals to identify locational variation (Bailey and Gatrell 1995). Nearby points are used to estimate the mean value for a set of unknown points. It is impossible to obtain data on all housing values within the study area. Consequently, a technique that interpolates the values for an unknown point is vital when trying to evaluate a complete study area.
Regression

In addition to the variogram and kriging model, a regression model was also used. In general, a regression model is used for two reasons: to make predictions and draw inferences. There are many different forms a regression model can take. Two common regression models are a simple (bivariate) or multiple model. The goal of a regression model is to estimate the change in a dependent variable from the change in the independent variables.

In this thesis, a type of multiple regression model, known as the hedonic model, was used. A multiple regression model is based on the fundamentals from a simple (bivariate) regression model, but is more complex. One difference is that instead of only one independent variable, multiple regression uses a set of independent variables to explain variation in the dependent variable. This model was developed because in many cases there was need for a more complex explanation of the dependent variable. To allow for a stronger and more complete explanation of the dependent variable, the models take the form $y = f(x_1, x_2, \ldots, x_n)$, where $y$ is a function of several independent variables, improving the models' explanatory power.
Misspecification can be problematic in a simple (bivariate) regression model because only one independent variable is used to explain the variation in the dependent variable. All of the explanation is attributed to one variable and may mask many other possible findings. More simply put specification errors occur when the model does not include all the relevant data. Many assumptions are made about the data in both simple and multiple regression models. Important assumptions for a regression model include the following (Poole and O’Farrell 1970; Osborne and Waters 2002).

1. There must be a linear relationship between the dependent variable and each of the independent variables. Using a scatter plot to plot the dependent variable against each of the independent variables can test this.

2. The independent variables must be independent of each other (lack multicollinearity among the independent variables). Using a scatter plot of the independent variables can test this.

3. Probability plot must be normally distributed. Using a histogram or a PP plot to visualize the distribution of the data can test this.

4. No pattern in residuals (homoscedasticity). Using a scatter plot to plot the residuals against the estimate can test this. Figure 8 below provides an example of residuals that do not violate this assumption. As one can see the residuals are around the zero line, if there were high concentrations of points located above or below the zero line then the assumption is violated.
5. Residuals must also be random spatially. This can be tested by mapping the residuals and/or using some spatial methods to ascertain presence of spatial autocorrelation.

![Residuals Plot]

Figure 8: Homoscedasticity Plot
Source: Osborne, Jason & Elaine Waters (2002)

As stated above, one of the assumptions of a regression model is that the joint distribution of your variables is normally distributed. However, the dependent variable (sale price) in this analysis was positively skewed and not normally distributed. This problem was corrected by transforming the variable. This was accomplished by taking the natural log of the sale price (Figure 9 and 10). The independent variable, neighborhood effect, was also recalculated using the log of the sale price since it had also used the sale price to create the average price of a home for each block.
One of the purposes of a multiple regression model is to predict the value of the dependent variable. This step is addressed in the data analysis chapter (V), but because the variable was transformed further explanation is needed for interpretation of the results. The predicted values for the home sale price are the estimates of the natural log of the housing prices. The estimates can be transformed into dollar values because the natural log values can be difficult to interpret. Taking the antilog of the estimates and subtracting it from the actual price will result in the residuals being generated as dollar amounts. These new residuals will explain what the regression model cannot. Positive residuals signify where the values of
areas/homes were “over predicted” by the regression model. Negative residuals signify where the values of areas/homes were “under predicted” by the regression model.

The data was tested to determine which variables will be used in the equation. Those variables that violate an assumption may be eliminated from the model or transformed. It must be noted that the regression models discussed above assumed that the spatial trend is removed from the data. Upon completion of the regression, residuals may be mapped to determine if spatial patterns exist in the data. This is a limitation that must be corrected when working with observations that are spatially distributed or when looking for spatial patterns within the data models.

One type of multiple regression model is the hedonic price method. The hedonic method is used to determine the implicit price or value of a good by looking at a variety of related attributes and will be used in this study to estimate the economic cost of property disamenities, such as the proximity and view of a nuclear power plant. This method is a good indication of value because it uses the preferences of the consumers and producers of the actual market (Hidano 2002). One important strength of the method is that the data, such as property records, property characteristics, and sales information are readily
available through many public and private organizations. In addition to the ease of access to the data, the method is versatile, fairly easy to interpret, and can be as straightforward or as complex as the users wants. In general, more complete models will give more precise estimates.

The hedonic approach also has a few shortcomings. Although the data is easy to come by, many times large amounts of data must be gathered, entered, and manipulated. The model assumes that there is a perfect competition in the market with perfect information (Hidano 2002) when in reality this is not always the case. The model will only disclose the person’s willingness to pay for a good based on their perceived feelings for certain attributes. For instance, a higher value for a good will only be reflected if people believe certain attributes will enhance the value for that good.

Several researchers have used the hedonic pricing method to determine if a disamenity affects the value of a property (Clark et al. 1997; Folland and Hough 2000; Gamble and Downing 1982; Espey and Lopez 2000; Clark and Herrin 2000). This method is based on the idea that the market value of a good is related to its characteristics. The quality of the characteristics will yield a price people
are willing to pay for that particular good (Hidano 2002). For example, the price of a house reflects the location, condition of the house, size of the lot and house, landscaping, age of the home, and accessibility to community amenities. Consequently, several characteristics may be used to estimate the price of a good. The hedonic price method assumes that several attributes or independent variables are used to determine the value of a home (Hidano 2002). The model used in this study includes the following independent variables: structural characteristics such as number of bedrooms, number of bathrooms, square feet of the home, and lot size, demographic information, distance to the plant, visibility of the plant, and properties located within a quarter mile from the Lake Michigan shoreline.

The multiple regression model is expressed as follows:

\[ \text{Housing Price} = a + b_1 \text{Beds} + b_2 \text{Baths} + b_n \text{SqFt} + \ldots \]

Dependent variable = Housing Price
Intercept = a
Coefficient = b_i
Independent variables = Beds, Baths, SqFt

Equation 1: Example of a Multiple Regression Model

In summary several methods will be used in this analysis. A variogram will be used to summarize the spatial data and to determine the amount of spatial dependence among the observations. Next, a kriging model
will be used to estimate housing values on a surface within the study area where sample points were not collected. The kriging model will use the parameters from the variogram to create a surface. In the next step of the analysis, a multiple regression model will use the values of the independent variables to predict the dependent variable (home sale price).
CHAPTER V

DATA ANALYSIS

To begin the analysis, assessment of the data was needed to ensure there were no missing data or data entry errors that would skew the results. The initial analysis of the data included a variogram model and a kriged surface to determine if there was any spatial dependence in the data. Subsequently, a hedonic regression model was used as a concluding examination of the data. The hedonic model was used to determine general relationships between the independent variables and the dependent variable and to be able to predict home sale prices for locations in the study area where data was unavailable. Finally, a variogram of regression model residuals was created to determine if further spatial autocorrelation existed in the data.

Variogram

First a variogram model was used to identify spatial correlation among housing prices. Typically points that are located near each other are more similar than points that are located further away, signifying spatial correlation. This phenomenon is often referred to as Tobler’s first law of geography, “everything is related to
everything else, but near things are more related than
distant things" (Tobler 1970). Observations appear to be
spatially independent where the variance (the differences
between observations) levels off after a certain distance.
In the variogram below (Figure 11), a Gaussian model was
used to identify the sill value of 0.55. The range value is
900, and the nugget value is 0.15. The range signifies
the distance over which spatial dependence remains. The
results suggest that properties within a distance of
approximately 900 meters will be spatially correlated with
each other. Beyond this distance housing prices are
spatially independent.

Kriging Model

The next step in the analysis was to create a kriged
surface. This was accomplished by using the parameters
from the variogram to interpolate values at locations where
measurements were unknown. Figure 12 shows the kriged
surface that represents housing values in dollar amounts.
A universal kriging method was used to create this surface
to show the overall spatial patterns in housing values.
Lighter shaded areas correspond to lower housing values.
Darker shaded areas correspond to higher housing values.
Figure 11: Variogram of the Log Values of the Dependent Variable- Sale Price

This kriged surface displays the range of housing prices in the study area. There is a large area of low prices in the middle of the study area. High housing prices are found in the northern region and southern region of the study area. Along the shoreline of Lake Michigan by the city of South Haven (northern region) and in the city of Coloma (southern region) there are very high housing prices.
Figure 12: Kriged Surface of the Housing Values ($)

Hedonic Model

The following independent variables were used in the hedonic model of housing prices: number of bedrooms (beds), number of bathrooms (baths), square feet (sqft), distance to the nuclear power plant measured in meters (distance), average lot size for each tract (ltsz) percent urban
(pcturban), median income of each block group (medinc), percent of homes built after 1970 (post70), the average sale price of a home for each block group (lnneigh), and two dummy variables. The two dummy variables included homes that were located a quarter mile from the shoreline of Lake Michigan (wf) and homes that could see the nuclear power plant (view). The dependent variable was the sale price of the home (lnprice). Therefore the regression model takes the form:

\[ \text{Lnprice} = B_1 \text{ (beds)} + B_2 \text{ (baths)} + B_3 \text{ (sq ft)} + B_4 \text{ (wf)} + B_5 \text{ (view)} + B_6 \text{ (distance)} + B_7 \text{ (ltsz)} + B_8 \text{ (pcturban)} + B_9 \text{ (medinc)} + B_{10} \text{ (post70)} + B_{11} \text{ (lnneigh)} \]

Equation 2: Initial Multiple Regression Model

Each independent variable will have a positive or negative relationship with the dependent variable. If the independent variable has a positive impact on the dependent variable, I would expect the independent variable to increase the sale price of the home. If the independent variable has a negative impact on the dependent variable, I would expect the independent variable to lower the sale price of the home. I expect the following relationships:

1. The number of bedrooms will have a positive impact on the sale price of a home.

2. The number of bathrooms will have a positive impact on the sale price of a home.
3. Square footage will have a positive impact on the sale price of the home.

4. Homes located within a quarter mile of the shoreline of Lake Michigan will have a positive impact on the sale price of a home.

5. View of the nuclear power plant will have a negative impact on the sale price of a home.

6. Distance to the nuclear power plant will have a positive impact on the sale price of a home. Small or short distances means close to the nuclear power plant, lower prices.

7. Average lot size will have a positive impact on the sale price of a home.

8. Percent urban will have a positive impact on the sale price of a home.

9. Median income will have a positive impact on the sale price of a home.

10. Percent of homes built after 1970 will have a positive impact on the sale price of a home. This variable will have a positive impact for two reasons: newer homes will be more valuable than older homes and houses built after the plants start up date will be void of the negative perception. Those who chose to build after the plants start-up date were aware of its presence and yet still decided to build in a nearby location because of other added amenities.

11. Average sale price in each block group will have a positive impact on the sale price of a home. This variable takes in account that houses located near each other tend to have similar prices. This variable represents the average sale price for homes located in the same block group. This phenomenon is called a neighborhood effect.
These above relationships will be tested in the regression model and will be discussed in further detail later in this section.

The results of the first regression model are based on the equation 2. It should be noted that the statistical test of the overall model and individual independent variables was used with a 95 percent confidence interval. The tables below (Tables 2-7) show output of the model and are artifacts of the output from SPSS, the statistical software used for this analysis. Overall, according to the adjusted $R^2$, the model explains 59.9 percent of the variation of the dependent variable (lnprice). The overall model is statistically significant because of the high F-test value (55.128) and associated probability (0.0000).

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>.781(a)</td>
<td>.610</td>
<td>.599</td>
<td>.5377557</td>
</tr>
</tbody>
</table>

a Predictors: (Constant), LNNEIGH, View, Beds, LtSz, MEDINC, POST70, Distance, PCTURBAN, WF, SqFt, bath
b Dependent Variable: LNPRICE

Table 2: Model Summary for the Initial Regression Model
## Table 3: Anova Table for the Initial Regression Model

Although the overall model is statistically significant, some of the independent variables are not statistically significant and should be removed from the equation. See the coefficient table below (Table 4).

According to the t-test and the significance level, the number of bedrooms, view of the plant, distance to the plant, lot size, median income, and percent of homes built after 1970 are all not statistically significant. These variables have significance levels greater than 0.05 and will be removed from the equation for future regression testing. It should also be noted that SPSS probabilities results are based on two-tailed. To calculate the significance level for one-tailed test, you have to divide the significance in half. For example, percent urban has an indicated significance level of 0.095. This significance level of 0.095 divided by two leaves a value of 0.0475, which is less than the test limit of 0.05.

###独立变量

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>175.361</td>
<td>11</td>
<td>15.942</td>
<td>55.128</td>
<td>.000(a)</td>
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<tr>
<td>Residual</td>
<td>111.913</td>
<td>387</td>
<td>.289</td>
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<td></td>
</tr>
<tr>
<td>Total</td>
<td>287.274</td>
<td>398</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**a** Predictors: (Constant), LNNEIGH, View, Beds, LtSz, MEDINC, POST70, Distance, PCTURBAN, WF, SqFt, bath  
**b** Dependent Variable: LNPRICE
are all highly statistically significant and will be used in a subsequent regression test.

Table 4: Coefficient Table for the Initial Regression Model

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>T</th>
<th>Sig.</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
<td>T</td>
<td>Sig.</td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>5.145</td>
<td>.673</td>
<td>7.643</td>
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<tr>
<td></td>
<td>Beds</td>
<td>-.052</td>
<td>.033</td>
<td>-.072</td>
<td>-1.59</td>
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<tr>
<td></td>
<td>bath</td>
<td>.171</td>
<td>.043</td>
<td>.200</td>
<td>3.946</td>
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<tr>
<td></td>
<td>SqFt</td>
<td>.000</td>
<td>.000</td>
<td>.396</td>
<td>8.366</td>
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<tr>
<td></td>
<td>WF</td>
<td>.284</td>
<td>.100</td>
<td>.116</td>
<td>2.857</td>
</tr>
<tr>
<td></td>
<td>View</td>
<td>.070</td>
<td>.057</td>
<td>.041</td>
<td>1.223</td>
</tr>
<tr>
<td></td>
<td>Distance</td>
<td>.000</td>
<td>.000</td>
<td>.002</td>
<td>.953</td>
</tr>
<tr>
<td></td>
<td>LtsSz</td>
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<td>.017</td>
<td>-.021</td>
<td>-.598</td>
</tr>
<tr>
<td></td>
<td>PCTURBAN</td>
<td>.115</td>
<td>.069</td>
<td>.061</td>
<td>1.671</td>
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<tr>
<td></td>
<td>MEDINC</td>
<td>.000</td>
<td>.000</td>
<td>.001</td>
<td>.988</td>
</tr>
<tr>
<td></td>
<td>POST70</td>
<td>.036</td>
<td>.197</td>
<td>.007</td>
<td>.182</td>
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<td></td>
<td>LNNEIGH</td>
<td>.473</td>
<td>.058</td>
<td>.359</td>
<td>8.182</td>
</tr>
</tbody>
</table>

a Dependent Variable: LNPRICE

The results of the initial regression model are somewhat counter-intuitive in that both distance to the plant and view of the plant are not statistically significant. These results indicate that which these two variables may impact the home sale price of a specific home; they do not do so in a statistically significant manner. However, it is interesting to see that both of the neighborhood variables, percent urban and average sale price of a home for each block group, are statistically significant and positively impact the sale price of a home. These results reveal that although distance to the plant and view do not impact the home sale price neighborhood
characteristics are statistically significant and important factors in home value.

After removing all the non-statistically significant variables, the equation for the subsequent model regression is:

\[ \text{Lnprice} = B_1 (\text{baths}) + B_2 (\text{sq ft}) + B_3 (\text{wf}) + B_4 (\text{pcturban}) + B_5 (\text{lnneigh}) \]

Equation 3: Final Regression Model

The model summary below (Tables 5 and 6) indicates that the equation explains 60.2 percent of the variation in the dependent variable (Lnprice). This is slightly higher than the previous model. After removing the insignificant variables, the overall model’s F-value more than doubles to 121.499 and confirms that the model is highly significant.

<table>
<thead>
<tr>
<th>Model</th>
<th>R</th>
<th>R Square</th>
<th>Adjusted R Square</th>
<th>Std. Error of the Estimate</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>.779(a)</td>
<td>.607</td>
<td>.602</td>
<td>.536395187529635</td>
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</tbody>
</table>

a Predictors: (Constant), PCTURBAN, bath, WF, LNNEIGH, SqFt
b Dependent Variable: LNPRICE

Table 5: Model Summary for the Final Regression Model

<table>
<thead>
<tr>
<th>Model</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>Regression</td>
<td>174.789</td>
<td>5</td>
<td>34.958</td>
<td>121.499</td>
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<tr>
<td></td>
<td>Residual</td>
<td>113.362</td>
<td>394</td>
<td>.288</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>288.151</td>
<td>399</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a Predictors: (Constant), PCTURBAN, bath, WF, LNNEIGH, SqFt
b Dependent Variable: LNPRICE

Table 6: Anova Table for the Final Regression Model
The coefficient table (Table 7) was used to interpret the relationships between the independent variables and the dependent variable. All independent variables are highly statistically significant with significance levels less than a probability of 0.05. The coefficients of each variable in Table 7 can be used interpret the how much value is added to the home sale price. Each additional bathroom will add 14.2 percent to the home sale price. Larger square footage will increase the home sale price. Homes located on the waterfront will increase the home sale price by 29.5 percent. A 1 percent change in the average sale price for all block groups will increase each home sale price by 0.481 percent. A 1 percent change in the percent urban for each corresponding block will increase each home sale price by 0.001 percent.

Lack of multicollinearity among the independent variables is another assumption of a regression model. Tolerance was used to test correlation among the independent variables. A tolerance level below 0.4 would indicate fairly high correlation between the variables. All independent variables have a tolerance level above 0.4, which indicates that there is not a strong correlation between independent variables.
The first regression model revealed that distance to the plant and having the nuclear power plant visible does not affect the sale price of a home. Structural characteristics such as number of bathrooms, square feet, and living in close proximity to the shoreline of Lake Michigan however, all positively impact the sale price of a home. In addition to structural characteristics, neighborhood characteristics, such as percent urban and the average sale price of a home for each block group will also positively impact the sale price of a home. Square footage and the neighborhood effect are the most significant in explaining the variation in the sale price of a home. This significance is indicated by the high beta values of 0.374 and 0.364 shown in the coefficient table above.

<table>
<thead>
<tr>
<th>Model</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>Collinearity Statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
<td>Std. Error</td>
<td>Beta</td>
</tr>
<tr>
<td>1</td>
<td>(Constant)</td>
<td>4.998</td>
<td>.603</td>
</tr>
<tr>
<td>bath</td>
<td>.142</td>
<td>.039</td>
<td>.166</td>
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<tr>
<td>SqFt</td>
<td>.000</td>
<td>.000</td>
<td>.374</td>
</tr>
<tr>
<td>WF</td>
<td>.295</td>
<td>.094</td>
<td>.121</td>
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<tr>
<td>LNNEIGH</td>
<td>.481</td>
<td>.051</td>
<td>.364</td>
</tr>
<tr>
<td>PCTURBAN</td>
<td>.001</td>
<td>.001</td>
<td>.057</td>
</tr>
</tbody>
</table>

a Dependent Variable: LNPRICE

Table 7: Coefficient table for the Final Regression Model

Homoscedasticity, a non-correlated, random distribution, of residuals is an additional assumption in regression testing. This phenomenon assumes that there is
no pattern in the residuals both statistically and spatially. The model results of the dependent variable are potentially heteroscedastic because of the large spread of home sale price for each of the observations used in this study. The scatter plot below (Figure 13) confirms that statistically, there is no pattern in the residuals. The predicted values (x axis) were plotted against the residuals (y axis); the points do not display any spatial pattern in the data.

The graduated symbol map and variogram shown in Figures 14 and 15 confirm, spatially, there is no pattern in the residuals. The residuals are displayed as different size symbols according to the size of the residual. Smaller residuals correspond to smaller symbols indicating over prediction in housing values and in turn larger residuals correspond to larger symbols indicating under prediction in housing values. Differing size symbols are located through the entire study area, there are no places where the same size symbol is found isolated in one area, this verifies there is no noticeable pattern among the residuals.
Figure 13: Scatter Plot: Predicted Values Plotted Against Residuals

The variogram model (Figure 15) is essentially all "nugget" which is equivalent to a random pattern. There is no noticeable pattern in the variogram, which confirms there is no spatial dependence in the data. The scatter plot, graduated symbol map, and variogram model all provide evidence that there is no additional spatial data left to use in the analysis.
Figure 14: Graduated Symbol Map of the Residuals

Figure 15: Variogram of the Residuals for the Regression Model
Furthermore residuals must be normally distributed, meaning the data must be symmetrically displayed around the mean of zero, typically resembling a bell shape curve. The histogram below (Figure 16) plots the residuals against the dependent variable (lnprice) and shows that the criteria for this assumption are met.

![Histogram Displaying Normal Distribution of the Residuals](image)

Figure 16: Histogram Displaying Normal Distribution of the Residuals

Throughout the analysis many steps were taken. A variogram was established to set the parameters for the kriged model. Next, a regression model was used to determine what variables affect the home sale price when located near a nuclear power plant. A second variogram
model was used to see if there was any spatial information left to test. The variogram of the residuals (Figure 15) indicates that no further spatial information exists in the model residuals and therefore no further analysis is necessary.

The results from the above tests in this chapter conclude that proximity to the plant and views of the plant do not affect housing prices in the study area. Structural and neighborhood attributes alone are significant in determining property values. The final chapter of this thesis will include final comments and a discussion of the results.
The purpose of this study was to determine if proximity to a nuclear power plant has any influences on the home sale price using a sample of homes in proximity to the Palisades nuclear power plant. Along with proximity many other factors were also tested. Those factors included view of the plant and several structural home characteristics: number of bedrooms, number of bathrooms, square feet of the home, lot size, and those homes located on the waterfront. In addition to structural characteristics, a neighborhood effect was taken into account and census information was included at the block group level, including variables such as percent urban, median income, and percent of homes built after 1970. This chapter will give an overview on the findings from the research of this thesis in conjunction with a discussion of possible reasons for the outcomes.

Findings

The two primary factors tested in the study, proximity and view of the plant were both found to not be influential factors with respect to residential home sale prices for
homes surrounding the Palisades nuclear power plant.

Residential home sale prices were hypothesized to be directly related to both proximity and to the visibility of the plant. It was disappointing to see that the results from the hedonic model determined that these two factors were not statistically significant, at least for this locale. On the assertion that nuclear power plants have negative affects on property values is proven to be incorrect for the area surrounding the Palisades nuclear power plant in Covert, Michigan. There are a few possible reasons why these two factors hold no influence on the residential home sale price.

Discussion

Over 500 observations were collected from the two public Internet sources used in the analysis. 100 observations were dropped because of missing data or other issues; they were located further out than the twelve-mile radius, or were matched with less than 75 percent accuracy in the geocoding process, leaving a sample of 400 observations. The observations covered the entire study area, but more observations were found in major city areas (Figure 17). Figure 18 show that there is an area just outside of the nuclear power plant where very few
observations were available. There were a total of 62 observations in a five-mile radius and only 22 observations in a three-mile radius extending outwards from the Palisades nuclear power plant. The lack of observations in areas closest to the plant may have distorted my results. Those properties found closest to the plant would have been most valuable to the data analysis. In theory, property found relatively close to the nuclear plant would show the most effect, while the effects on properties further away would decline as the distance from the plant increased.

In addition to the lack of observations in relatively close proximity to the plant, the location of the homes for sale in relation to the nuclear power plant was also a factor. As stated above the majority of the homes for sale were located near a city, and few were located in the outskirts of the study area. Similarly, the Palisades nuclear power plant is also located on the outskirts of town away from the cities. As mentioned in Chapter 2, high-income residential areas are located just outside of the heart of a city. These high quality homes are located near a city because accessibility to work, shopping, and transportation systems are valued. Very few houses were for sale within 3-miles of the plant, indicating very few
amenities are found in this area or that there may be building restrictions.

Figure 17: Major Urban Areas of the Study Area

Figure 18: 12 and 5 Mile Radius Extending Outwards from the Palisades Nuclear Power Plant

The view of the plant was hypothesized to negatively impact the home sale price. Although visual effects of an unsightly containment building with smoke pouring out may be disturbing to others, environmentally, but not economically, especially in regards to sale price of residential homes in this study area. This economic effect or the lack thereof may be because people living in or
considering moving to this study area do not associate any negative imagery to the nuclear power plant. Among those properties that can visually see the plant several were located along the waterfront. Waterfront properties therefore in this study area value the beauty and prestige of living on the shoreline of Lake Michigan over unsightliness and perceived potential risk involved with the Palisades nuclear power plant.

The early startup date of the plant is another possible reason distance to the plant and view of the plant do not impact the sale price of residential homes in the study area. The plant started operation in 1970. At least three decades have past since this time. Galster (1986) mentioned areas that are located near nuclear facilities would eventually reach a state of reequilibrium. His theory of reequilibrium suggests that when the plant is first introduced, initial effects are felt, and this would cause short-term effects. Those who do not wish to live in close proximity will move further away from the plant and those who are indifferent to potential risks associated with nuclear power plants will move into the zone of externalities. Eventually, the price gradient for homes inside the zone of externalities and outside the zone of externalities will smooth out and become continuous
throughout the region. I believe this phenomenon has occurred in this study area because of the time lag between the present time and the initial start up year in 1970. This study area not only has had many years to adjust the dynamic residential market in the area, but the surrounding communities have several saleable attributes that attract homebuyers and builders.

There has been much debate over the controversy that the negative imagery associated with nuclear power plants and the influence of residential home sale price. My results are similar to those of Clark et al. (1997), Metz and Clark (1997), Galster (1986) in regards to long-term considerations, and Gamble and Downing (1982). I conclude proximity and view of a nuclear power plant do not influence the price of residential homes.

Although the hedonic model from this analysis determined distance and view not statistically significant in explaining the variation in the dependent variable, it did identify other important factors that influence the sale price of residential homes in the study area. Structural characteristics such as number of bedrooms, square footage of the home, and location on waterfront, along with neighborhood attributes, average sale price, and
percent urban in each block group all contribute to explaining 60.2 percent of the variation in sale price.

The study reveals that even though many may perceive nuclear facilities as negative imagery or potential risk, the unsightliness and risks are not so overwhelming that it is a main factor in determining where people choose to live and how much they buy or sell a home for. While I speculated Galster’s reequilibrium theory occurred in the surrounding areas around the Palisades nuclear power plant, I would still question the years directly following the plants start up date. Were there any short-term effects in this study area? And if there was, when did the study area reach a state of reequilibrium?
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