DEVELOPMENT OF A COMPOSITE MODEL OF QUALITY OF LIFE:

A CASE STUDY IN AUSTIN, TEXAS

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San Marcos, Texas
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DEVELOPMENT OF A COMPOSITE MODEL OF QUALITY OF LIFE:

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ABSTRACT

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Recent literature in Geography and Urban Planning has focused on the assessment of Quality of Life (QOL) experienced by residents. Despite the lack of a universal method for study, researchers have generally accepted common variables related to reported QOL. This research examines how QOL may be studied empirically for Austin, Texas by using social, economic, and environmental variables at the census tract level. In addition to factors examined by previous researchers, crime rate and commute time are included to better understand their effect on QOL.

Economic and social variables, including crime rate and commute time, were derived from the U.S. Census and the Austin Police Department. The environmental quality variables were derived from Landsat 7 ETM+ imageries. A factor analysis approach was used to indicate how variables relate to each other as well as QOL for the study area. Using the percentage of variance for each variable as a weight, a synthesized index was developed to assess QOL in Austin, Texas. Model validation by using median home value normalized by number of rooms indicated the usefulness of a synthetic QOL index to predict relative market value at the census tract level.

I. INTRODUCTION

"We go forth all to seek America. And in the seeking we create her. In the quality of our search shall be the nature of the America that we created."

~ Waldo Frank

Overview

Over the past several decades the United States has experienced rapid growth in the demographic and geographic extent of urban regions. As cities continue to grow so do expenditures in infrastructure development, a necessity to promote economic vitality. Population growth, however, is often accompanied by disparity between socioeconomic and racial groups represented in a city's geography. To balance the needs of a diversifying population, urban planners and resource managers must consider the effects of the built environment on the human experience. As the living standard has reached a new height in the twenty-first century, there has been increasing concern for relating the design of an urban area to the quality of life (QOL) amongst its residents (van Kamp et al. 2003; Pacione 2003; Li and Weng 2007). In this study, QOL was defined as being the composite of exogenous facts and factors of one's life and endogenous perceptions of these factors and of one's self (Szalai 1980). This study however focused on the exogenous factors with the understanding that perception plays an important role in the QOL of an individual.

Examining the Effects of Disparity on Quality of Life

As policy-makers continue to address the disparities that plague many cities, people have become increasingly interested in their built environment (Pacione 2003). Greatly advanced over the industrial centers of the early 19^{th} Century, the American city of the new millennium is diverse in culture, opportunity, and structure.

The environment in which residents live often influences the extent of opportunities available to them. Residents with lower educational attainment are less likely to have high incomes, which reduces their choice of neighborhood residence. A resident may be forced to live in a high crime area to meet their financial requirements, consequently increasing exposure to physical harm or material loss.

Gentrification, another consequence of recent urbanization, describes socioeconomic changes in an urban area as new wealthier residents displace lower-income residents through redevelopment and increased property values. A consequence of gentrification is the loss of cultural communities and reduced housing opportunities for lower-income residents.

Although the effects of urban disparity have been widely documented, little is known about the interactions of variables pertaining to QOL in urban regions. Previous research indicated a consensus amongst researchers that psychological, economic, social, and physical factors should all be considered when examining urban QOL for a large population (Li and Weng 2007). These categorical factors are further refined to include: income, wealth and employment; physical environment; health; education; social disorganization; alienation and political participation (Smith 1973; Pacione 2003). Before these interactions can be studied with relative consistency, tools must be created and improved to empirically describe QOL across urban regions.

Application of GIS and Remote Sensing

Geographic Information Systems (GIS) and remote sensing tools continue to expand their utility and application by allowing analysts to simultaneously explore the spatial trends of multiple variables across a landscape. With its roots originated from thematic cartography (Collins et al. 2001), GIS has a long tradition in urban planning and remains versatile in addressing complex, multi-dimensional problems at various scales. For this purpose, these tools are ideal for studying and comparing the empirical measures of QOL between city regions. GIS provides spatial and statistical methods where multiple variables pertaining to QOL may be examined and visualized individually or as a composite of several indicators.

The ability of GIS to examine variables using mathematical functions is beneficial for comparing QOL between regions, as well as modeling change over time. GIS allows for variables to be mapped across urban regions and to be overlaid and weighted differentially to explore their spatial relationships. This capability allows for analysis of variables pertaining to QOL to be spatially analyzed for patterns. Given the diversity of the Austin landscape, the application of GIS may likely reveal significant differences in the distribution of QOL and the associated socioeconomic and demographic characteristics of population groups.

In the context of urban planning, remote sensing provides the spatial data essential to monitor the dynamic change of Land Cover/Land Use (LC/LU) over time. The United States Geological Survey (USGS) Landsat program provides public access to data captured from multiple satellite platforms. Multispectral imageries, such as the Landsat 7 Enhanced Thematic Mapper (ETM+), provides 7 bands of remotely sensed data, including the visible, near and far infrared at 30-m spatial resolution and a thermal infrared band at 60-m. Using digital image processing techniques, the spectral signature of various geographic features, such as vegetation, can be uniquely identified and extracted systematically from the multi-spectral imageries. The thermal band of Landsat images can also be used to derive a surface temperature for the urban area by converting data stored as digital numbers into percent reflectance.

Recent QOL studies have integrated census data with remotely sensed data to describe the social and economic indicators of well-being, as well as the environmental conditions of neighborhoods (Li and Weng 2007). The derived QOL indices are designed to portray a snap-shot of the well-being of an individual or family, independent of outside interactions. The ability to integrate indicators of environmental stressors within an urban region is significant as it allows for a dynamic analysis of QOL.

Uniqueness of Austin

Located in south central Texas, the city of Austin has developed along the Balcones fault line on a stretch of the Colorado River (Figure 1.1). This unique landscape divides the Texas Hill Country in the West from the Blackland Prairie leading east to the Gulf of Mexico. The variation in natural vegetation and topography is apparent from a cursory visual observation. The Austin city limits include approximately 251 square miles in area and is home to approximately 786,000 residents as of 2009 (U.S. Census Bureau 2010).

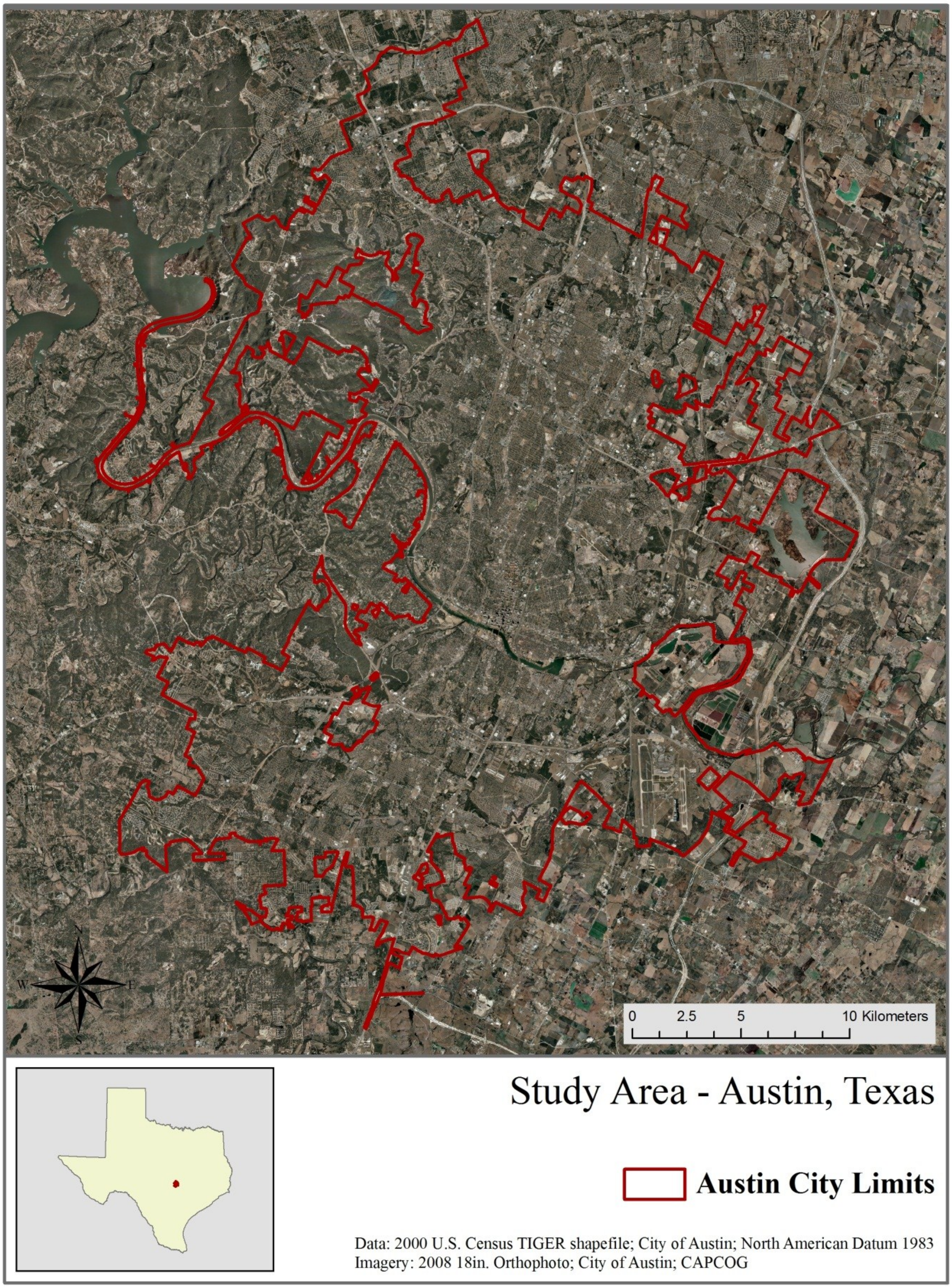

Figure 1.1 City of Austin study area.

The Austin population is diverse with no single ethnic group representing a majority share of the total population (Robinson n.d.). However, a rapidly growing Hispanic population plays a significant role in Austin's development. The dense increase of Hispanic residents in several neighborhoods has established representative ethnic communities with unique businesses catering to the needs of a unique population. While the most densely populated Hispanic neighborhoods are on the east side of Austin, the influence of Hispanic culture is reflected across the entire urban area. Similarly the Asian population in Austin has been increasing since the 1990's, although not at the same rate or with the same spatial concentration. By contrast, the African American proportion of the population has been in decline as other demographic groups have increased more rapidly and African American residents have relocated to the suburbs. The racial and ethnic diversity in Austin is one of its greatest assets and introduces a wealth of cultural resources and opportunities (Robinson n.d.).

As the state capitol and home to the University of Texas, Austin has strong economies particularly in education, government, and technology fields. The level of educational attainment amongst Austin residents is above average; 40.4% of Austin residents 25 and older hold bachelor's degree or higher, in comparison to 23.2% among the Texas population (U.S. Census Bureau 2010). The presence of such a highly educated population is significant to QOL notably as reported life satisfaction increases with further education over an individual's life expectancy (Yang and Waliji 2010). Cultural and recreational opportunities, job opportunity, and regional population dynamics have led to a population boom in the past decade (Figure 1.2).

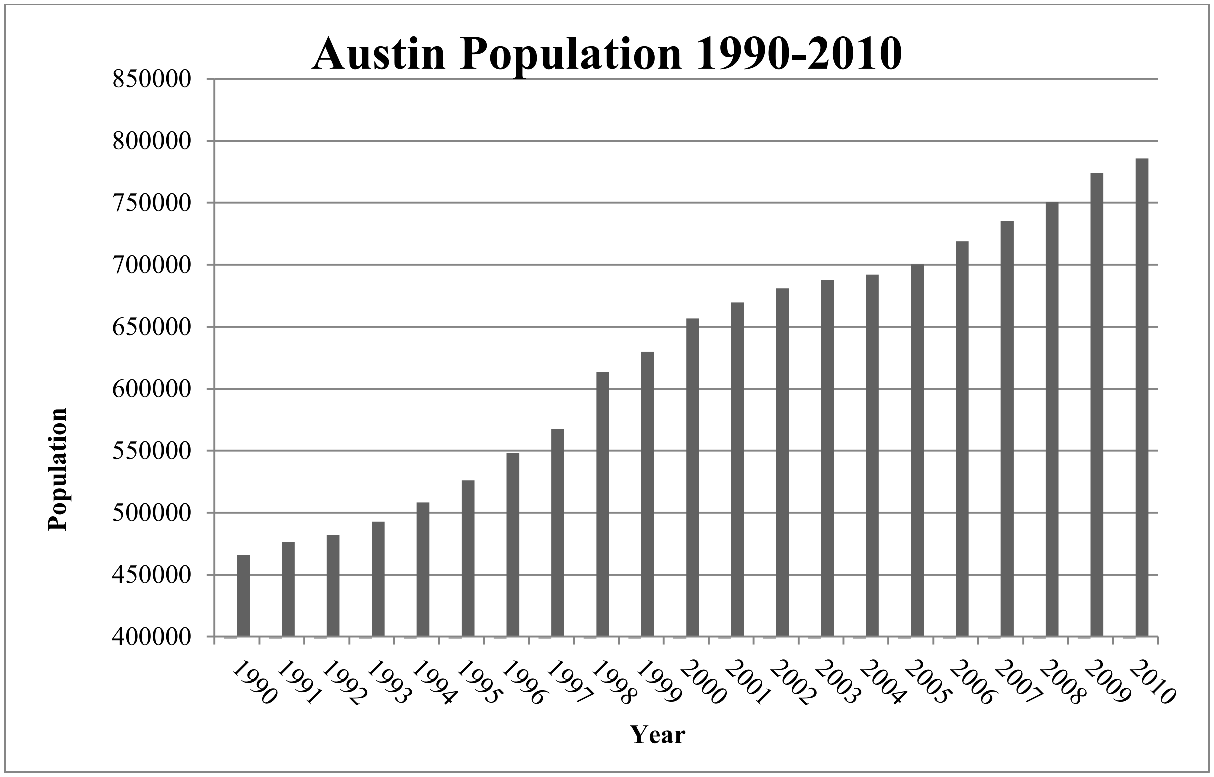

Figure 1.2 Population growth of the City of Austin over the past decades (Robinson 2010).

With all the perceived amenity and growth, Austin is an excellent location to study QOL due to the presence of multifaceted demographic characteristics and variability in the urban built environment. A highly educated and diverse population provides a distinct setting to examine previously attempted QOL assessment strategies with the incorporation of new variables. Furthermore, the rapidly growing population and consistent recognition in popular media indicates there is a quality that warrants further investigation. Austin is widely appreciated for a well-known live music scene (Hartman 2008), and while national and regional growth has been increasing, many locals are very attached to the “weird” and funky landscapes of the city (Long 2010). A sample of recognition for Austin includes the number one Best City for the Next Decade by

Kiplinger's and a 2009 top ten Best Places to Live by U.S. News and World Report (Mullins 2009; Frick 2010).

Thesis Purpose

The objectives of this research were three-fold: 1) to develop a general framework that extends from previous research by incorporating crime rate and average commute time to model QOL, 2) to examine the effectiveness of synthesized QOL indices in correlating with actual market value of real estate, and 3) to explore the spatial distribution of modeled QOL in the city of Austin, Texas. Social, economic, and environmental variables were expanded upon with the inclusion of environmental stressors.

This thesis first introduces the importance of assessing QOL, the roles of GIS and remote sensing, and a brief description of the Austin study area. The introduction chapter is followed by a review of literature on QOL assessment and the contribution of this research in expanding the body of knowledge. The methodology chapter states the research questions and outlines the general framework to pursue this proposed research. Following the methodology chapter, the results chapter reports the findings based upon the results of spatial and statistical analysis. The discussion chapter poses some interpretation on the results both for the city of Austin and QOL research as a whole and suggests areas for future study. Finally, the conclusion chapter reiterates the main points which were raised and locates this work in the landscape of QOL research.

II. LITERATURE REVIEW

Quality of Life Assessment

Quality of Life (QOL) has been studied in geography, criminology, urban planning, and sociology as a multidisciplinary subject (Michalos and Zumbo 2000; Pacione 2003; Van Kemp et al. 2003). As the concept of QOL itself is multifaceted and loosely-defined, literature studies have revealed that no universal framework for assessing and describing QOL and human well-being currently exists (Leidelmijer et al. 2002).

A literature review conducted in 2003 by the National Institute for Public Health and the Environment in the Netherlands, sought to consolidate research to create a model of the essential concepts related to QOL. The consensus amongst researchers is that QOL is a multi-dimensional concept and therefore exhibits the potential to be studied in terms of individual indicators such as income, or as a composite concept which includes many unique variables. (Van Kamp, et al. 2003).

Within QOL research, certain themes persist, including livability, environmental quality, and sustainability. Livability focuses on human interaction with the urban environment, for which environmental quality and sustainability are important variables. According to Newman (1999), “Livability is about the human requirement for social amenity, health and well-being and includes both individual and community well-being”.

However, as van Kamp et al. (2003) pointed out, authors have previously written about these key terms using slightly varied definitions throughout the last several decades. The proliferation of Smart Growth planning principles, which incorporates these same themes, is a useful tool for making cities more livable. Geller (2003) discussed the potential for improved physical health as communities chose to implement Smart Growth planning principles.

Research on the perception of environmental quality reveals that employees view their workplaces more favorably and consumers prefer parking areas with more trees and less impervious cover (McPherson 2001; Kaplan 2007). Environmental quality within urban regions also enhances economic sustainability. For example, reduced urban temperatures have been associated with reduced energy costs and conserved resources (Souza et al. 2009). While these distinct themes are common throughout research related to human well-being, their interactive and myriad effects to QOL assessment are not well understood.

The Dichotomy of Environment and Perception

A unique challenge to QOL study is the distinction between empirical and subjective QOL indicators. Exogenous factors of a person’s life represent the objective reality of their environment, while endogenic factors represent their state of mind, perception and cognition of their life experience (Szalai 1980; cited by Van Kamp et al. 2003). This concept of duality within measures of QOL has been further developed within the literature. Grayson and Young (1994) wrote “there appears to be a consensus that in defining quality of life there are two fundamental sets of components and processes operating: those that relate to an internal psychological mechanism produsing a sense of satisfaction or gratification with life and those external conditions which trigger the internal mechanism”. Pacione referred to this duality as the *city on the ground* and the *city in the mind* (Pacione 2003).

Pacione (2003) described two case studies that illustrate both the difference between exogenous and endogenous variables and the methods used to study them. The first case study examined the social indicators which create variability in the QOL experienced by marginalized populations of Glasgow, Scotland. Census data on 64 factors relating to demographics, economics, social and living conditions were examined to statistically analyze populations experiencing disadvantage across multiple indicators. The results were then mapped to identify the geographic locations of these populations. In this study, the use of objective variables removed bias based on personal perception and experience to describe exogenic factors affecting the population.

By contrast, the second case study offered by Pacione examined endogenous indicators influenced by the perception of individual members of the population. Data were collected through interviews to determine the extent to which genders differentially experience fear of crime. The results revealed that residents perceived the risk of crime differentially despite living in the same neighborhoods. Pacione’s (2003) work suggested that subjective experience influenced QOL beyond what could be measured through objective methods and the importance of crime in shaping such perception.

Quality of Life Reseach in GIScience

The utility of GIScience and remote sensing has continued to expand within urban studies. As computing hardware and software has continued to advance, so have the capabilities of GIS to derive exogenous variables relating to the urban structure on a variety of scales. While these variables are often studied independently, each represents a unique aspect of QOL and can be used to create a composite indicator of urban environmental conditions (Pacione 2003; Van Kamp et al. 2003; Li and Weng 2005).

Remote sensing imageries and census data are often combined into GIS to spatially analyze the distribution of social and economic conditions across urban space (Li and Liu 2006; Apparicio et al. 2008). Previous research has largely focused on examining the distribution of individual criterion related to QOL or QOL amongst a particular segment of the population. Apparicio et al. (2008) examined indicators such as Normalized Difference Vegetation Index (NDVI) to determine the condition of the neighborhoods surrounding public housing units in the city of Montreal. Hall et al. (2001) combined remote sensing and GIS in urban studies to look for pockets of urban poverty. In recent years, research has been extended to examine QOL through GIS for large geographic areas (e.g. city-wide) using data such as Landsat imageries (Lo and Faber 1997; Li and Weng 2005).

By examining the QOL in Indianapolis, Li and Weng (2005) provided a compelling framework for the integration of Census data and remotely-sensed environmental variables to assess the QOL in a medium-sized metropolitan area. Li and Weng (2005) identified 26 variables from previous literature related to QOL including population density, housing density, median family income, median household income, per capita income, median house value, median number of rooms, percentage of college above graduates, unemployment rate and percentage of families under the poverty level. These census variables were analyzed along with variables extracted from Landsat 7 Enhanced Thematic Mapper Plus (ETM+) imageries, such as surface temperature, greenness and imperviousness. Principal Component Analysis (PCA) was then used to identify the underlying factors and reduce redundancy between variables. To create a model of synthetic QOL, regression analysis was also used to associate QOL index values with environmental and socioeconic variables. The outcome of the analysis was a synthetic QOL model with a R^2 value of 0.94.

QOL as an empirical study provides numerous opportunites for additional investigation. Previous research has focused on the city as geographically static with little discussion of variables to describe the interaction between regions. However, the QOL that one experiences is influenced greatly by the events and interactions between citizens in the context of urban geography, such as transportation. The research described in this paper is intended to advance the understanding of QOL assessment in several key ways.

Expanding on the Existing Literature

Commute time is an important element to QOL because it is inversely related to the time one could have spent otherwise engaged in more productive or meaningful activities. All forms of commute result in opportunity and financial cost; as commute time increases, so does the opportunity cost (Lyons and Chatterjee 2008). Shorter commute time to one's destination could potentially result in additional bonding personal relationships, reduced stress, or additional income (Rahn 2009).

Crime is often associated with living standard as well (Michalos and Zumbo 2000). Crime is a universal experience in all cities, large or small. However, the frequency and magnitude of crime can vary greatly across neighborhoods. Crime is multi-faceted in both character and cost; affecting a person and his/her property to varying degrees and with long-lasting ramifications. The potential of becoming the victim, or the loss resulting from realized crime(s) can introduce stress and affect personal interactions in a neighborhood (Bacigalupe et al. 2010). However, the functional relationship between crime and QOL is not well understood.

This research sought to quantify the importance of crime in QOL study by describing the spatial distribution of crime rate across the urban area and examining its relationship with other variables related to QOL. Furthermore, the variable of commute time was examined to describe the loss of productive time associated with various regions of the city. This study was conducted in the hope of enhancing our understanding regarding the role of these variables in quantifying the individual/composite indicators and providing additional insights into QOL research. The focus on Austin would also add to the understanding of QOL by providing an assessment of a unique and diverse urban region.

III. METHODOLOGY

Research Questions

This research sought to answer the following questions: 1) What is the spatial distribution of QOL in the City of Austin based on socio-economic and environmental variables? 2) What is the relationship between QOL and crime rate? 3) What is the relationship between QOL and commute time? 4) What is the relationship between QOL and perceived neighborhood desirability described in terms of home value? By describing the QOL in Austin as a demonstration, this research sought to further the understanding of empirical QOL modeling for urban areas using GIS and remote sensing techniques.

Data

Data used in the QOL assessment for the city of Austin were acquired directly from a variety of sources and in multiple formats. Census 2000 tract data were used to explore the socioeconomic and demographic profiles. Specifically, the socioeconomic variables identified in previous research and used for analysis include: population density, housing density, median family income, median household income, per capita income, educational attainment, unemployment rate, and percentage of families above the poverty level (Smith 1973, Weber and Hirsch 1992, Lo and Faber 1997, Li and Weng 2005). A complete summary of variables used in this research can be found in Table 3.1.

Table 3.1 Complete list of variables.

Variable Category	Variable Name	Variable Description	Variable Source
For Identification Purposes	Tract ID	Tract Identification Number	Census 2000, Summary File 1
Economic	Median Rooms	Median Number of Rooms	Census 2000, Summary File 3
	Median Home Value	Median Home Value	Census 2000, Summary File 3
	Median Rent	Median Rent	Census 2000, Summary File 3
	Mean Commute	Mean Commute Time for Residents 16 and Older	Census 2000, Summary File 3
	Median Household Income	Median Household Income	Census 2000, Summary File 3
	Median Family Income	Median Family Income	Census 2000, Summary File 3
	Per Capita Income	Per Capita Income	Census 2000, Summary File 3
	Unemployed	Percent Unemployed	Census 2000, Summary File 3
	Families in Poverty	Percent of Families Living Below the Poverty Line	Census 2000, Summary File 3
	Individuals in Poverty	Percent of Individuals Living Below the Poverty Line	Census 2000, Summary File 3
Environmental	Population Density	Population Density	Calculated from Census 2000, Summary file 1 and Area
	Housing Density	Housing Density	Calculated from Census 2000, Summary file 1 and Area
	Surface Temperature	Average Surface Temperature for Census Tract	Calculated from Landsat 7 ETM+ dated August 3, 2000
	Percent vegetative cover	Percent of Census Tract with Vegetative Cover	Calculated from Landsat 7 ETM+ dated August 3, 2000

3.1 Complete list of variables. (Table 3.1 - Continued)

Environmental	Percent impervious cover	Percent of Census Tract with Impervious Cover	Calculated from Landsat 7 ETM+ dated August 3, 2000
	Percent Water	Percent of Census Tract Covered with Water	Calculated from USGS National Hydrography Dataset
	Square Miles	Census Tract Area in Square Miles	Calculated with ArcGIS tools
	Housing	Total Number of Housing Units	Census 2000, Summary File 1
	Population	Total Population	Summary file 1
Social	Aggravated assault	Incidents per 1,000 residents in 2000	Austin Police Department
	Auto theft	Incidents per 1,000 residents in 2000	Austin Police Department
	Burglary	Incidents per 1,000 residents in 2000	Austin Police Department
	Murder	Incidents per 1,000 residents in 2000	Austin Police Department
	Rape	Incidents per 1,000 residents in 2000	Austin Police Department
	Robbery	Incidents per 1,000 residents in 2000	Austin Police Department
	Theft	Incidents per 1,000 residents in 2000	Austin Police Department
	9th grade Education	Percent of Residents who completed 9th grade or less	Census 2000, Summary File 3
	High School Education	Percent of Residents who completed 9th through 12th grade; no diploma	Census 2000, Summary File 3
	High School Graduate	Percent of Residents who earned a High School Diploma	Census 2000, Summary File 3
	Some College	Percent of residents who completed some college, but no degree	Census 2000, Summary File 3
	Associate's Degree	Percent of residents with Associate's Degree	Census 2000, Summary File 3
	Bachelor's Degree	Percent of residents with Bachelor's Degree	Census 2000, Summary File 3
	Graduate Degree	Percent of residents with Graduate or Professional Degree	Census 2000, Summary File 3

It should be noted that some socioeconomic variables were not explicitly found within the census data such as population density and housing density. However, these variables were calculated from one or more variables found in Census summary files 1 and 3. In addition to the variables suggested by previous researchers, this assessment also included commute time and crime. Commute time describes the self-reported amount of time spent commuting to work daily among the residents age 16 and older who work outside of home. Crime referred to the reported violent crime incidents per 1000 residents for each census tract in several offense categories. Selected socio-economic variables are illustrated below, including population density, median household income, commute time, and crime rate (Figures 3.1-3.4). For ease of interpretation, crime here is represented as a composite rate of all variables. However, during the final analysis, crime was examined crime by specific type to determine if the distribution of crime varies by offense.

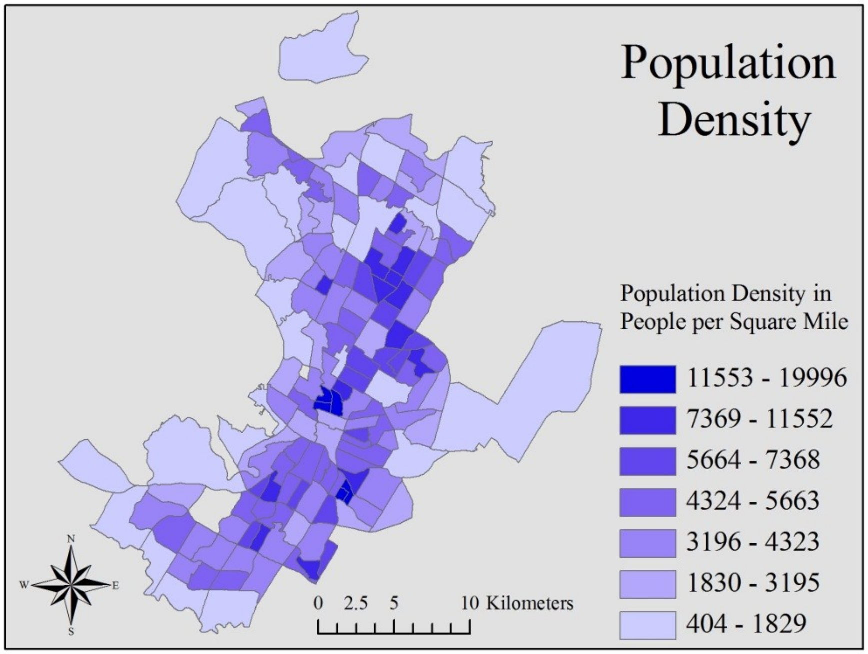

Figure 3.1. Population Density in the City of Austin.

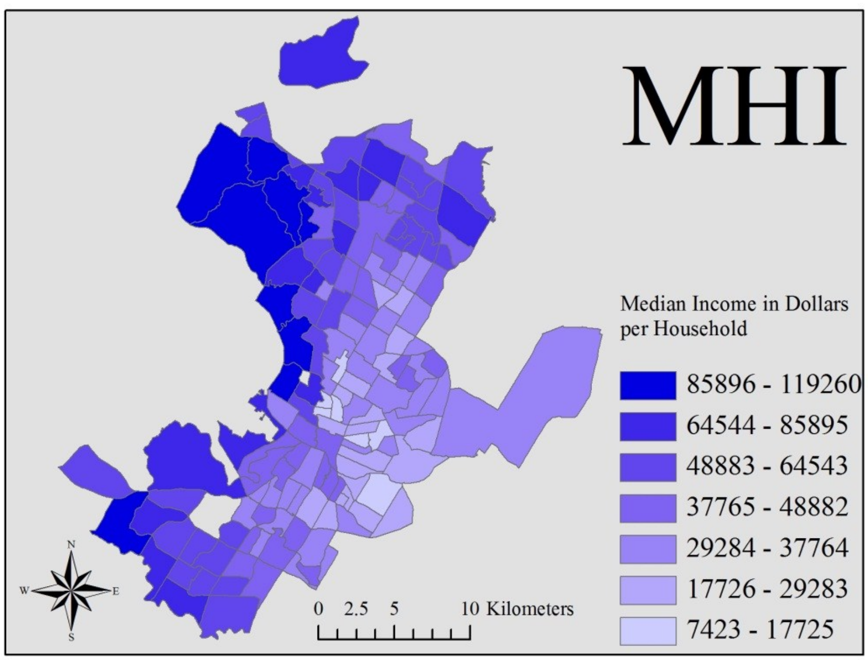

Figure 3.2. Median Household Income in the City of Austin.

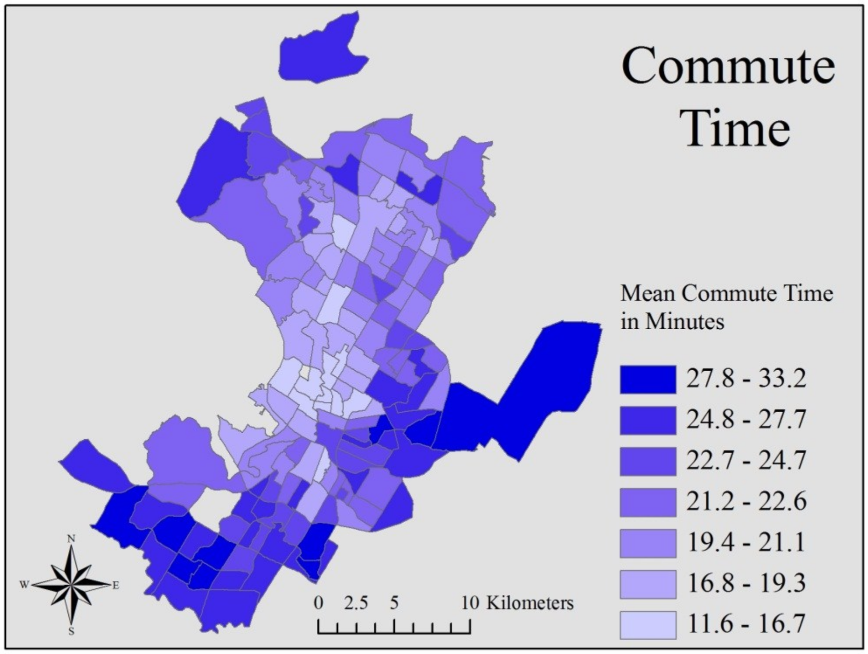

Figure 3.3. Mean Commute Time in the City of Austin.

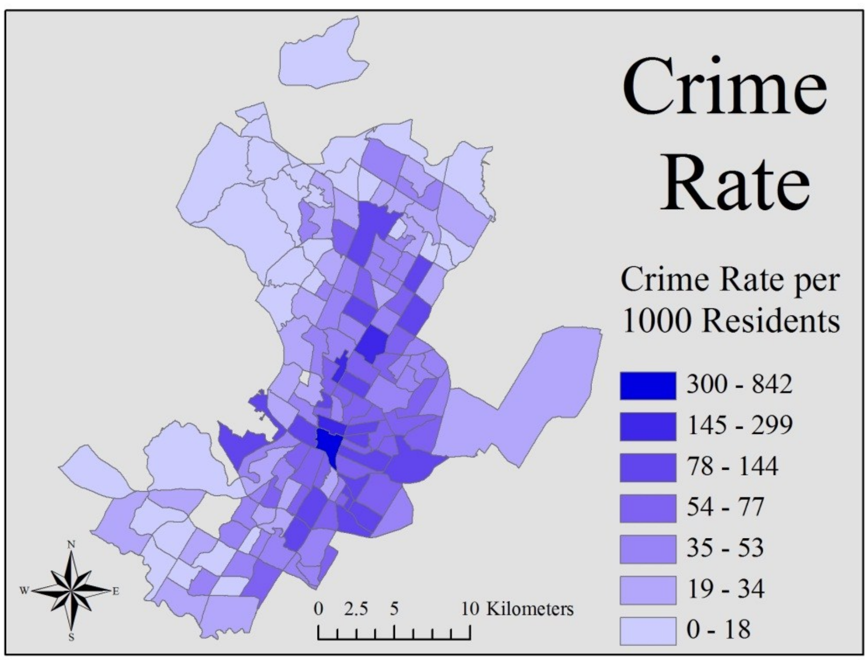

Figure 3.4. Incidents of Crime in the City of Austin.

The inclusion of crime as a variable of social disorganization is an important element in this assessment. Provided by the City of Austin police department (APD), the pre-processed crime data were aggregated to the census tract level. Crime rate was used to indicate the level of safety that the residents would feel in their neighborhood.

To extract the environmental variables for the city of Austin, multispectral data was acquired from the Landsat 7 ETM+ imageries. Landsat 7 ETM+ provides multispectral imagery in 7 spectral bands and a panchromatic image. These spectral bands allow the analyst to identify land cover (LC) by their unique spectral signature. Using ERDAS Imagine software, a Normalized Difference Vegetation Index (NDVI) was be calculated (Jensen 2005) as follows:

$$NDVI= \frac{P_{nir}- P_{red}}{P_{nir}+ P_{red}} \qquad \text{(Equation 3.1)}$$

Where:
P_{nir} is the infrared band
P_{red} is the red band

The NDVI value represents the greenness associated with the image for each pixel. Based on the NDVI histogram, minimum and maximum thresholds were identified for vegetation and impervious cover. The LC output was then used to derive the percentage of each land cover class present in each census tract.

The percentage of each tract containing water was determined based on the polygon layer of local water bodies created by the United States Geological Survey and considered for modeling QOL. Impervious surface cover included all man-made materials such as roads, buildings, and parking structures, while vegetated cover included both natural vegetation and manicured landscaping. For the QOL assessment of Austin, the percent of water, impervious surface and vegetated surface was included in the QOL index. High resolution remote sensing data, such as the multispectral data of QuickBirds, at 2.4 m spatial resolution, would likely yield more precise statistics. However, Landsat 7 ETM+ imageries is appropriate for the scale of investigation and provided thermal imageries as discussed below.

The final environmental variable, surface temperature was derived from the thermal band of the Landsat 7 ETM+ imagery in three steps. Landsat values were initially recorded as Digital Numbers (DN) which must be converted to a radiance value for a given pixel using the Spectral Radiance Scaling Method (Yale Center for Earth Observation 2010):

$$L_\lambda = \left(\frac{LMAX_\lambda - LMIN_\lambda}{QCALMAX - QCALMIN}\right) * (QCAL - QCALMIN) + LMIN_\lambda \qquad \text{(Equation 3.2)}$$

Where:
L_λ is cell value as radiance
QCAL = Digital Number
$LMIN_\lambda$ = spectral radiance scales to QCALMIN
$LMAX_\lambda$ = spectral radiance scales to QCALMAX
QCALMIN = the minimum quantized calibrated pixel value
QCALMAX = the maximum quantized calibrated pixel value

Atmospheric correction was then applied using local values for transmittance, upwelling radiance, and downwelling radiance to increase the accuracy of the radiance values by using the equation (Coll et al. 2010; Cited in Yale Center for Earth Observation 2010):

$$CV_{R2} = \frac{CV_{R1} - L\uparrow}{\varepsilon\tau} - \frac{1-\varepsilon}{\varepsilon} L\downarrow \qquad \text{(Equation 3.3)}$$

Where:

CV_{R2} is the atmospherically corrected radiance value
CV_{R1} is the radiance cell value
$L\uparrow$ is the upwelling Radiance
$L\downarrow$ is the downwelling Radiance
τ is Transmittance
ε is emissivity

Once the atmospheric correction was completed, cell values representing radiance were converted to degrees Kelvin. The average temperature for each tract was calculated for QOL assessment within the study area. The conversion of radiance to degree Kelvin was completed using equation 3.4 (Yale Center for Earth Observation 2010).

$$T = \frac{K_2}{\ln\left(\frac{K_1}{CV_{R2}}+1\right)} \qquad \text{(Equation 3.4)}$$

Where:

T is degrees in Kelvin
CV_{R2} is the atmospherically corrected radiance cell value
K_1 is 666.09
K_2 is 1282.71

Modeling Quality of Life

The social, economic and environmental variables were used to derive single/composite indicators to be included in the assessment of QOL. Individual variables were compared using Pearson's correlation to look for communality and reduce the redundancy between individual factors (Li and Weng 2005).

Once compiled, the variables were examined through factor analysis, a data reduction technique when examining a phenomenon with unknown underlying dimensions. Each integrated dimension can be a composite of multiple individual variables and explains a percentage of the total variance amongst the observations. In factor analysis, the first factor typically explains the majority of the variance, with each subsequent factor explaining a decreasing amount of remaining variance. In this study, each factor can be regarded as a specific aspect of QOL, such as livability and sustainability, as a function of the composition of contributing variables. Factor loadings with a cutoff threshold of 0.7 were used to group variables into each factor and indicate their relative importance amongst the remaining variables.

Using the % of variance explained for each variable as a weight (*W*), specific or synthesized QOL index *j* can be modeled for census tract *i* by using the following formula at the census tract level (Li and Weng 2005):

$$QOL_{i,j} = \sum_{1}^{n} F_i W_i \qquad \text{(Equation 3.5)}$$

where F_i is the factor score of a census tract *i* in a specific factor identified by factor analysis and *n* is the number of factors selected. Weighted linear combination (WLC), a method for weighting factors by their relative importance in site assessment, was used to create a composite score output in GIS. In the context of QOL assessment, WLC synthesizes various aspects of QOL across the urban space.

Model Validation

Currently, there is no consensus regarding a common standard for validating a QOL index. Ideally, the outcome of any QOL assessment should be compared to the actual quality of life experienced by residents. Given the nature of QOL, however, data collection from individual citizens may be artificially influenced by the varied nature of human perception in a given context. In this research, median home value, normalized by room number, was used for model validation.

First, the MHV for each tract was normalized to account for home size and room number. This normalization prevents larger homes from having too great of an effect on the QOL validation. Pearson's correlation was used to correlate the QOL score to the average home value for each tract. The result of this model validation represents the perceived value of a neighborhood and its market desirability. The null hypothesis can be stated as:

$$QOL_{i,j} = MHV_i \qquad \text{(Equation 3.6)}$$

where $QOL_{i,j}$ is the specific or synthesized QOL index j in census block i. The coefficient of determination (R^2) was used to examine the effectiveness of synthesized QOL indices in correlating with MHV. Multiple regression was used to model MHV by using the identified factors as the independent variables. The F-statistics and t-test (n = 147) were used to determine if the overall regression model and individual QOL predictors are statistically significant to model MHV at the 0.05 level.

IV. RESULTS

Overview

As described in the methodology chapter, this chapter lays out the results from correlation, factor analysis, and multiple regression. The correlation between variables related to QOL indicates that factor analysis could be useful in distilling the many variables into related factors to reduce the underlying dimensions. Prior to factor analysis, the data was examined to ensure it met the assumptions of a normal distribution for PCA and regression analysis. In some cases, a log transformation was used to increase the suitability for PCA and regression analysis. Following the calculation of the component factors, Weighted Linear Combination (WLC) was used to create a composite QOL index. Finally, this chapter concludes with the extraction of regression coefficients and R^2 values for each factor, the composite QOL index, and the validation variable of median home value.

Correlation

Data on 29 variables related to QOL were compiled and processed for statistical understanding using PASW Statistics 18 software, concurrently known as SPSS, and Microsoft Excel. The 29 variables represent the economic, environmental and social conditions of citizens for each of 147 census tracts within the study area. In addition to variables previously examined in QOL research are the variables of commute time and crime. Commute time is represented by a single value of mean travel time to work for residents age 16 and over, while crime is represented by seven individual variables each describing the incidence of a particular crime per 1,000 residents.

The distribution of each variable was examined prior to proceeding with factor analysis (Table 4.1). The descriptive statistics of crime data revealed a nonlinear distribution as some tracts experienced significantly greater incidence of crime outside of a normal distribution. To account for this nonlinearity, the log of each crime type was used to preserve the suitability of crime data for multiple regression later in analysis. Similarly, variables of housing density, population density, and water land cover required data transformation to meet the assumptions of multiple regression based on a normal distribution due to extreme kurtosis. Values of 0 were changed to .00001 to allow for a log transformation which requires positive numbers. The variable exhibiting the strongest kurtosis, water land cover, was later dropped in the multiple regression as it did not meet the 0.7 threshold cutoff in any of the identified factors. Descriptive statistics of all variables are found in table 4.1.

Table 4.1 Descriptive Statistics of all variables.

Descriptive Statistics						
	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic
MUR	0.00	0.57	0.05	0.11	2.29	4.88
RAP	0.00	2.51	0.35	0.41	1.92	5.92
ROB	0.00	18.86	1.41	2.18	4.30	28.46
AGG	0.00	21.79	1.93	2.75	3.78	20.83
BUR	0.00	42.75	8.81	5.93	1.84	7.10
THT	0.00	724.22	37.10	64.93	8.59	87.59
AUT	0.00	31.85	3.20	3.61	3.95	27.01
POD	404.25	19996.15	4811.60	3373.39	2.10	5.85
HOD	106.95	8690.00	2079.73	1538.10	2.33	7.27
COM	11.60	33.20	22.11	3.80	0.13	-0.15
MHI	7423.00	119260.00	46691.79	22090.51	1.18	1.43
MFI	16250.00	142656.00	56449.05	26509.93	1.05	0.86
PCI	3620.00	71028.00	24862.68	12418.04	1.21	1.87
UEM	0.00	8.70	3.02	1.74	0.93	0.78
FPV	0.00	46.60	9.79	9.03	1.22	1.42
IPV	0.00	69.40	14.42	12.53	1.66	3.67
9TH	0.00	42.80	8.19	9.76	1.41	1.28
HS	0.00	28.50	8.37	7.17	0.85	-0.19
HSG	2.60	32.60	17.11	8.00	-0.05	-1.16
COL	6.00	36.40	21.03	5.93	0.07	-0.15
ASC	0.20	11.10	4.87	2.43	0.34	-0.60
BAC	1.30	58.10	25.73	13.13	-0.09	-1.12
GRD	0.40	43.50	14.70	10.49	0.71	-0.59
VeQ	0.37	0.43	0.39	0.01	0.78	0.97
PUR	0.32	1.00	0.76	0.14	-0.45	-0.33
PVE	0.00	0.68	0.23	0.13	0.46	-0.21
PWA	0.00	0.36	0.01	0.04	7.31	67.80
TEM	74.91	85.15	80.56	2.10	-0.35	-0.05

AGG	Aggravated Assault	IPV	Individuals in Poverty
AUT	Auto Theft	FPV	Families in Poverty
BUR	Burglary	UEM	Unemployed
MUR	Murder	PCI	Per Capita Income
RAP	Rape	MFI	Median Family Income
ROB	Robbery	MHI	Median Household Income
THT	Theft	POD	Population Density
9TH	Ninth Grade Education	HOD	Housing Density
HS	High School; no diploma	COM	Mean Commute
HSG	High School Graduates	VeQ	Vegetation Quality
COL	College; No Diploma	PVE	Percent Vegetation land cover
ASC	Associate's Degree	PUR	Percent Urban land cover
BAC	Bachelor's Degree	PWA	Percent Water land cover
GRD	Graduate Degree	TEM	Temperature

Pearson's correlation was used to explore the strength of the relationship among individual variables (Table 4.2). In the context of QOL assessment, the correlation matrix found in Table 4.2 indicates that commute time is negatively related to per capita and family income (r = -0.329 and -0.176) at the 0.01 and 0.05 levels respectively, suggesting that higher income individuals spend less time commuting than lower income individuals. Similarly, commute time had a significant negative relationship with residents who had earned Bachelors' (r = -0.503) and Graduate degrees (r = -0.550) at the 0.05 level. However, commute time had significant positive relationships, with correlation coefficients ranging from 0.166 to 0.460, among residents who had less formal education, including those who obtained 9th grade, high school or an associate degree as the highest education level. These findings suggest that residents with higher education tend to have shorter commutes, but only at the Bachelor and higher level. Residents with less formal degrees, particularly at the level of high school graduate and below, tend to have longer commutes.

Table 4.2 Correlation Matrix for all variables.

Correlations

	AGG	AUT	BUR	MUR	RAP	ROB	THT	9TH	HS	HSG
AGG	1									
AUT	.705**	1								
BUR	.572**	.680**	1							
MUR	.178	.170	.372*	1						
RAP	.495**	.469**	.452**	.433*	1					
ROB	.687**	.574**	.524**	.148	.476**	1				
THT	.440**	.673**	.755**	.333	.469**	.473**	1			
9TH	.698**	.582**	.493**	-.126	.342**	.525**	.277**	1		
HS	.724**	.618**	.497**	.018	.421**	.500**	.307**	.870**	1	
HSG	.513**	.414**	.237**	-.178	.129	.258**	.111	.577**	.717**	1
COL	-.209*	-.188*	-.386**	-.216	-.295**	-.275**	-.335**	-.336**	-.200*	.259**
ASC	-.272**	-.243**	-.395**	-.400*	-.232*	-.368**	-.333**	-.331**	-.235**	.124
BAC	-.666**	-.543**	-.382**	.158	-.300**	-.409**	-.193*	-.829**	-.895**	-.870**
GRD	-.522**	-.439**	-.192*	.224	-.178	-.276**	-.044	-.661**	-.754**	-.876**
IPV	.448**	.538**	.519**	-.247	.340**	.395**	.510**	.509**	.484**	.163*
FPV	.561**	.554**	.499**	-.273	.344**	.485**	.411**	.712**	.678**	.355**
UEM	.412**	.468**	.404**	-.012	.260*	.351**	.330**	.555**	.507**	.288**
PCI	-.487**	-.534**	-.335**	.305	-.247*	-.288**	-.253**	-.642**	-.706**	-.690**
MFI	-.462**	-.548**	-.383**	.280	-.217*	-.298**	-.321**	-.622**	-.671**	-.620**
MHI	-.477**	-.618**	-.493**	.077	-.327**	-.334**	-.509**	-.530**	-.576**	-.462**
POD	.050	.272**	.248**	-.358	.009	.049	.216**	.226**	.188*	.035
HOD	-.027	.263**	.242**	-.280	-.026	-.001	.237**	.081	.051	-.101
COM	.204*	.004	-.031	-.056	.133	.078	-.264**	.388**	.464**	.460**
VeQ	.154	.047	.170*	-.085	.182	.205*	.182*	.097	.128	.031
PVE	-.191*	-.307**	-.197*	.123	-.030	-.149	-.218**	-.215**	-.210*	-.203*
PUR	.151	.270**	.179*	-.180	-.030	.103	.175*	.181*	.178*	.224**
PWA	.129	.092	.038	.291	.163	.158	.135	.096	.092	-.103
TEM	.140	.294**	.066	-.309	.003	.078	.075	.229**	.271**	.408**

	COL	ASC	BAC	GRD	IPV	FPV	UEM	PCI	MFI	MHI	POD	HOD	COM	VeQ	PVE	PUR	PWA	TEM
COL	1																	
ASC	.571**	1																
BAC	-.092	.059	1															
GRD	-.331**	-.253**	.835**	1														
IPV	-.400**	-.383**	-.336**	-.195*	1													
FPV	-.393**	-.362**	-.553**	-.399**	.869**	1												
UEM	-.193*	-.201*	-.444**	-.372**	.695**	.683**	1											
PCI	-.103	-.067	.713**	.789**	-.606**	-.658**	-.593**	1										
MFI	-.041	.029	.655**	.707**	-.620**	-.696**	-.553**	.921**	1									
MHI	.026	.131	.535**	.524**	-.738**	-.707**	-.587**	.832**	.901**	1								
POD	-.063	-.160	-.121	-.142	.605**	.438**	.474**	-.469**	-.494**	-.526**	1							
HOD	.021	-.190*	-.010	.011	.499**	.280**	.355**	-.308**	-.391**	-.477**	.883**	1						
COM	.166*	.243**	-.503**	-.550**	-.092	.090	.125	-.329**	-.176*	.023	-.141	-.228**	1					
VeQ	-.266**	-.084	-.061	.045	.195*	.266**	.074	.018	-.033	-.035	-.141	-.176*	.019	1				
PVE	-.104	-.012	.210*	.297**	-.304**	-.247**	-.215**	.419**	.417**	.457**	-.447**	-.402**	.095	.375**	1			
PUR	.150	.056	-.196*	-.312**	.283**	.232**	.215**	-.430**	-.410**	-.439**	.422**	.377**	-.101	-.399**	-.964**	1		
PWA	-.191*	-.176*	-.022	.102	.035	.016	-.037	.111	.041	.004	.025	.031	.037	.146	.019	-.283**	1	
TEM	.270**	.204*	-.318**	-.511**	.165*	.208*	.172*	-.519**	-.475**	-.387**	.336**	.275**	.118	-.258**	-.756**	.798**	-.279**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

AGG	Aggravated Assault	IPV	Individuals in Poverty
AUT	Auto Theft	FPV	Families in Poverty
BUR	Burglary	UEM	Unemployed
MUR	Murder	PCI	Per Capita Income
RAP	Rape	MFI	Median Family
ROB	Robbery	MHI	Median Household
THT	Theft	POD	Population Density
9TH	Ninth Grade Education	HOD	Housing Density
HS	High School; no diploma	COM	Mean Commute
HSG	High School Graduates	VeQ	Vegetation Quality
COL	College; No Diploma	PVE	Percent Vegetation
ASC	Associate's Degree	PUR	Percent Urban land
BAC	Bachelor's Degree	PWA	Percent Water land
GRD	Graduate Degree	TEM	Temperature

Crime of all types were negatively associated with all income variables and levels of education beyond high school graduates and positively associated with high school education and below. The exception was murder which had a significant correlation to residents with Associate degrees and rape significant at the 0.05 level. Due to the urban heat island effect, temperature was also negatively associated with variables describing vegetation (i.e. VeQ and PVE) and water, while being positively associated with percent of urban land cover at the 0.01 level. Hence, tracts with more vegetation and water land cover have lower temperatures than those with more urban land cover. An interesting observation was that temperature was positively associated with education levels through high school and negatively associated with bachelor's degree and higher. These relationships indicate that residents with higher education typically experience lower temperatures within their neighborhoods. The correlation matrix reveals that many of the variables described are correlated and confirms the need to reduce the redundancy of the variables and examine underlying relationships for factor analysis.

Data Suitability for Factor Analysis

Prior to factor analysis, the dataset was examined using the Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity. The KMO test compares the correlation and partial correlation statistics to determine if the variables contain sufficient divergence to extract unique factors. The threshold value of 0.5 was met with a KMO value of 0.649 for all 29 variables. Bartlett's Test of Sphericity (BTS) ensures there is correlation between variables, amongst the population. In other words, BTS checks the correlation matrix to validate that it is not an identity matrix in which correlation values are 0 for each pair of variables beyond the value of 1, which representing the correlation of each variable with itself. For the study variables, Bartlett's Test of Sphericity value was significant < 0.001, validating that correlation between variables does exist in the population.

Communality, which describes the extent to which a variable can be predicted, using the remaining variables as factors, was used to determine if any variable should be excluded from the factor analysis (Table 4.3). Generally, lower communality values indicate that a variable may not be sufficiently described by the data set as a whole and may not be useful in the factor analysis. Although temperature exhibited a low value for commonality, it was included in factor analysis as the use of the 0.7 threshold later determined the significance of this variable.

Table 4.3 Communalities Table for all variables.

Communalities		
	Initial	Extraction
Aggravated Assault (log)	1.00	0.83
Auto Theft (log)	1.00	0.83
Burglary (log)	1.00	0.73
Murder (log)	1.00	0.84
Rape (log)	1.00	0.67
Robbery (log)	1.00	0.82
Theft (log)	1.00	0.69
Ninth Grade Education	1.00	0.88
High School; no diploma	1.00	0.96
High School Graduates	1.00	0.91
College; No Diploma	1.00	0.82
Associate's Degree	1.00	0.75
Bachelor's Degree	1.00	0.94
Graduate Degree	1.00	0.93
Individuals in Poverty	1.00	0.87
Families in Poverty	1.00	0.90
Unemployed	1.00	0.85
Per Capita Income	1.00	0.92
Median Family Income	1.00	0.90
Median Household Income	1.00	0.87
Population Density (log)	1.00	0.81
Housing Density (log)	1.00	0.80
Mean Commute	1.00	0.64
Vegetation Quality (NDVI > 0.34)	1.00	0.47
Percent Vegetation land cover	1.00	0.88
Percent Urban land cover	1.00	0.93
Percent Water land cover (log)	1.00	0.79
Temperature	1.00	0.33
Extraction Method: Principal Component Analysis.		

One interpretation of communality would relate each variable to the percent of its variance explained by the overall dataset. For example, the communality table indicates only 33% of the variance within the variable of temperature is explained; whereas 93% of the variable representing residents with graduate degrees is explained. This would suggest that the factor analysis is more successful in describing graduate degrees than temperature. However, variables should not be assessed based on communalities alone, but on the context of the variable with related variables and the extent to which it aids in interpreting each factor.

Factor Analysis

Principal Component Analysis (PCA) was used as the factor analysis method within this study. Using an eigenvalue threshold greater than one, PCA identified seven components explaining a cumulative 77% of the variance within the data model (Table 4.4). A varimax rotation in PASW was used to assist in interpretation of the PCA analysis. The rotated component matrix was examined for variables with a cutoff threshold of 0.7. The first factor exhibited high loadings on variables related to education and commute time, indicating short commute times are related to either higher education (i.e. Bachelor or graduate degrees) and high school graduates. Factor 2 was a composite economic and density index related to poverty and density, both housing and population. Factor 3 was related to auto theft, burglary and theft. Hence, factor 3 represented the property safety index. Factor 4 represented an environmental index as indicated by high factor loadings on temperature and terrestrial land cover types. As described in factor 4, temperature increases with percentage of urban land cover and decreases with vegetative land cover. Factor 5 loaded on the variables of college; no degree, and associate’s degree.

This factor appears to be related to moderate education, or possibly to current students. Future investigation including the age of residents (e.g. 18-21) may be helpful in further defining the significance of factor 5. Factor 6 loaded on the single variable of rape, although it is worth noting that the variable of murder also had a high loading of 0.622, just missing the cutoff threshold. Clearly, factor 6 is related to violent crimes.

Table 4.4 Rotated Component Matrix.

Rotated Component Matrix[a]

	Component					
	1	2	3	4	5	6
Aggravated Assault (log)	.58	.07	.61	-.02	.24	.09
Auto theft (log)	.35	.29	**.74**	-.13	.11	-.02
Burglary (log)	.14	.28	**.76**	.02	.24	-.13
Murder (log)	-.29	-.02	-.13	.02	-.30	.62
Rape (log)	-.02	-.12	.12	.05	.11	**.73**
Robbery (log)	.33	.04	.63	-.01	.32	.17
Theft (log)	-.06	.27	**.84**	.01	.14	.01
Ninth Grade Education	**.74**	.25	.26	-.06	.43	-.14
High School; no diploma	**.82**	.23	.31	-.04	.27	-.08
High School Graduates	**.85**	.11	.18	-.11	-.24	-.02
College; No Diploma	.12	-.03	-.20	-.19	**-.84**	-.02
Associate's Degree	.12	-.07	-.30	-.06	**-.72**	.08
Bachelor's Degree	**-.89**	-.18	-.25	.06	-.01	.10
Graduate Degree	**-.88**	-.21	-.09	.21	.26	.06
Individuals in Poverty	.17	**.73**	.28	-.04	.46	.11
Families in Poverty	.43	.62	.23	.00	.49	.05
Unemployed	.34	.65	.12	-.02	.30	.07
Per Capita Income	-.67	-.62	-.13	.24	.06	.00
Median Family Income	-.55	-.69	-.20	.20	.04	.05
Median Household Income	-.34	**-.76**	-.37	.19	.00	.00
Population Density (log)	-.05	**.77**	.13	-.28	-.06	-.33
Housing Density (log)	-.24	**.71**	.21	-.26	-.15	-.34
Mean Commute	**.73**	-.15	-.26	.09	-.06	-.01
Vegetation Quality	.08	.16	.14	.62	.10	.15
% Vegetation land cover	-.07	-.23	-.20	**.88**	-.02	.05
% Urban land cover	.07	.24	.14	**-.92**	-.01	-.03
% Water land cover (log)	-.07	-.28	.21	.41	.01	-.18
Temperature	.29	.20	.04	**-.80**	-.16	.03
Initial Eigen values	10.32	3.84	3.35	1.60	1.21	1.18
% of Variance	36.84	13.70	11.95	5.72	4.31	4.22
Cumulative %	36.84	50.54	62.48	68.21	72.52	76.74

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

To facilitate interpretation of the factor distribution maps below, the expression of factors have been inversed to reflect their true relationship to QOL, where a positive number represents greater QOL. Figure 4.1 illustrates the distribution of factor 1 across the study area. Higher scores in factor 1 are related to higher formal education and shorter commute time. Figure 4.2 illustrates factor 2 where higher scores correlate to decreased poverty, decreased population density and housing density. Figure 4.3 illustrates the distribution of factor 3, where lower values are associated with greater incidence of property crime. Figure 4.4 relates to factor 4, environmental quality, where higher numbers represent increased vegetation and decreased temperatures. Figure 4.5, factor 5, illustrates mid-levels of education where higher numbers are associated with increased populations with some college, and populations with associate degrees. Figure 4.6 shows the distribution of factor 6 where lower values are associated with decreased incidence of personal or violent crime.

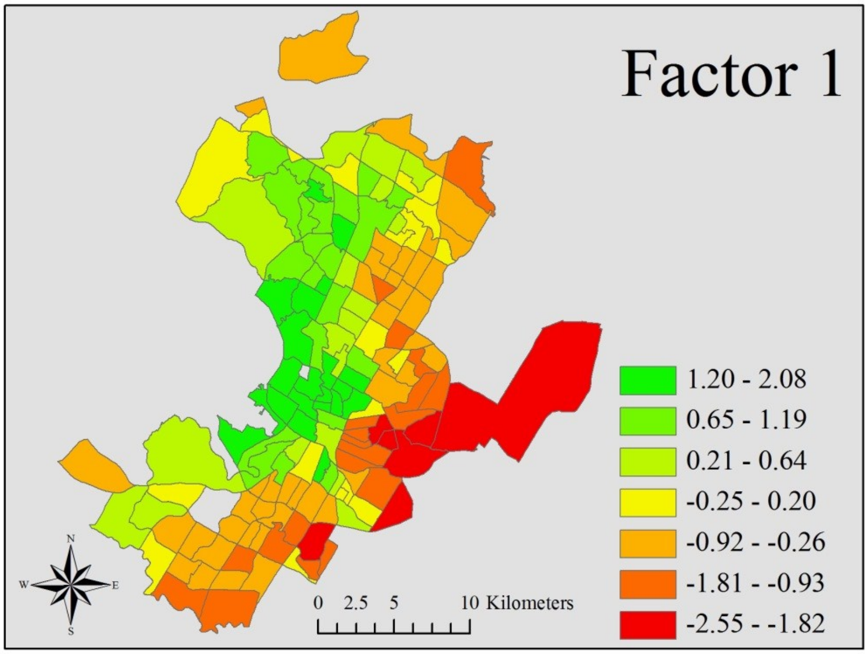

Figure 4.1 Factor 1 – Higher Education and Commute Index.

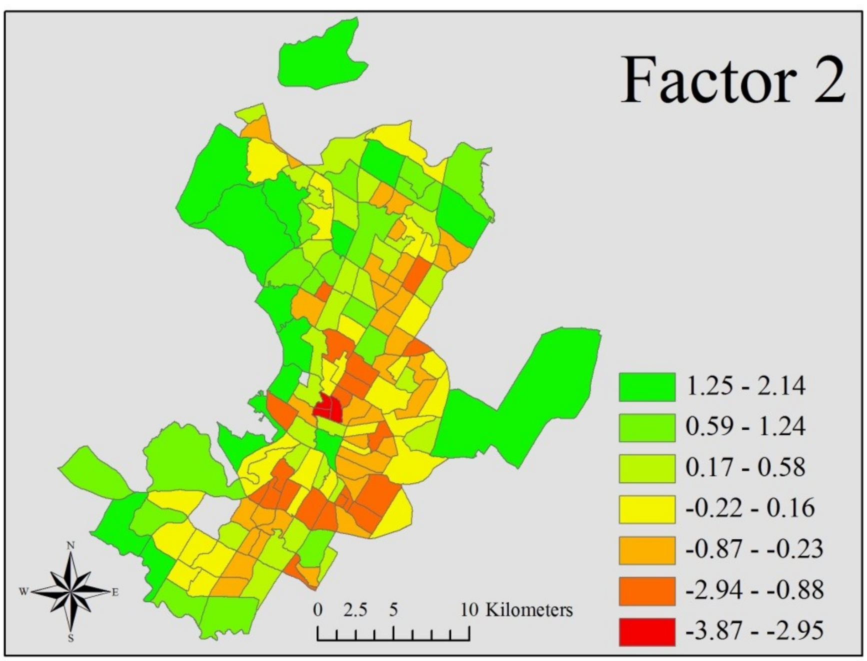

Figure 4.2 Factor 2 – Economic and Density Index.

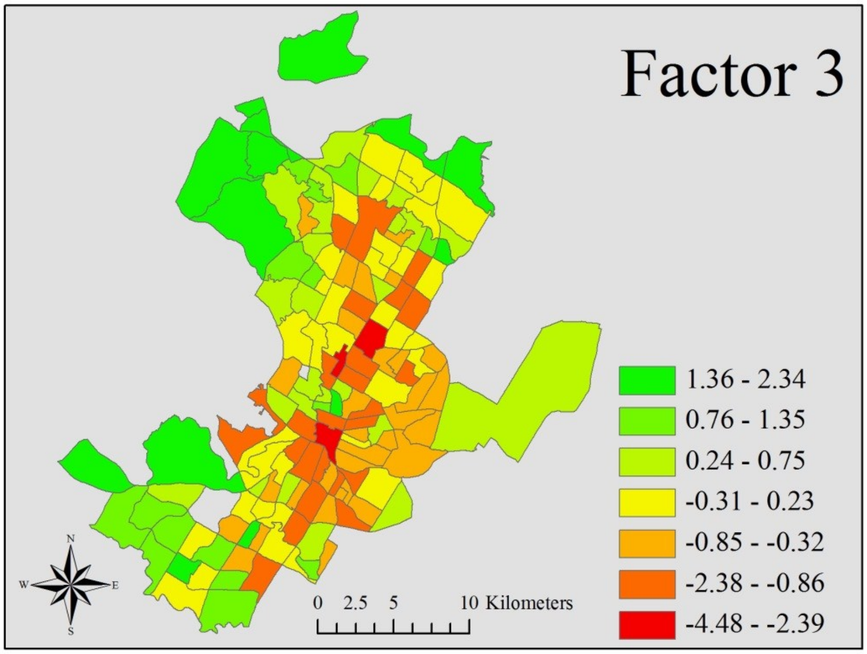

Figure 4.3 Factor 3 – Property Safety Index.

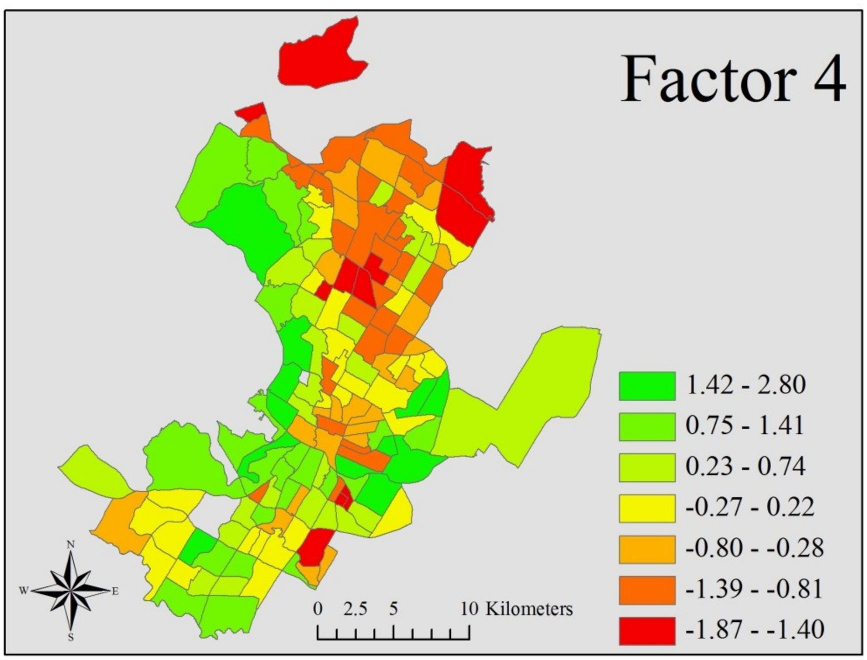

Figure 4.4 Factor 4 – Environmental Index.

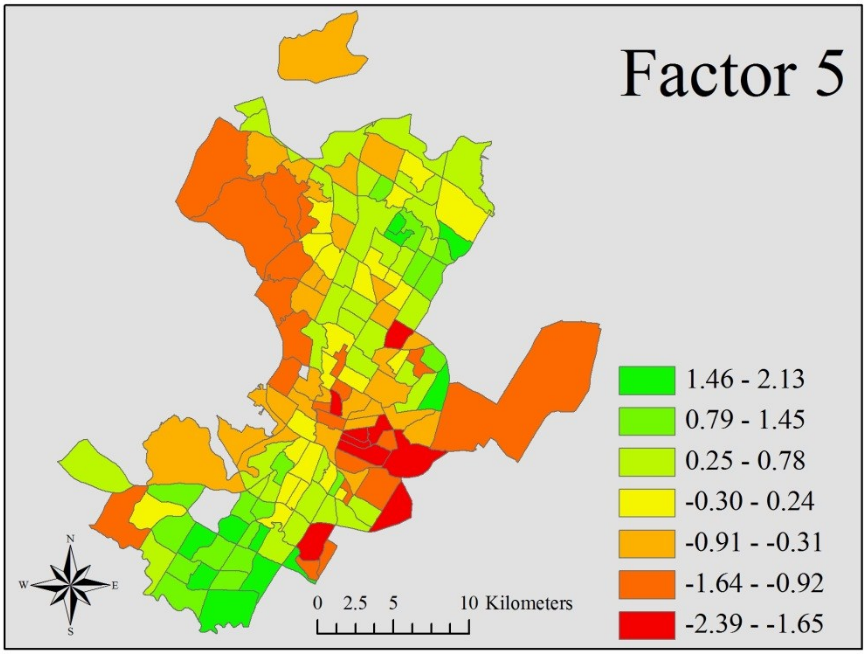

Figure 4.5 Factor 5 – Some College Index.

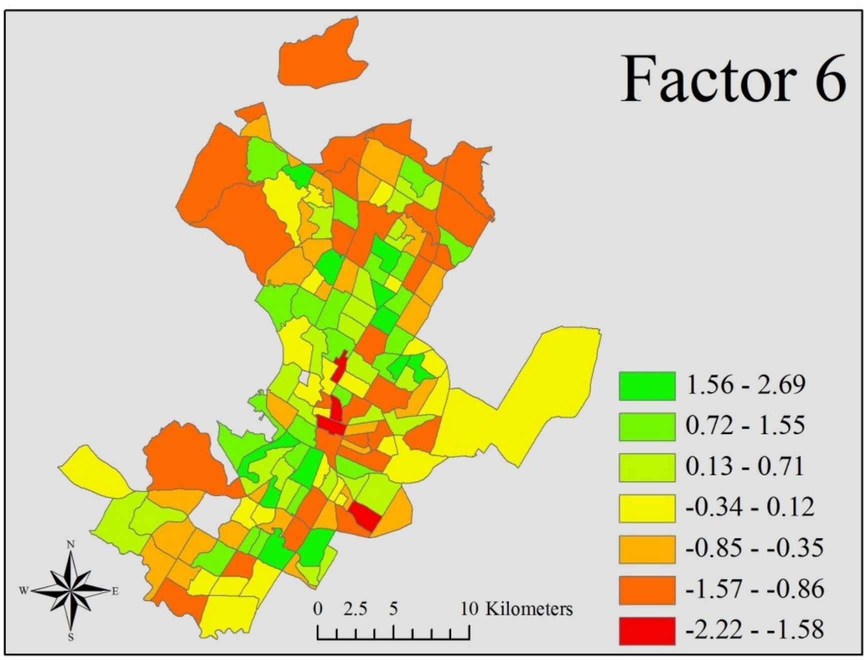

Figure 4.6 Factor 6 – Personal Safety Index.

Composite Quality of Life

Following the extraction of individual components, a synthetic QOL index was created by using the percent variance explained to weight each factor based on its relative importance (equation 3.5). Equation 4.1 was used to synthesize the overall QOL for the entire study area where f_n represents the each of the seven factors identified.

$$QOL = (f_1 * 36.838 + f_2 * 13.699 + f_3 * 11.945 - f_4 * 5.724 + f_5 * 4.314 + f_6 * 4.223)/100 \quad \text{(Equation 4.1)}$$

Figure 4.7 illustrates the distribution of synthetic QOL across the study area. Computing factor scores in PASW creates a scale score with an arithmetic mean of 0. These scores can be useful for urban policy-makers as the positive or negative term of the QOL score can quickly identify tracts which may require intervention. QOL index scores for Austin ranged from -1.12 to 0.78 with 64% of all tracts falling within one standard deviation of the mean. Census tracts which scored above 0.5 tended to have highly educated residents, shorter commute times, and reduced urban density. In contrast, tracts which scored below -0.5 tended to have high urban density, high crime, and have large populations in poverty.

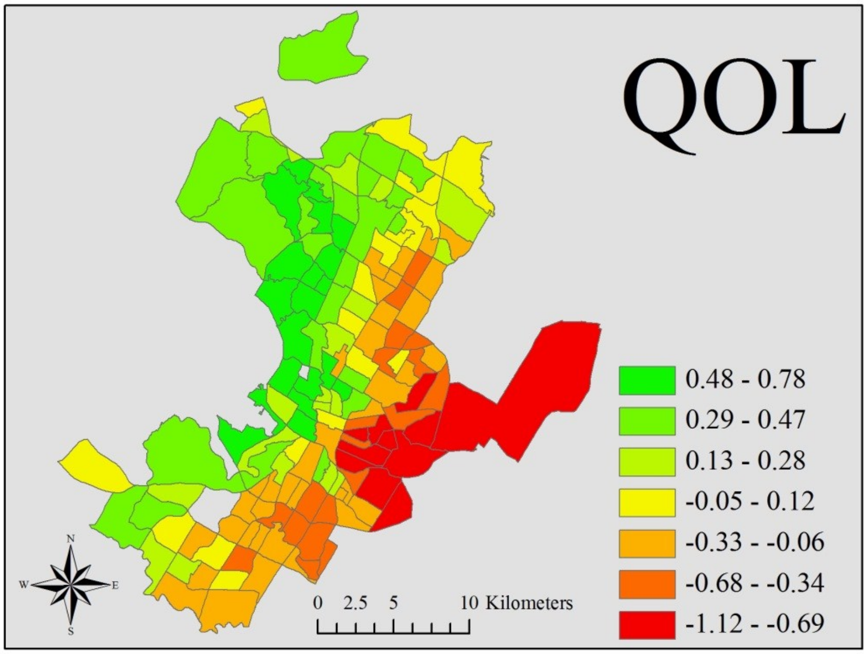

Figure 4.7 Synthetic Quality of Life Index.

Multiple Regression

Median home value (MHV), normalized by the number of rooms, was used for model validation. Synthetic QOL values for each tract were compared to MHV using Pearson's correlation, resulting in an *r* of 0.61, significant at the 0.01 level. As synthetic QOL increases, so does the MHV within the census tract.

Multiple regression analyses were used to evaluate if the variables contribute significantly to predicting individual factors, synthetic QOL and MHV (Table 4.5).

Table 4.5 Multiple Regression of individual factors and Synthetic QOL. All predictors shown were significant to model individual response at the 0.05 level indicated by the *t*-tests.

Models	Predictors	Coefficients	R^2
Factor 1 (Education and Commute Time)	(Constant)	-2.30	0.94
	less than high school education	0.01	
	Some High School; no diploma	0.02	
	High School Graduates	0.03	
	Bachelor Degree	-0.01	
	Graduate Degree	-0.02	
	Commute time	0.09	
Factor 2 (Density)	(Constant)	-5.55	0.79
	Median Household Income	1.11	
	Individuals in Poverty	0.50	
	Population Density	0.00	
	Housing Density	0.00	
Factor 3 (Property Crime)	(Constant)	-2.46	0.78
	Auto Theft	0.58	
	Burglary	0.60	
	Theft	1.29	
Factor 4 (Environmental Quality)	(Constant)	11.14	0.86
	Percent Vegetation	-0.13	
	Percent Urban	-5.90	
	Temperature	-0.08	
Factor 5 (Some College)	(Constant)	2.97	0.79
	Some College, no diploma	-0.11	
	Associate Degree	-0.15	
Factor 6 (Personal Crime)	(Constant)	0.60	0.54
	Rape	2.62	
Synthetic QOL	(Constant)	-0.43	0.88
	Bachelor Degree	0.03	
	Population Density	-0.02	
	Theft	-0.06	
	Percent Urban	-0.43	
	Some College, no diploma	0.01	
	Rape	-0.16	
MHV	(Constant)	141057.07	0.77
	Aggravated Assault (log)	-8462.87	
	Auto Theft (log)	4802.59	
	Robbery (log)	-5694.77	
	Graduate Degree	684.77	
	Families in Poverty	590.47	
	Median Family Income	0.27	
	Median Household Income	-0.28	
	Percent Urban	21328.42	
	Temperature	-1561.78	
	Population Density (log)	-53261.26	
	Housing Density (log)	52987.50	

A backward stepwise regression method was used to determine the predictive strength of the synthetic QOL index to model MHV at the 0.05 level. Beginning with all 27 variables, a maximum R^2 of 0.77 was achieved with 11 variables. Variables including population and housing density; family, household and per capita income; residents with graduate degrees, aggravated assault, robbery, and families in poverty were significant at the 0.05 level.

V. DISCUSSION

Spatial Distribution of Quality of Life in the City of Austin

The results of Pearson's correlation and PCA reveal several unique observations about the distribution of QOL in the City of Austin. While the population in Austin tends to be highly educated as compared to the national average, the distribution of educated residents is not uniform across the landscape. Factor 1 indicates a clear division in education between the approximate west and east (Figure 4.1). Commute time, which tends to be longer for the periphery, was also negatively correlated with education. Tracts with highly educated residents living close to the urban core scored well in factor 1.

One possible explanation for this pattern in Austin may be related to its position as a state capital. The downtown region of Austin is generally a busy, vibrant scene. As the meeting location of the state legislative bodies, highly educated public servants may choose to live near the state offices and experience short commute times to the capital and associated law firms, court buildings, and other administrative offices.

The relationship between high education and short commute time in Austin may also be partially explained by the presence of the University of Texas. Just north of the capital area, the University of Texas is one of the largest research universities in the United States with over 50,000 undergraduate and graduate students and 24,000 faculty and staff (University of Texas at Austin 2011). Graduate students and faculty living near the campus strengthen the correlation between advanced education and short commute although this is more transient population than traditional residential neighborhoods. It should be noted that the commute time statistic does not take into account distance. In other words, longer commute times do not necessarily imply greater distances to work. Considering that caveat, one potential explanation for longer commutes for residents with less education may by the use of public transportation. Individuals who choose not to own a car, cannot afford a car, or are not able to drive may spend more time commuting as a result of their reliance upon public transit. However, many highly educated residents may choose this method of commuting as well. More research on the populations using public transportation as well as its geographic availability would be useful.

Factor 2 illustrates the distribution of housing and population density, as well as individuals in poverty and median household income (Figure 4.2). However, it is worth noting that all economic variables exhibited relatively high loadings (Table 4.4), even those who did not meet the 0.7 threshold (e.g. unemployed, MFI, etc). Within the city of Austin, urban density is the greatest inside a central corridor extending from the southwest to the northeast.

Property crimes are predominant in factor 3, specifically theft, auto theft, and burglary. The distribution in property crimes shows significant variation between the west and the east, with a cluster of high crime incidence in the eastern reaches of the urban core (Figure 4.3). This hotspot for property crime corresponds to the Sixth Street section of Austin, an entertainment district known for bars, live music, and late night entertainment. Tourists, college students, and local residents often frequent Sixth Street, particularly during one of the many festivals and conferences held in Austin each year. In addition to the adult entertainment, this stretch of Sixth Street is adjacent to Interstate 35, allowing for easy movement for criminals in and out of the area.

In contrast to the previous factors, environmental quality displays a greater variation between the northern and southern regions of Austin (Figure 4.4). In the north, the data reveals less vegetation, more urban land cover, and corresponding higher surface temperatures. One explanation for this distribution is the varied nature of retail within Austin. Within the region of lower environmental quality found in the northern parts of the city, several large shopping centers are located with vast expanses of impervious surface parking and large square footage retail structures. By comparison, relatively few multi-entity retail locations exist in south Austin. One exception is the separate municipality of Sunset Valley, excluded due to a lack of data. Located in the southwest region of Austin, Sunset Valley is largely retail and a further examination of this area would likely indicate lower environmental quality than the surrounding tracts. As population growth extends south, however, more large retail is being developed and the environmental quality in Austin should be monitored for future change.

Factor 5 represents residents with some college training but no degree, or residents who have earned associate degrees. It is possible that some of this population is composed of current undergraduate students at the University of Texas, Austin Community College, or one of several other academic institutions in the city. The distribution of factor 5 may potentially be explained by the type of housing available in each tract. Future research may be useful which incorporates the percentage of rental properties in each tract for example. The separation of factors 1 and 5 within PCA indicates that this population represents a more difficult population to categorize. These residents possess educations between high school graduates and residents with Bachelor's degrees. Consequently, this population likely presents attributes in common with higher and lower education residents in terms of their geographic distribution, though with higher concentrations further from the urban core (Figure 4.5). However, similar to higher education residents, factor loadings for this group were negative, suggesting that residents with some college education may have more in common with higher education residents, though not sufficiently similar to be grouped in factor 1.

Figure 4.6 illustrates the incidence of rape, though it should be noted that murder also had a relatively high loading in factor 6 (Table 4.4). It is important to note that the personal and property crimes significantly differ in nature and spatial distribution. While clear regions of high property crime existed, personal crimes appear to be much more dispersed. One further distinction is the incidence rate related to rape and murder, which both occur far less commonly than the property crimes included in this analysis. For example, the murder rate in Austin is relatively low for a city of its size. In 2000, there were 33 murders in Austin and only one census tract which had more than one murder, at three (APD 2000). In contrast to the infrequency of murder, rape is a violent crime which is widely considered to be underreported (Fisher et al. 2003). The results of this research suggest that the lack of data and the nature of violent crimes may indicate uncertainties for QOL assessment than property crimes would. However, violent crime may be more valuable as a variable in cities with high violent crime or urban areas with prevalent gang territories.

Individual factor and synthetic QOL indices reveal a very distinct variation in the distribution of QOL in Austin, specifically high QOL in the north and west, declining toward the east and south. As the PCA results suggest, this trend is largely explained by the differences in educational attainment, commute time, crowdedness, crime and environmental quality. While these are clear distinctions, the factors of middle education levels and personal safety appear to be more nuanced and likely require further investigation. In the case study of Austin, the use of PCA was useful for separating factors in terms of their relative significance. An R^2 of 0.88 is achieved using the six variables which had the highest factor loadings for each factor: bachelor degrees, population density, theft, percent urban land cover, some college (no degree), and rape.

Synthetic Quality of Life

A synthetic index simplifies QOL assessment by creating a single value that is the synthesis of many variables. As previously described, variables are weighted to reflect their relative importance and relationship with other variables. However, researchers must take caution in the creation and publication of synthetic QOL.

As the synthesis of multiple values, a synthetic index obscures the nuances of individual variables in favor of creating a generalized representation of a given concept. One example is found in the economic and density factor, factor 2. An examination of figure 4.5 shows a tract in the central section of west Austin which had a negative score in factor 2, indicating low income and higher urban density, figure 5.1 shows this tract in greater detail. Ground truth examination of this tract reveals the presence of graduate student and graduate family housing belonging to the University of Texas. The high population of graduate students in this tract is one possible explanation for the low income observations. Nevertheless, this nuance of factor 2 is largely obscured in the synthetic index map, figure 4.7.

Figure 5.1 University of Texas graduate student housing.

Nevertheless, a synthetic QOL index can be extremely useful for local policy makers attempting to target or prioritize improvement efforts in the community. While the number of variables which may be considered is infinite, this study expanded the general framework of QOL assessment laid down by previous research and outlined a useful technique for quickly assessing an urban area using a value that is easy to understand and compare.

Quality of Life and Median Home Value

The results of Pearson's correlation (r=0.61) indicates that synthetic QOL is significantly correlated with MHV over the study area. Using multiple regression, eleven variables: population and housing density; family, household and per capita income; residents with graduate degrees, aggravated assault, robbery, and families in poverty were considered significant to predict MHV (R^2=0.77). Three of these variables, household income, per capita income, and robbery however did not meet the 0.7 cutoff threshold to be included in the multiple regression for each factor and synthetic QOL. This suggests that more research into the relationship of these variables is needed. One limitation of MHV is the personal motivation residents may have for living in a particular neighborhood. Although, the data appears to suggest that income may be of more significance for MHV than it is for QOL.

In this study MHV is intended to indicate the market desirability of a neighborhood based on the perceived QOL of potential home buyers. While the relationship with QOL indices is significant, it leaves room for an improved method of model validation. Future research may examine MHV in conjunction with additional variables to form a more robust method for validating the empirical assessment of QOL.

There are intrinsic difficulties defining and measuring QOL over a large and unique landscape. One difficulty is in the definition of QOL and the identification of significant variables for assessing QOL. Once created however, the validation of the index can create difficulties. Not only is it impossible to directly measure QOL, but a researcher must also be careful not to introduce redundancy between the index and the validation statistics.

In chapter 3, the null hypothesis states that there is no difference in the QOL of a specific census tract and the corresponding MHV (equation 3.6). Based on the results of Pearson's correlation (r=0.61), the null hypothesis is rejected as there is a significant positive correlation between QOL and MHV at the 0.01 level.

VI. CONCLUSION

Quality of Life in Austin

Using variables previously identified in QOL research, as well as the new variables of crime and commute time, important observations can be made about regional variations in QOL. Residents in the west and northwest tracts of Austin tend to have higher education, higher incomes, shorter commutes, and less property crime in the surrounding neighborhood than people in either the central or eastern portions of the city. Examination of the individual factors reveals these characteristics are highly significant in explaining the variance of QOL across the urban landscape. Education, commute time, MHI, density, and property crime comprise the first three factors and 62% of the variance alone. Each of these factors displays the aforementioned pattern of variation from the west and northwest to the east. As a consequence, this pattern is also highly visible in the final synthetic QOL index.

The residents of Austin could be well-served by future research aimed at understanding this pattern of QOL. One of the many benefits of QOL research is the ability to quickly examine the distribution of a composite of indicators related to the well-being of a population. This information could be helpful in targeting neighborhoods or populations that may be experiencing a unique variation of marginalization.

Although a city may not be capable of directly influencing income in particular neighborhoods, programs aimed at increasing post-secondary enrollment and reducing crime specifically targeted at the east side of Austin could be a valuable step to addressing the needs of its residents. Perhaps ironically, as neighborhoods experience reduced crime and revitalization, property values will likely rise as well. By working to increase the average education of the residents on the east side of Austin, the long term benefit would likely be increased income and the ability to afford the rising property values as the neighborhood becomes more desirable. By adopting this long-term focus, Austin could potentially increase its highly educated population, improve the QOL of its residents, and consequently benefit from increased property tax revenues. The precision investment in residents begins with the identification of local neighborhoods experiencing reduced QOL and the specific needs in these areas. The synthetic QOL assessment presented here is a valuable first step.

Quality of Life Study

The findings of this research are largely consistent with the findings of Li and Weng in their study of Indianapolis (Li and Weng 2007). In their examination of QOL in Indianapolis, Li and Weng identified education and income, environmental quality, and density, as being the most significant factors, respectively. Clearly, education, income, environmental quality, and density are important to QOL and should be considered when examining QOL in any location. However, this research includes the unique variables of commute time and crime to the composite assessment. Based on the case study of Austin, these variables add an important dimension to QOL. Commute time and property crime were included in the first and third factors respectively, indicating they are significant to explaining the variance of the data set. One important aspect of these variables is that they are dynamic, implying potential movement between neighborhoods.

Commute time illuminates the possibility that residents may choose neighborhoods which are distant from their place of work. This implies a cost to productive time and the ability to foster healthy relationships and trust with family, community members, and the general public. Further research into the effect of commute time on QOL may examine the role of public transportation. Some residents may have long commutes measured by time based on their reliance on public transportation, even if the distance travelled is not substantial. However, public transportation can also offer a resident the opportunity to be productive during their commute. It would be valuable to understand these dynamics in future QOL study.

This study also illustrates the importance of crime in QOL assessment. Property crime displayed a greater predictability in distribution than personal crimes, suggesting that the nature of a crime may influence its extent across the urban landscape. Property crime was most prevalent in the central corridor of Austin and spreading to the east. This pattern, while not as strong as with factors one and two, is clearly apparent. By contrast, the incidents of personal crimes were far less predictable, occurring broadly across the study area. As one would expect, this is an indication that there are influences beyond financial gain that may instigate these violent crimes. This research indicates that the influences of crime are critical to understanding QOL.

Model Validation

Median home value, normalized by room number, was used for model validation in the study of Austin. The results of correlation and regression indicate that MHV can be accurately predicted using variables related to QOL. The eleven variables used in the backward regression met, or nearly met, the 0.7 cutoff threshold in the first three factors. Cleary MHV does display a strong relationship with QOL. This research suggests that the MHV represents increased market desirability of a specific neighborhood. In other words, homes are more valuable because the QOL in the surrounding neighborhood is perceived as high.

This model validation represents a successful attempt at relating QOL to a market index. The relationship of QOL to real estate market desirability presents a potentially valuable tool for real estate professionals, perspective home buyers, and neighborhood representatives. In addition, this validation also lends credence to the concept that cities could financially prosper from improving the QOL in certain areas, thereby increasing property tax revenue from increased home values. Real estate purchases are based on complicated variable, however, and a resident may choose a home based upon its proximity to a personal or natural landmark, facility, or even identification with the culture of current residents. Future research which creates a composite validation index which includes variables in addition to MHV may be useful.

Limitations

QOL is the aggregate of socio-economic and environmental variables, individual perception of unique life events, and any additional factors that may influence the human-environment interface. Due to the role of individual variables, a synthetic QOL index may not be applicable at a larger scale.

While the synthetic QOL indices are strong indicators of the perceived environmental quality and economic position of a neighborhood, it should be noted that a resident's decision to live in a given location may also be influenced by many factors including proximity to family, friends, or work. Therefore the validity of the model may be the most useful for comparing tracts with greater disparity in QOL, rather than slight differences.

The timeframe of this research required the use of Census data from 2000. While the results will portray a historical QOL in the recent past, it will be interesting to use the proposed framework to examine current QOL based on Census 2010 data to be released in March/April. It is important to acknowledge the change of population dynamics between census collections when discussing the results of this research in light of current QOL in the city of Austin.

Quality of Life as a Topic for Research

This research has added to the understanding of empirical QOL assessment by adding the variables of commute time and crime rate, applying the model to a new study area, and examining the relationship between QOL and MHV. Building upon the work of previous researchers, this study continues the examination of a fascinating and critical topic. Understanding and assessing the QOL of residents over a large area gives policy-makers the ability to identify the needs of their constituent populations. Using this knowledge, the potential exists for advocacy programs to target specific neighborhoods with campaigns aimed at supplementing the identified needs of the residents.

QOL is a fascinating topic of research which, by its very natures, is dichotomous. As a composite of endogenous and exogenous factors, QOL exhibits the potential to be studied using quantitative, qualitative, and mixed-method techniques. The use of GIS and remotely-sensed variables is a unique solution to empirical study of a concept that is difficult to define. However, it is not meant to replace personal study of small groups or individuals.

Since there is no currently accepted framework for studying QOL (Leidelmijer et al. 2002), researchers and policy-makers have the opportunity to both define its characteristics and the methods for assessment. Undoubtedly, this will require a multi-disciplinary approach as QOL varies between cities, and more significantly, globally. The task of understanding QOL and tools for assessing it over large populations is nevertheless vital for future development of American cities, and potentially the world. Disparity between groups is certainly not a new facet of human civilization, but rather the natural manifestation of unequal access to power and resources. In the 21st century these resources are increasingly defined by new technology and the ability to leverage these technologies for the advancement of our life quality. QOL research develops the opportunity for technologies like GIS and remote sensing to assess the condition of large groups quickly and inform positive and efficient change directed at specifically identified needs.

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VITA

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