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Evaluating Neighborhoods through Empirical Analysis and Geographic Information Systems

ABSTRACT

Assessing and mapping neighborhood quality has a long legacy towards enhancing vitality and quality of life in cities in the United States. This study utilized factor analysis and GIS weighted overlay techniques for assessing neighborhood quality in Milwaukee, Wisconsin. The study integrates several objective neighborhood parameters that address important neighborhood tenets. First, a data reduction tool was invoked to reduce large number of variables into several comprehensive indicators that relate to established socioeconomic and contextual paradigms. These factors were then ranked and aggregated using GIS overlay techniques to produce a map depicting neighborhood integrity. The approach shown here demonstrates how several types of administrative datasets can easily be utilized in a GIS based modeling environment to reach neighborhood quality indices. The results show promise for persons involved in neighborhood planning or defining neighborhoods where objectivity and often multiple competing criteria are present.

Keywords: Neighborhood Quality, Factor Analysis, GIS Overlay, Sustainability, Milwaukee

INTRODUCTION

As various cities in the United States continue to grapple with population emigration, economic decline, and general strife- human scaled approaches are now seen as a promising approach to reverse these ill effects. Recently, in many cities, once thriving neighborhoods with dense populations, transportation equality, and vibrant economic activity have fallen to the wayside. This condition is due in part to city and regional planning during the post WWII era that promoted expansion outside of the city boundaries and resultantly left many urban neighborhoods in disrepair (Cronon 1992, Randall and Baetz 2001). This phenomena may be an artifact of the human desire to reside in smaller settlements that are less dense and more widespread (Dahmann 1985). In the 1970's, in light of the apparent externalities resulting from sprawled suburban land use patterns, government agencies, industry, grassroots organizations, and academia began to critically re-evaluate planning strategies by focusing on local economic conditions that would help revitalize decaying urban areas (Sawicki and Flynn 1996). Since then, human scale analysis continues to see resurgence in sustainability, livability, and bottom up neighborhood planning strategies (Talen 1999b, Black et al. 2002, Ghose and Huxhold 2002, Talen 2005).

The geography of localized social spaces have been studied since at least the early of the 20th century (Burgess and Park 1925, Shevky and Bell 1955). There is a long standing precedence that neighborhoods are a justifiable unit of analyses that can effectively measure local conditions that affect human health. Because of this, neighborhood scale analysis has a rich tradition of representing and deciphering localized forces that affect and shape people's lives. The forces that shape and define neighborhoods are deeply rooted in inhabitant perception and environmental attributes. These foundations are witnessed inside the literature in the form of contextual properties and perception of space that define what many call "sense of place" (Jordan et al. 1998, Meersman 2005). Notwithstanding a renewed interest in neighborhood scale analysis, boundaries and attributes that make up local places can be intricate and entwined, leading to convoluted definitions and sometimes misaligned modeling techniques (Ellen and Turner 1997).

Neighborhood attributes contain contextual and perceptual properties that typically consist of administrative data sources and intangible societal properties related to social cohesiveness (Sawicki and Flynn 1996, Meersman 2005). Notable attributes that are typically included in neighborhood analysis are crime, demographics, urban form, transportation, resident personalities, and land uses (Greenberg 1999, Sampson 2003). At the same time, several disciplines have studied neighborhoods from many different viewpoints. Examples of neighborhood studies include, planning (Huxhold 1996), health (Krieger 2003), brownfields (Clarke 1997), urban change analysis (Kitchen and Williams 2009), child development (Ellen and Turner 1997), crime (Murray et al. 2001), and sustainable transportation (Black et al. 2002). Significant neighborhood findings include Cervero (1996) who investigated how neighborhood form affects travel mode choice and Schwanen et al. (2005) corroborated these studies by assessing how the type of neighborhood is self selected by persons based on a preferred transportation mode choice. Another notable neighborhood assessment is the National Neighborhood Indicators Project (Sawicki and Flynn 1996). This multi-year project advanced the institutionalization of neighborhood measures for changing social, physical, and economic conditions in the United States. Jacobs (1961) also alluded to the importance of neighborhoods and quality of life in her seminal text. She posited that neighborhoods can enhance the quality of life for its residents-given the right conditions. In summary, despite the strong associations between neighborhood effects and quality of life, neighborhood definitions suffer from divisive idiosyncrasies that are based on differing stakeholder outlook of neighborhood delineation and composition.

In this study an attempt is put forth to objectively assess neighborhood quality using variables that speak to several neighborhood components. The research purpose presented here is to overcome current objective neighborhood analyses by entering easily obtainable variables from administrative sources that will address previous shortcomings regarding neighborhood definition and composition. As Greenberg (1999) and Galster (2001) suggest, most neighborhood studies do not incorporate the full spectrum of variables that make up a neighborhood. Therefore, in this paper, the purpose of including a myriad of variables is to quantify as many tangible geographic and socio-economic constructs as possible, some of which are not traditionally included in objective neighborhood analysis. Prior to enacting a quantitative assessment of neighborhood analysis, section 2 presents the conceptual framework for this research, followed by a thorough review of empirical studies that have invoked neighborhood analysis (section 3). Section 4 describes the study area and data sets used, followed by a detailed assessment of the methods utilized (section 5). Section 6 describes the results from our multi-level empirical analysis and finally we conclude in section 7.

CONCEPTUAL FRAMEWORK

Neighborhood boundaries typically conform to major streets, determined administratively, or follow physical boundaries. Regrettably, these boundaries may not reflect actual social bonds or contextual factors that influence one's well being (Massey 1994, Galster 2001). The manifestation of what a neighborhood entails wanes among several disciplines, making a common definition indeterminate (Galster 2001, Kitchen and Williams 2009). The challenge of defining neighborhoods dates back to the 1960's when geographic places were vaguely summarized as space based conglomerations of commonly held residential attributes (Galster 2001). An example of early neighborhood definition is that of Keller (1968) who posited that neighborhoods consist of physical as well as symbolic boundaries. Several additional early neighborhood definitions attempted to address intangible views such as common sense walking limits (Morris and Hess 1975), sociological and ecological paradigms (Schoenberg 1979, Hallman 1984) and spatial boundaries bounded by shared public space or social networks (Schoenberg 1979). Particularly, a comprehensive study by Knox (2006) conceived three types of neighborhoods: entirely arbitrary neighborhoods, homogenous neighborhoods, and community neighborhoods.

The commonality among all neighborhood studies is the importance of implied and explicit perceptions of contextual environmental properties. Moreover, contextual neighborhood properties may serve as precursors to perceptions of neighborhoods (Meersman 2005). The implied and explicit neighborhood components are virtually tied to human perception of space. For example, Batty (1997) postulated that the conceptualization of how humans react and define their space is married to visual perceptions of their localized world. This concept relates to individual perceptions of space that is ultimately realized through environmental affordances. Space and perception is at the center of Gibson's (1979) theory of ecological psychology. This theory posits that humans inherently view space in optic arrays and subsequent affordances. The objects present in one's view then impact information received by humans, thus affecting how they define and interact within this space. We can infer from this that environmental objects are integral in defining the neighborhood both physically and cognitively. The concept of vision and information-environmental exchange was also forwarded by Watts (1998), who indicated that as one moves through the environment the degree of openness is correlated to the amount of visual information afforded by the environment. This finding is also observed in the works of Hillier (1996) who claimed that space predicts movement and aids in organizing society. Hillier's body of work is predicated on the fact that environmental design and space dictates human interaction and social organization all of which speak to concepts of sense of place. This insight lends credibility towards the fact that objective physical features directly influence neighborhood functionality-integral to its prosperity and/or revitalization. This theory is also evident in many other literatures that have investigated local human-environmental phenomenon such as urban form, livable cities, sustainability, and smart growth (Talen 2005). Moreover, it has been found that observable neighborhood features may also mimic subjective responses regarding its vitality (Meersman 2005). Therefore, objective neighborhood elements can serve as antecedents to individual neighborhood experience. Objective measures of the environment are vital in implicitly and explicitly characterizing neighborhood composition and integrity and it is within this realm that this research is based.

OBJECTIVE NEIGHBORHOOD ANALYSIS REVIEW

Neighborhood analysis can be measured either subjectively or objectively. Subjective measures require the collection of responses from persons to measure perceptions and attitudes of the immediate environment. Qualitative data can include resident responses of neighborhood safety, disorder, and social interactions (Raudenbush 1999, Krieger 2003). On the other hand, objective measures utilize data derived typically from administrative sources, which depict neighborhood attributes. Administrative data are generally obtained from the United States Census, police departments, department of natural resources, other government departments, public health surveys etc. Dahmann (1985) classified objective data into four categories, built environment, streets, pollution, and public safety. Despite the vast array of qualitative and quantitative information available to accurately describe and measure neighborhood conditions, uncertainty remains an issue regarding model development and suitable data types.

There appears to be some ambiguity regarding the appropriate objective and subjective measures, and data, to effectively capture pertinent neighborhood constructs. This may stem from the fact that objective observations from unbiased participants and subjective neighborhood perceptions may in fact be similar (Ross and Mirowsky 1999). This inconsistency was highlighted by Quillian and Page (2001) who found that the racial composition of the survey participants was correlated to perceptions of crime levels, but when objectively determined crime rates proved otherwise. Similarly, Sampson and Raudenbush (2004) found that the socioeconomic status and ethnicity of neighborhoods predicted the perception of crime and disorder when objective measures were controlled for. Jacob (1994) found incongruent statistical results between Pennsylvania residents choices and county government data. This is also corroborated by studies that have determined that neighborhood residents, when asked about their neighborhood, can neither provide unbiased assessments or agree on what neighborhood attributes matter most (Ellen and Turner 1997). Vague results from unsound methodological approaches and incompatible datasets likely contribute to the ambiguity surrounding neighborhood definitions and assessment strategies. Therefore, a solution, and the one utilized here, is to solely focus on objective contextual data and empirical techniques regarding neighborhood quality analysis. At the forefront of this approach is the integration of Geographic Information Systems (GIS) coupled with strict empirical strategies.

GIS has the unique ability to manage, visualize, and analyze data, and has been used extensively in land use, zoning, transportation, urban modeling, neighborhood planning, participatory planning, and economic development (Shiffer 1998, Sui 1998, Kellogg 1999, Peng

2001, Ghose and Huxhold 2002). GIS's greatest asset is the capacity to spatially analyze multiple datasets and layers, and subsequently view the interactions between them. This benefit allows stakeholders to spatially view the complex connections between person and place-which is vital to neighborhood studies (Sawicki and Flynn 1996). As a result, GIS methods have made great strides towards objectively assessing and visualizing neighborhood planning (Sawicki and Flynn 1996, Kellogg 1999, Ghose and Huxhold 2002, Talen 2005, 2007). Ghose et al. (2002) utilized GIS extensively as a visualization and mapping tool to quantify neighborhood health at varying geographic scales. As pointedly stated by Kellogg (1999: 16), "GIS is potentially a most appropriate technology to tailor spatial representation to neighborhood perceptions."

One empirical approach that is often joined to GIS analysis is indicator studies. Neighborhood indicators and GIS have garnered much attention due to the fact that they are seen as a legitimate and objective multi-scale tool that can have a large impact on individuals (Ghose and Huxhold 2002). This point is exemplified by Sawicki et al. (1996) who summarized several neighborhood indicator projects in the U.S. that relied on GIS and empirical data. Index development represents a condensed factor derived from a large number of other influential variables (Ebert and Welsch 2004). The influential variables can be represented as "layers" in a GIS. In neighborhood analysis, the layers can be weighted based on importance. A weighting method requires that the weights be assigned by expert knowledge or by statistical derivations. The expert knowledge method weighs layers based on the perceptions of the researcher or of a group of professionals (experts) and mostly apply equal weights to various indicators without stating why or explaining how differential weights might change indices (Hagerty and Land 2002). A common statistical weighting method is the additive approach, where the raw data is summed after multiplying the weights with the indicators. For example Talen (2005), utilized multiple objective GIS layers and overlaid them using a weighting scheme to produce a composite map of desirable neighborhood urban form. Another common approach in neighborhood studies is the statisitcal approach where the weight assigned to each layer is determined by the statistical relationships that exist among multiple variables.

Index development typically involves a multitude of factors and is often difficult to assess due to highly correlated response variables. Factor analysis is one way to minimize multicolinearity by reducing data into groups or “factors” (Riitters et al. 1995). The utility of this method is that it can quickly assess and reveal underlying relationships among many, often diverse variables (O'Sullivan and Unwin 2003). Data reduction techniques such as factor analysis are suitable to neighborhood analysis because it can allude to spatial patterns between numerous different quantities and types of variables which is often the case in quantifying neighborhood quality. For example, Johnston et al. (2004) utilized factor analysis in order to determine homogenous response variables to predict how neighborhood context affected voter turnout at multiple scales, and a study by Doolittle et al. (1978) in Milwaukee WI, used factor analysis to group “sense of community” indicators and then verified them with local community members. Another notable study conducted by Ross et al (1999) used factorial analysis to aggregate many objective contextual factors to measure neighborhood disorder.

To sum, the purpose of our assessment is to fully utilize objective contextual information from easily obtainable sources, using acceptable empirical strategies to measure neighborhood quality. The contextual data used will address all significant environmental and societal constructs that comprise a neighborhood. Furthermore, this information will explicitly address physical environmental features, as well as speak to inherent perceptions regarding local neighborhood conditions. It is within this framework that this study will enact a new indicator of neighborhood quality.

DATA AND STUDY AREA

The City of Milwaukee, Wisconsin consists of 90 neighborhoods (Figure 1). The administrative neighborhood boundaries were obtained from the City of Milwaukee's GIS and Planning department in GIS format. Milwaukee neighborhood's have strong ties to the community, but like many major cities in the U.S., are not without problems such as poverty, blight, segregation, and socioeconomic disparities (Ghose and Huxhold 2002). To counter these problems, the City of Milwaukee and the Community Block Grant Administration (CBGA) has made concerted efforts to distribute federal monies to neighborhoods with need (Ghose and Huxhold 2002). To justify where grant dollars are allocated, a precedent of empirical neighborhood strategic planning and analysis continues to be utilized in Milwaukee, WI (Huxhold 1996). This legacy is evidenced by a study that delved into how communication effectively creates a sense of community in Milwaukee's neighborhoods (Doolittle and MacDonald 1978). Resultantly, the study presented here follows a pattern of empirical investigations using Milwaukee neighborhoods as a test case.

Figure 1. City of Milwaukee, WI and Neighborhoods

The data and methods used in this study address the current need for a comprehensive objective neighborhood assessment that involves a multitude of factors that significantly impact neighborhood quality (Table 1). The bounding units in this analysis are administratively derived City of Milwaukee GIS based neighborhood polygons. This defining unit is reasonable as it's been determined in the literature that administratively derived boundaries reasonably represent non-overlapping nested residential groupings, that although may be flawed, are usable in most cases (Sampson et al. 2002). The neighborhood boundaries will serve as a baseline for synthesizing model results in this study. Demographic and income related variables were obtained for the year 2000 at the block level from the United States Census Bureau. To remain in line with previous neighborhood studies, socio-demographic and economic variables such as income, race, sex, household size, etc. were retrieved. The 2006 Milwaukee Master Property File (MPROP) data was obtained from the City of Milwaukee Information Technology Management Department. The information used from this dataset includes current and past year's property and building value, as determined by the city assessor's office, as well as number of building rooms, total number of rooms, bath rooms, building height, parcel size, and land use. These factors provided insight into the general housing condition and quality, housing density, and land-use diversity. Parks, schools, and recreational area data was obtained from the Milwaukee County Parks Department and was utilized in this study to account for desirable neighborhood attractions and community space. Public spaces such as these represent areas for people to congregate and promote chance encounters that serve to strengthen community bonds (Langdon 1997). Business data consisted of gasoline/convenience stores was obtained from the City of Milwaukee and selected via the federal Standard Industrial Classification code. This data attends to explicit ingredients needed to produce viable heterogeneous neighborhoods (Talen 1999a). The presence of noxious land uses has been shown to correlate to neighborhood disinvestment and disorder (Greenberg et al. 2000). As a result, the toxic release inventory dataset was obtained from the Wisconsin Department of Natural Resources (WDNR) to address this vital neighborhood component. Crime at any level is associated with neighborhood disorder (Dahmann 1985, Ross and Mirowsky 1999). Therefore, all crimes from the year 2000 were obtained from the City of Milwaukee Police Department via the MV400 database and included in this study.

Transportation data in GIS format was also incorporated into this study to measure neighborhood access and mobility options, and more importantly, address neighborhood factions that have shown to affect neighborhood health, boundary definition, and adolescent health (Grannis 1998, Cervero 2002, Sampson et al. 2002). The GIS road network layer consists of the Fire Dual Independent Map Encoding (DIME) developed by the City of Milwaukee and is currently the most precise road network available. Highway engineering road variables for all roads in southeastern Wisconsin were obtained from the Wisconsin Department of Transportation (WIDOT). The engineering road data, coupled with the Fire DIME network, contains traffic counts, heavy truck volume, and travel lanes. These variables will provide additional insight regarding the intensity of traffic and design in each neighborhood. The use of non-motorized transportation is primarily used by poverty stricken populations and is also an indicator of neighborhood attractiveness, therefore, including bicycle usage data is germane to this study (Gannon and Liu 1997, Saelens et al. 2003). There are currently 96.5 miles of existing on-street bicycle facilities in the City of Milwaukee and well over 100 miles of off-street bicycle routes (Turner 1997). Bicycle accident vector point data from the year 2003 was obtained from the City Milwaukee Police Department. The bicycle crash data was added in order to serve as an indicator of income, non-motorized demand, and general traffic safety conditions in each neighborhood. A Bicycle Level of Service (BLOS) safety index was also included in this study. The algorithm consist of per-lane motor vehicle traffic volume, speed of motor vehicles, traffic mix, potential cross-street traffic generation, pavement surface condition, and pavement width for bicycling various roadway infrastructures such as, average daily traffic, roadway width, traffic speeds (Landis et al. 1997).

Name of the variables	Description
White	Total proportional white population (percent)
Black	Total proportional African American population (percent)
Male	Male population (percent)
Female	Female population (percent)
Pop < 5	Population (percent) in the age group under 5
Pop 5-17	Population (percent) in the age group 5 to 17
Pop 18-22	Population (percentage) in the age group 18 to 22
Pop 22-30	Population (percent) in the age group 22 to 30
Pop 30-40	Population (percent) in the age group 30 to 40
Pop 40-49	Population (percent) in the age group 40 to 49
Pop 50-65	Population (percent) in the age group 50 to 65

Pop >65	Population (percent) greater than 65
Median Age Male	Average of median age of males
Median Age Female	Average of median age of females
Family Size	Average of family size
Current Land Value	Average of the current land assessed value
Current Improvement Value	The average of the current assessed value of all improvements on the property
Current Total Value	The average of the sum of current assessed land and improvement value
Previous Land Value	The average of the previous year's assessed land value
Previous Improvement Value	The average of the previous year's assessed property improvement value
Previous Total Value	The average of the sum of the previous year's assessed land and improvement value
Households	Total no of households
Household Size	Average of household size
Owner Occupied	Total number of owner occupied dwellings
Renter Occupied	Total number of renter occupied dwellings
Number of Stories	The average of the number of stories above grade in the building (does not include the basement). For multi-structure properties, the number of stories of the predominant building is shown
Housing Units	Summation of the number of dwelling units on the property
Building Area	Average of the total useable floor area of the structure in square feet
Number of Rooms	Average of the total number of rooms per total dwelling units (total room count excluding bathrooms, powder rooms and recreation rooms, this total includes sunrooms, breezeways, and legal basement bedrooms)
Bedrooms	Average of number of bedrooms per dwelling unit
Bathrooms	Average of total number of bathrooms per dwelling unit (total number of bathrooms in the building, or the number of bathrooms predominantly found in each dwelling unit)
Lot Area	Average size of the property in square feet
Median Household Income	Average of median household income
Land Use Types	Count of different types of landuses (landuse code 5000 to 6000 from Mprop data was used to get the number)
Toxic Release Sites	Summation of the total number of toxic releases per neighborhood
Number of Crimes	Summation of the total number of all crimes per neighborhood
Recreation Area	Total area of recreation sites per neighborhood including parks
Length of Bicycle Roads	Total miles of the most suitable roads for bicycle usage
Vehicle Miles Traveled	Summation of total Annual Vehicles Miles Traveled per neighborhood

Annual Daily Traffic	Summation of total Annual Average Daily Traffic per neighborhood
Bicycle Level of Service	Mean Bicycle Level of Service on all roads within each neighborhood
Pavement Quality	Mean pavement condition as determined by the Wisconsin Department of Transportation
Heavy Truck Traffic	Mean percent heavy vehicle traffic per neighborhood
Schools	Total number of schools per neighborhood
Bike-Car Collisions	Total number of bike-car collision per neighborhood
Gas Stations convenience stores	Total number of Gas station/convenience stores per neighborhood
Length of Bus Routes	Total miles of bus routes within each neighborhood

Table 1. Variables and Data

METHODOLOGY: ANALYSIS OF MILWAUKEE'S NEIGHBORHOODS

After obtaining the pertinent data for the study area and deriving the research framework, the data were aggregated or extrapolated based on the existing neighborhood boundaries of City of Milwaukee. Subsequently, exploratory data analysis was carried out to better understand the relationship within and among different variables. In order to reduce the dimensionality of the data, factor analysis was carried out in the SPSS statistical software (SPSS Inc. Chicago, IL, USA). Factor analysis has the distinct advantage of reducing the initial number of variables into lesser number of variables called "factors" with a minimal loss of information (Hair Jr et al. 1995). In this paper, we have used exploratory factor analysis, which used principal component method to extract the factors, and then applied a Varimax rotation with Kaiser Normalization to retain only those factors whose eigenvalues exceeded 1.0. The exploratory factor analysis produces a Scree Plot which is a simple line segment plot that shows the number of factors against their corresponding eigenvalues. Factor analysis also produces factor loadings and factor scores. Factor loadings explain the relationship between individual initial variables and a particular factor. A factor loading value close to ± 1.0 indicates a strong relationship between the variable and the factor. Also, apart from being helpful in reducing the dimensionality of data, factor analysis is helpful in determining the underlying structure of neighborhood indicators and could form groups of like indicators as homogenous groups or factors (Ross and Mirowsky 1999). Factor scores are standardized values for each and every neighborhood where a higher score means that the factor under consideration has a strong influence on that particular neighborhood.

In this study, an indexed map overlay technique was used that employed factor scores to form a composite index and prepare a single thematic map which could help evaluate the neighborhoods of Milwaukee. The index overlay technique is a traditional procedure to reduce several metrics into one overall comprehensive index (O'Sullivan and Unwin 2003). The factor scores are integral in this process and were used in three different ways: (1) a simple summation of all the factor scores; (2) the summation of the squared factor scores; and (3) a weighted overlay method in GIS. The uniqueness of this approach rests on the full utilization of the factor scores and the percentage variance explained by each and every factor in neighborhood evaluation. The premise for the squaring of all the factor loadings was to account for the negative influences (crime, bicycle collisions, VMT, etc.) on the overall index. By squaring all the factor loadings, the results would be positive and also account for the dragging influence of the negative indicators. Prior to enacting the weighted overlay method, the factor scores of various neighborhoods were converted into raster format. The raster pixels were produced to represent a normal mid-western block (330 $feet^2$). Each factor score raster layer was then classified into seven classes using the Natural Breaks (Jenks) method for classification. A seven point classification scale was subsequently used in ArcGIS software where a value of 1 has the lowest significance in the final index and a value of 7 has the highest significance (Table 2).

However, for factors related to price of land and building, crime, and poverty an inverse ranking was used where a value of 7 has lowest significance and a value of 1 has highest significance. The inverse ranking was based on the premise that very high price of land and structures, concentration of commercial landuse types, high crime rate, and higher poverty negatively affects neighborhood health and counters new urbanism ideals.

	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7	Factor 8	Factor 9	Factor 10
Class 1	1	7	7	1	1	1	1	1	1	1
Class 2	2	6	6	2	2	2	2	2	2	2
Class 3	3	5	5	3	3	3	3	3	3	3
Class 4	4	4	4	4	4	4	4	4	4	4
Class 5	5	3	3	5	5	5	5	5	5	5
Class 6	6	2	2	6	6	6	6	6	6	6
Class 7	7	1	1	7	7	7	7	7	7	7

Table 2. Factor Score Classes and Ranks

RESULTS AND DISCUSSION

Based on the results of the exploratory factor analysis and resulting Scree plot (Figure 2) we decided to use the first ten factors having eigenvalues greater than 1.0. Although the 11^{th} factor had an eigenvalue greater than 1.0, as it was not representing any significant underlying process which could help evaluate the neighborhoods in Milwaukee, 11^{th} factor was not included in the final analyses. As a result, the original 47 variables were reduced to 10 new uncorrelated variables (factors) with a loss of information of only 19.0 percent (Table 3).

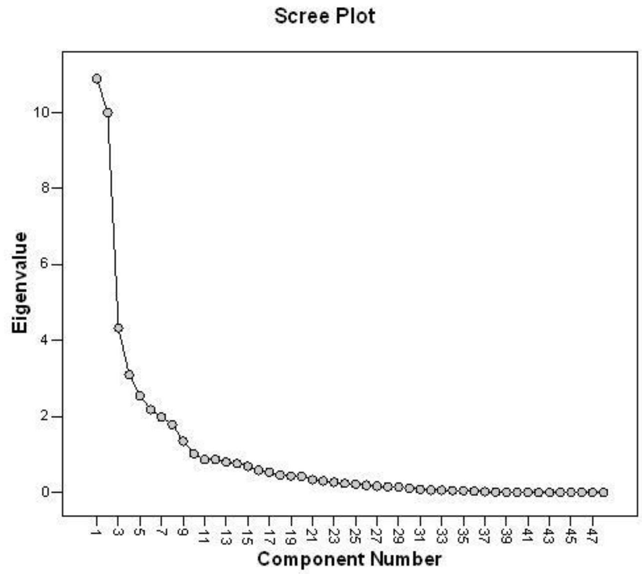

Figure 2. Scree Plot of 47 Neighborhood Variables

	Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Factors	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.89	22.68	22.68	9.48	19.75	19.75
2	9.99	20.82	43.51	7.41	15.44	35.19
3	4.33	9.01	52.52	5.17	10.77	45.96
4	3.09	6.44	58.96	3.47	7.23	53.19
5	2.54	5.30	64.26	3.09	6.44	59.64
6	2.18	4.54	68.80	2.61	5.44	65.07
7	1.98	4.13	72.93	2.58	5.37	70.45
8	1.79	3.72	76.65	2.08	4.34	74.79
9	1.35	2.81	79.45	1.84	3.84	78.63
10	1.01	2.11	81.57	1.41	2.93	81.57
Extraction Method: Principal Component Analysis.						

Table 3. Percentage Variance

The result reveals that factor 1 explains around 20.0 percentage of total variance (Table 3) and the variables relate to concepts pertaining to healthy neighborhoods. This is evidenced by strong positive correlations among dense housing pattern, high rate of owner occupancy, mixed-land use types, increased recreation facilities and low numbers of renter occupied housing (Table 4). Factor 1 also has a strong correlation with mixed land use types, higher number of recreation facilities, bus routes, bike lanes, bike crashes, VMT, number of gas stations, convenience stores and schools (Table 4). These observations also appear in literatures those investigated neighborhood quality and its ties to walkability and bikability (Talen 1999a, Cervero and Duncan 2003, Saelens et al. 2003). Hence, factor 1 is termed as the “new urbanism” factor as it speaks to umbrella principles that have its roots in equal multi-modal transportation access, high population density, and mixed land-uses. An additional finding in factor 1 is its positive association with vehicle mile traveled (VMT). This correlation appears to be in contradiction to the new urbanism ideals but can be inferred to represent income and socio-economic status. While factor 1 primarily speaks to new urbanism ideals, the inclusion of VMT can be construed as an indicator of economic status. We can infer that the neighborhoods having elevated factor 1 scores exhibit characteristics that pertain to new urbanism constructs, but at the same time, represent a demographic that has the ability to utilize the automobile for major transportation needs. Overall, factor 1 is in line with our expectations and matches the national trend of what comprises neighborhood quality.

From the results it was found out that the next significant factor (factor 2) relates to land and structure value. It was also found that there is a strong positive linear relation between land value and size. Factor 2 explains around 15.5 percentage of total variance (Table 3). This factor is very important as the quality and price of both the land and building are crucial for good quality sustainable neighborhoods. The results reveal that factor 2 is highly correlated with both the current and previous year’s assessed value of land and building (Table 4). This positive correlation between current and previous assessments indicates that the increase or decrease in the price of the land and building is consistent for a given neighborhood. We can also glean from this, that factor 2 represents stability in terms of viable parcels and those that are not due to vacancies or disruptions. Furthermore, we can infer that neighborhoods having higher factor 2 score are those with larger lots and high valued properties with less fluctuation from year to year. As the study included Milwaukee downtown and the commercial properties within the neighborhoods it was observed that the neighborhoods having elevated factor 2 scores (Figure 3b) are either in and around downtown or in the northwestern suburbs of the commercial business district (CBD) where the acreage of commercial properties are higher. On the other hand, the neighborhoods having lower factor 2 scores are those with average sized lot, moderate valued structures, and mixed-land use types which relate to the new urbanism ideals. Therefore, based on the result we can associate lower factor 2 scores with good quality neighborhoods

Factor 3 is positively related to young population, children, crime and African American population, and negatively related to the median income and white population (Table 4). Based on these correlation characteristics, factor 3 speaks of crime and poverty tenets and explains around 11.0 percentage of total variance (Table 3). So we could infer that neighborhoods having higher factor 3 score are those with higher young African American population, lower income, lesser white population, higher crime and to a lesser extent elevated bike-car collision rates. The negative association between bicycle collisions and high neighborhood quality alludes to a significant population that utilizes non-motorized transportation, but exposed to adverse bicycling conditions. From the results, factor 4 was found to be positively associated with quality and type of buildings in terms of number of stories, total number of rooms, bed rooms, bath rooms etc (Table 4). Factor 4 is also positively correlated with income which is expected, as housing quality is directly related to income; thus, we find a positive association between these two variables. Factor 4 contains a negatively correlated neighborhood health parameter, toxic release sites. As evidenced in the literature, noxious land-uses have a deleterious effect on neighborhood quality; therefore, this result lends credence to our finding. Moreover, factor 4 explains more than 7.0 percentage of the total variance (Table 3) which is almost half of the land and building price factor (factor 2). Based on the characteristics of this factor, factor 4 is realized as a habitation and environmental quality neighborhood component.

Factor 5, factor 6, and factor 7 are related to various demographic characteristics of the neighborhoods. In particular, factor 5 is positively related to the average family size and number of households in a neighborhood. Factor 6 is positively related to the age group from 30–50 and negatively related to female population. Factor 7 is positively related to younger population (age 18–30) and is negatively related to the older population (age 40 and above). These demographic factors suggest that a neighborhood having a high score for these factors (factor 5, factor 6, and factor 7) relates to elevated number of households, average family size, more young male population, increased number of employed persons, and containing a younger generation. Factor 8 is related to Bicycle Level of Service (BLOS), pavement quality, and the percentage of heavy vehicle traffic (Table 4). This factor provides an indicator of safe latent transportation mobility conditions in each neighborhood. Pavement quality and heavy vehicle traffic are included in the BLOS algorithm resulting in an expected positive correlation. Factor 9 is positively correlated to income and people in the age group of 30-40 and negatively correlated with the people aged 65 and above (Table 4). Interesting enough, factor 10 displays a positive relationship with average lot area and negative correlation with number of stories (Table 4). It only explains 3.0 percentage of total variance (Table 3). The factor loadings indicate that the quality of the pavement has a strong correlation with factor 10 (Table 4).

Variables	Factors									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
White	-0.20	0.12	**-0.88**	0.06	-0.03	0.11	-0.02	0.03	0.17	0.02
Black	0.20	-0.12	**0.88**	-0.06	0.03	-0.11	0.02	-0.03	-0.17	-0.02
Male	0.02	0.18	-0.10	-0.16	-0.11	**0.92**	0.10	0.08	0.10	-0.06
Female	-0.02	-0.18	0.10	0.16	0.11	**-0.92**	-0.10	-0.08	-0.10	0.06
Pop < 5	0.11	-0.23	**0.74**	0.03	0.09	-0.28	-0.14	-0.05	0.26	0.06
Pop 5-17	0.14	-0.24	**0.85**	0.21	0.14	-0.14	-0.17	-0.04	0.00	0.05
Pop 18-22	0.01	0.11	-0.07	-0.07	-0.22	0.00	**0.80**	0.10	-0.28	0.07
Pop 22-30	0.11	0.20	-0.11	-0.30	-0.15	-0.01	**0.63**	0.01	0.40	-0.15
Pop 30-40	0.08	0.12	-0.10	0.02	-0.13	0.17	-0.06	0.06	**0.84**	-0.10
Pop 40-49	-0.13	0.01	-0.22	0.04	-0.08	**0.67**	**-0.46**	0.02	-0.05	0.23
Pop 50-65	-0.15	0.09	-0.34	0.25	-0.04	-0.15	-0.39	-0.05	0.00	0.28
Pop >65	-0.14	-0.02	**-0.60**	-0.09	0.23	-0.10	**-0.43**	-0.04	**-0.42**	-0.23
Median Age Male	-0.13	-0.19	**-0.58**	0.23	**0.56**	-0.15	-0.26	-0.06	-0.18	0.02
Median Age Female	-0.11	-0.19	**-0.51**	0.18	**0.60**	-0.05	-0.32	-0.08	-0.29	-0.02
Family Size	0.09	-0.32	0.26	0.21	**0.80**	-0.17	-0.09	-0.07	-0.06	0.03
Current Land Value	-0.06	**0.93**	-0.11	-0.15	-0.06	0.11	0.03	0.06	-0.01	0.16
Current Improvement Value	0.01	**0.96**	-0.11	-0.06	-0.10	0.02	0.06	0.02	0.05	-0.07
Current Total Value	-0.01	**0.98**	-0.11	-0.08	-0.09	0.04	0.05	0.03	0.04	-0.02
Previous Land Value	-0.06	**0.93**	-0.11	-0.15	-0.06	0.11	0.03	0.06	-0.01	0.16
Previous Improvement Value	0.01	**0.96**	-0.11	-0.06	-0.10	0.02	0.06	0.02	0.05	-0.07
Previous Total Value	-0.01	**0.98**	-0.11	-0.08	-0.09	0.04	0.05	0.03	0.04	-0.02
Households	**0.90**	-0.11	-0.04	-0.05	0.22	-0.06	0.18	-0.03	0.10	-0.06
Household Size	0.07	-0.28	0.32	0.28	**0.74**	-0.16	-0.07	-0.09	-0.10	0.08
Owner Occupied	**0.80**	-0.21	-0.16	0.17	0.16	-0.11	-0.13	-0.04	0.13	0.05
Renter Occupied	**0.77**	-0.02	0.04	-0.18	0.21	-0.02	0.35	-0.02	0.05	-0.12
Number of Stories	0.28	0.19	0.05	0.29	0.24	0.07	**0.49**	-0.04	0.17	**-0.49**
Housing Units	**0.91**	-0.15	0.05	-0.03	0.21	-0.01	0.18	-0.04	0.06	-0.05
Building Area	-0.01	**0.80**	0.07	-0.35	-0.28	0.19	-0.03	0.00	0.05	0.08
Number of Rooms	0.03	-0.35	0.07	**0.83**	0.22	-0.04	-0.09	-0.04	-0.03	-0.09
Bedrooms	-0.05	-0.33	-0.01	**0.82**	0.25	-0.07	-0.22	-0.05	0.01	-0.05
Bathrooms	-0.03	-0.17	-0.01	**0.87**	0.07	-0.13	-0.04	-0.03	-0.01	-0.03
Lot Area	-0.14	**0.40**	0.10	-0.14	0.20	0.06	-0.10	0.07	-0.12	**0.66**
Median Household Income	-0.11	0.03	**-0.47**	**0.47**	-0.06	-0.13	0.06	-0.08	**0.41**	0.11
Land Use Types	**0.75**	0.08	0.24	-0.14	-0.07	0.12	-0.05	0.03	-0.07	0.10
Toxic Release Sites	0.40	0.10	0.16	-0.29	-0.32	0.07	-0.11	-0.03	0.01	0.29
Number of Crimes	**0.41**	-0.13	**0.53**	0.01	0.06	0.04	0.14	-0.03	-0.28	-0.06
Recreation Area	**0.55**	-0.13	0.00	-0.09	0.01	-0.15	-0.08	-0.14	0.20	0.17

Length of Bicycle Roads	**0.93**	-0.13	0.07	0.09	0.02	-0.05	-0.06	-0.07	0.05	0.05
Vehicle Miles Traveled	**0.84**	0.14	0.14	-0.01	-0.18	-0.08	-0.05	0.11	0.02	-0.07
Annual Daily Traffic	**0.90**	0.07	0.20	0.02	-0.13	0.01	0.03	0.08	-0.04	-0.12
Bicycle Level of Service	-0.01	0.11	-0.01	-0.03	-0.13	0.06	0.09	**0.94**	-0.02	0.04
Pavement Quality	-0.01	0.08	0.08	-0.40	0.01	0.08	-0.10	**0.41**	-0.10	**-0.43**
Heavy Truck Traffic	-0.03	0.02	-0.06	-0.06	-0.01	0.07	0.02	**0.94**	0.09	-0.02
Schools	**0.69**	0.14	0.20	0.01	-0.06	0.08	0.27	-0.06	-0.12	-0.15
Bike-Car Collisions	**0.72**	-0.02	0.37	-0.01	0.11	0.13	0.23	0.01	-0.12	-0.10
Gas Stations convenience stores	**0.66**	-0.11	0.08	0.02	0.05	0.03	-0.03	-0.04	0.03	0.00
Length of Bus Routes	**0.79**	0.18	0.13	0.00	**-0.41**	0.01	-0.05	0.07	-0.08	-0.04

Table 4. Factor Loadings

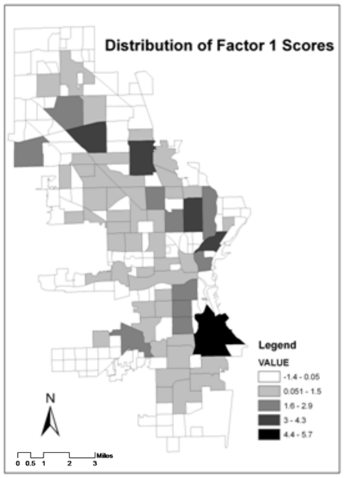

Figure 3a

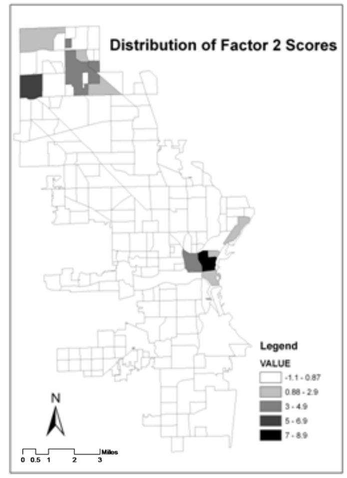

Figure 3b

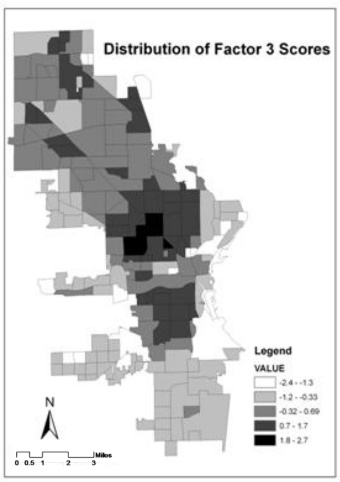

Figure 3c

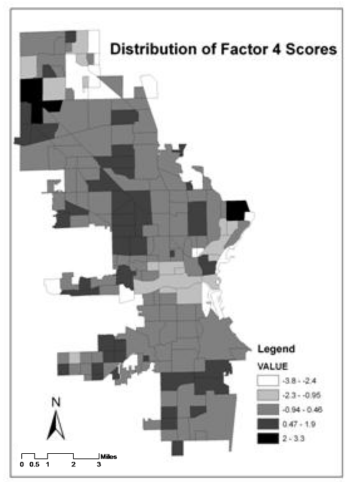

Figure 3d

Figure 3e

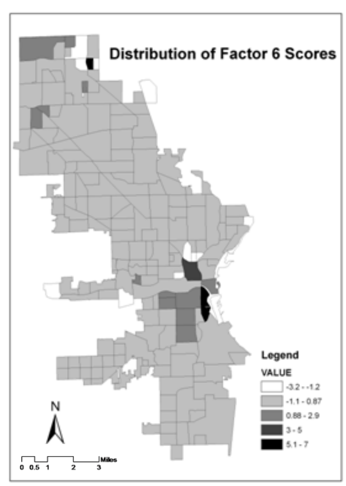

Figure 3f

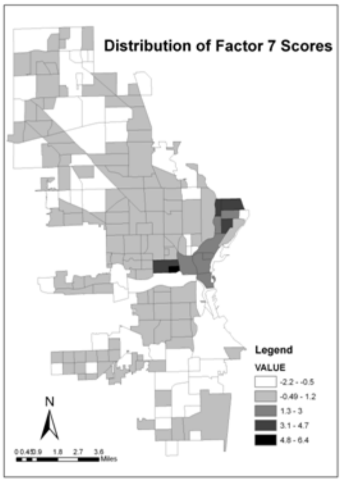

Figure 3g

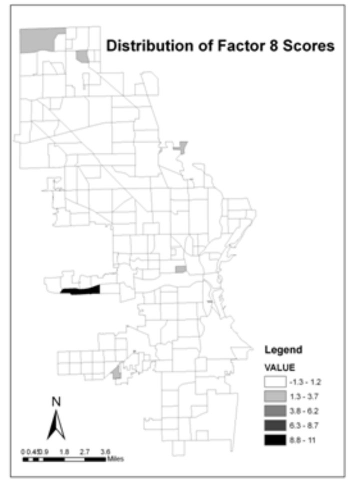

Figure 3h

Figure 3i

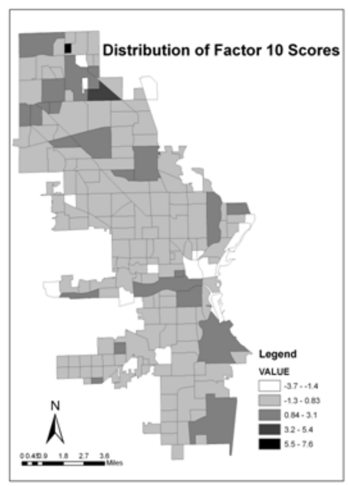

Figure 3j

Figure 3. Factor Score Maps, City of Milwaukee, WI

After selecting the ten factors discussed above, individual factor scores for all the neighborhoods in Milwaukee were obtained from the factor analysis results and then visualized (Figure 3a - 3j) in the ArcGIS environment to relate it to reality. Subsequently, following the three methods (simple summation of all the factor scores, summation of the squared factor scores and weighted overlay method) we used the factor scores to produce three composite indices and three thematic maps representing the overall quality of neighborhoods. The thematic maps (Figure 4, 5, 7) reveal that the simple summation of factor scores map displays the marginalized neighborhoods with higher quality and neighborhood index values but the squared factor scores summation map helped in better evaluating neighborhoods of Milwaukee. From this result, we can infer that the squared factor summation map indicates a more robust output because the index value of the marginalized neighborhoods dropped. However, in both the methods there are several neighborhoods which lack logical merit regarding high quality neighborhoods. For example, the Juneau Town neighborhood (Figure 6) has a very high index value in both the methods because of its high property value which does not necessarily mean high levels of neighborhood quality. Another example of this disparity is the Menomonee River Valley (Figure 6) which is yielding high index values in squared factor scores method because of the derived high factor scores pertaining to family and household size, and certain population age group. The visual analysis of the two results, comparison of the original data behind some of the neighborhoods in doubt, and the local knowledge of Milwaukee city, helped us to think if we could produce a better neighborhood quality index and thematic map. Following the discussed index weighted overlay method, we used the factor scores and respective percentage variance to prepare a third composite index and a map which displays the quality of neighborhoods in the study area in a much more descriptive manner. As discussed earlier, for each and every neighborhood, a seven point classification scale was used to classify the factor scores of all the factors. Then these classes for all the factors except factor 2 and factor 3 were ranked in a scale of 1 to 7 (Table 2) where 1 has the lowest significance and 7 has the highest significance in the final index. For factor 2 and factor 3 reverse scales were used where 7 has the lowest significance and 1 has the highest significance (Table 2). This was done because the results revealed that neighborhoods having higher factor 2 (price of land and building) and factor 3 (crime and poverty) scores are not the good quality neighborhoods in the city of Milwaukee. When the result obtained through weighted overlay method (Figure 7) is compared to the results of the other two methods it was found that the weighted method gave a far better neighborhood quality map which very much relates to the perception of the residents of City of Milwaukee.

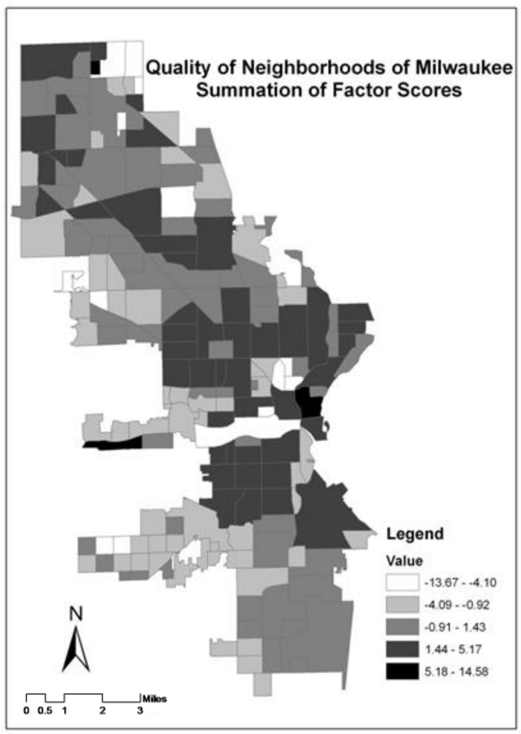

Figure 4. Neighborhood Factor Score Summation

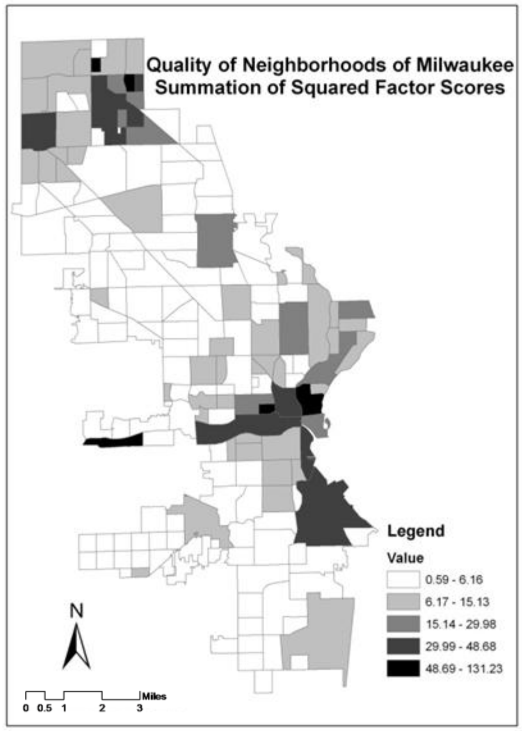

Figure 5. Neighborhood Squared Factor Score Summation

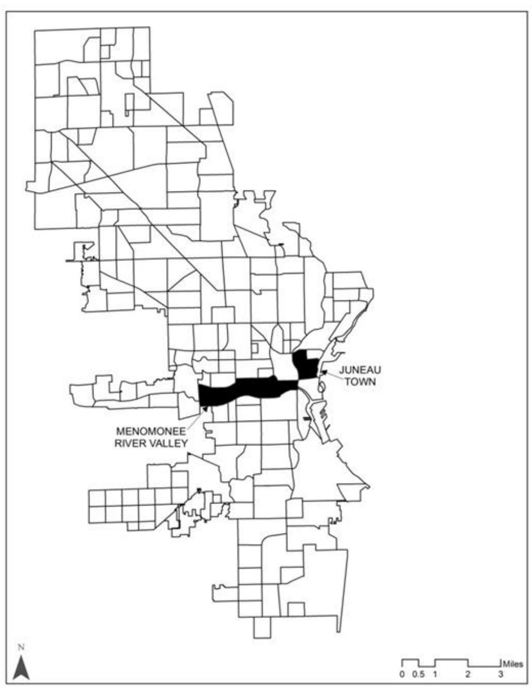

Figure 6. Juneau Town and Menominee Valley Neighborhoods

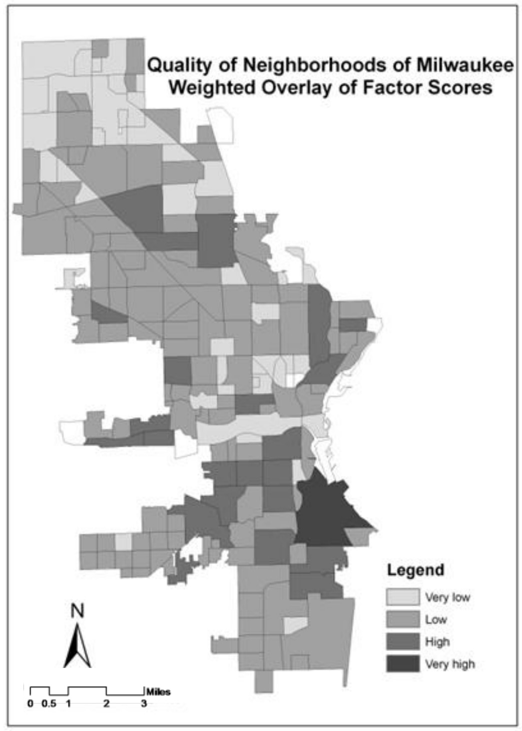

Figure 7. Neighborhood Factor Score Weighted Overlay

CONCLUSION

Neighborhood planning continues to be the root of many strategies for cities that struggle to remain vibrant in today's global economy. Since the dawn of neighborhood planning efforts, there have been countless methods and sources of data utilized to derive optimal policies, define boundaries, and strategies to bring positive change into neighborhoods. The various datasets and methods employed in neighborhood analysis since the early 20th century are indicative of the importance of local planning efforts for stakeholders such as community organizations, planners, government officials, and researchers. In order to better understand the intricacies of localized neighborhood constructs, a two-pronged approach consisting of objective and/or subjective measures remain at the helm of neighborhood planning strategies. Unfortunately, there remains little consensus on which methodology or dataset captures all personal, social, economic, or environmental neighborhood constructs. Reasons for this disagreement may be due to practical reasons such as costs, time, lack of data, or ambiguous research outcomes due to spurious quantitative and qualitative results. Therefore, this research set out to clarify this vagueness by advancing an empirical neighborhood analysis that includes a multitude of easily obtainable administrative datasets.

The focus of this study was to invoke a purely empirical analysis of easily obtainable contextual and socio-economic parameters to measure neighborhood quality using GIS and data reduction techniques. The objective of this research was to enlist the strength of GIS and factor analysis to derive a reasonable neighborhood quality index for Milwaukee, Wisconsin. Specifically, this research has made strides into GIS based neighborhood planning on two fronts; advancing a suitable methodology that is easily employable to measure neighborhood quality within GIS environment, and deriving an innovative neighborhood index by integrating empirically derived weights and weighted overlay technique in GIS. It should be noted that the importance of local perceptions or attitudes are not dismissed in this research, rather, we have argued that our datasets and methodology internalizes societal perceptions of neighborhood ecology by way of including several precursors of perception, i.e., environment and design measurands. The culmination of objective measures and traditional socio-economic parameters has addressed the primary functional neighborhood components, and by exploiting these factors using GIS and empirical analysis, this study has led to the development of an innovative neighborhood quality index that can be transferred to many other communities in the U.S.

Through 3 different GIS overlay methods, a sound technique was arrived at to explain normative neighborhood quality. Through factor analysis, 10 factors were extracted from many variables that captured neighborhood processes such as, new urbanism principles, housing character, and non-motorized transportation access. The indicator weights were derived and summed up in three different ways to form the composite sustainability index. The common way to summarize many different variables was compared to a weighted statistical derivation approach where the percentage variances of various factors were used as weights. This insightful approach to weight derivation is pertinent to neighborhood analysis because it groups highly correlated indicators and in this case, are grouped into categories that speak to neighborhood quality paradigms. This analysis has produced a neighborhood level index evaluation method which seems highly effective in explaining the neighborhood quality in Milwaukee, Wisconsin. In summary, the practicality of this analysis resides in the fact that it reflects commonly held neighborhood planning goals and constructs, while demonstrating a reliable methodology using easily obtainable data sources. Neighborhood level analysis of this type can serve as a baseline for further outreach to policy makers, community organizations, and other stakeholders to better their community.

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