MINNESOTA POPULATION CENTER

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Working Paper Series

Urban Form and Family-Engaged Active Leisure: Impact Assessment Using the Census Data and Nighttime Satellite Images

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July 2010

Working Paper No. 2010-01
https://doi.org/10.18128/MPC2010-01

Abstract: This research examines whether urban form indicators are useful predictors of family-engaged active leisure among U.S. population. The study sample includes 23,759 adult respondents from the 2003-2008 American Time Use Survey who lived with family members in 326 metropolitan counties. Urban form is measured at the county level by two methods: one uses the remotely-sensed nighttime satellite imagery and generates scale-adjusted sprawl indices based upon per capita land consumption, and another uses the ground-based Census data and generates a multi-dimensional measurement system, termed 3C+P: compactness, continuity, centrality, and proximity. Regression results across models consistently suggest a significant and negative association between sprawl and daily time spent on family-engaged active leisure. The scale-adjusted sprawl indices are found to be on par with the 3C+P indicators in measuring urban sprawl and predicting family-engaged active leisure. Implications of the findings for researchers and practitioners are discussed.

Keywords: urban form; sprawl; active leisure; physical activity; family; nighttime satellite imagery

Acknowledgements: This study was funded, in part, by a proposal development grant at the Minnesota Population Center and by the Grant-in-Aid of Research, Artistry and Scholarship Program at the University of Minnesota.

Introduction

Recent decades have witnessed dramatic changes in American family structure. According to the 1976-2008 March Current Population Survey (King, Ruggles, Alexander, Leicach, & Sobek, 2009), the number of dual-earner families increased 95% over the past three decades, more than double the overall family growth rate (40%)[1]. We have also witnessed increases in divorce, in children born outside marriage, and as a result, in single parenthood. From 1976 to 2008, the number of single-parent families, overwhelmingly headed by the mother, increased 116%. By 2008, out of 47 million families with children, about 32% (15 million) were single-parent families. The increasing prevalence of dual-earner couples and single parents means an upsurge in time squeezes for American families, as dual-earner families face many hours of combined work and as single-parent families face a constant tug-of-war between the need to support their children and the need to spend time with them (Jacobs & Gerson, 2004). When compared to people who live alone, families have suffered much more decline in leisure time and impoverishment of lifestyles. However, existing analyses of trends and patterns in leisure time use have typically focused on individuals and few studies have examined leisure time use in light of the changing nature of family life. Even fewer have paid specific attention to dual-earner couples and single parents, yet it is clear that these two family groups have replaced the traditional male-breadwinner model in both numbers and social significance.

Further, leisure time looks and feels different from the point of view of families than it does from the point of view of individuals. Allocation of daily leisure time,

[1] These estimates based upon survey data collected in Current Population Survey (CPS) are different from decennial Census data. While the CPS samples are designed to be geographically and demographically representative, sample statistics are likely to be subject to sampling and nonsampling errors.

compared to hours at work, is more deeply marked by negotiation among family members (Fan & Khattak, 2009). The critical role that intra-household dynamics play in shaping leisure-time activity engagement underscores the need for family-centered analysis in which individuals within families are recognized as having unique concerns, strengths, and values. By choosing individuals who live with family members as the study population and focusing on family-engaged active leisure, this research advances the existing understanding of the built environment-activity engagement link by bringing into play family interaction and joint engagement dynamics. The family-centered approach also brings the problems associated with families—single parenthood, the work-family divide, and so on—into the forefront.

Role of Urban Form in Influencing Family-Engaged Active Leisure

The last half century in the U.S. can be characterized as an age of dispersal. Census 2000 confirmed more Americans living in suburbs than in central cities and rural areas combined. While the migration to the suburbs has been in part fuelled by a desire to escape the mix of classes and ethnic groups of urban areas, and by government- and market-shaped economic incentives, the suburban ideal has, from its beginnings, been associated with a vision of family togetherness—the desire of finding an environment in which family ties can be strengthened (Miller, 1995). However, American families may find themselves moving in the opposite direction from the healthy and rich family life that they intended to live. Most suburban neighborhoods built in the past several decades contain little mix of retail, office, or recreational spaces, which distance residents from activity opportunities (Ewing, Pendall, & Chen, 2003). The 2003-2008 American Time Use Survey (ATUS) shows on average American spent 75 minutes per day on trips to various activities, almost three times as much as thirty years ago (BTS, 2001). Time is scarce: more time spent on trips means less time available for family, recreation, and other leisure activity opportunities. Ultimately, this means impoverished family life and more sedentary activity patterns with a limited variety of leisure activities that one can engage in.

In recent years, researchers have widely investigated the role of the built environment in shaping daily activity patterns of residents (Ewing, Schmid, Killingsworth, Zlot, & Raudenbush, 2008; Frank & Engelke, 2001; Frank, Engelke, & Schmid, 2003; Handy, Boarnet, Ewing, & Killingsworth, 2002). However, it is rarely recognized that the built environment may play a much larger role in influencing activity patterns of families than individuals. Joint activities require coordination of family members' timetables and such coordination is likely to reduce the potential locations for joint activities to a relatively small space around the residence (Fan & Khattak, 2009). Consequently, the amount of activity opportunities available in the residential neighborhood matters more to families than individuals. Given such apparent importance of residential environments to joint activity engagement among family members, it is disconcerting that the vast majority of studies on the built environment and physical activity do not distinguish individuals who live with families from those who live alone. This research addresses this knowledge gap by focusing on US adults who live with family members, by examining the prevalence of family-engaged active leisure among these adults, and by assessing how urban form may influence their time use decisions towards family-engaged active leisure.

Data and Study Area

This research uses publicly available data from the 2003-2008 ATUS. The target population for the ATUS are all civilian US residents age 15 or older, with the exception of active military personnel and people residing in institutions such as nursing homes and prisons (Basner, et al., 2007). ATUS participants are selected randomly from households completing their final month interviews in the Current Population Survey (CPS)—a monthly, federally administered, continuous survey that has been conducted for more than 50 years. The participants in the 2003-2008 ATUS included a fraction of CPS participants in a time frame spanning from August 2002 to October 2008. ATUS does not collect any geographic information from its participants. In this research, geographic identifiers of each ATUS participant were obtained by linking the participant to the corresponding household in CPS. Within confidentiality restrictions imposed by the U.S. Census Bureau, ATUS-linked CPS files provide Federal Information Processing Standards (FIPS) codes for a total of 326 metropolitan counties. This offers an opportunity to link county-level urban form measures to individual time use behavior. Figure 1 illustrates the locations of the 326 identifiable counties in the 2003-2008 ATUS.

[insert Figure 1]

ATUS involves computer-assisted telephone interviewing (CATI) in which survey respondents are interviewed on the next day of a preselected day about how they spent their time from 4AM on the preselected day to 4AM of the interview day (days are selected to ensure proportional distribution across the days of the week and even distribution across the weeks of the year). Each activity described by the respondent is coded using a three-tiered scheme, going from a top-level category of activities, to subcategories, to third-tier activities that describe very specific actions. For example, “sports, exercise, and recreation” is a top-level category, which includes a second-tier category of “participating in sports, exercise, or recreation” under which “playing baseball” is a third-tier activity. Besides the three-tier activity lexicon code describing “what” is the activity, each activity record is associated with several other attributes including the starting and ending time attributes describing “when”, the location attribute describing “where”, and the company attribute describing “with whom”. Detailed household/personal socio-demographic information is reported in the ATUS respondent file. In addition, there is the ATUS-CPS file which contains information collected in the CPS about each ATUS respondent and his/her household members.

While attempts have been made to collect the most accurate data possible, the ATUS data do have limitations. First, the response rate of the 2003-2008 ATUS data ranged from 52.5% to 57.8%. With a higher than 40% rate of non-response, concerns have been raised about whether the results can be generalized to the target population. Abraham, Maitland and Bianchi (2006) found modest differences between estimates calculated with and without non-response adjustments, and suggested that although the possibility of non-response being a source of bias is not large in ATUS, such possibility cannot be ruled out (Abraham, Maitland, & Bianchi, 2006). Second, despite the Census Bureau’s quality assurance procedures, errors could occur during data entry and coding. Third, the sampling strategy of the ATUS is primarily designed to ensure demographic representativeness of the sample, which does not contain much consideration of the sample’s geographic distribution. One could argue that, to some extent, the ATUS sample is geographically representative as the sample is drawn from those who participate in the CPS and the CPS selects sample counties across the United States. However, within each sample county, the CPS does not make any efforts to ensure the sampled households to be distributed across various parts of the county. The degree to which the county-level variation in family-engaged active leisure is due to spatial sampling bias (e.g., households living in central cities are consistently oversampled in less sprawling metropolitan areas) is unknown. As a result, study findings from this research must be interpreted with caution.

With a focus on individuals within families, the final sample in this research is limited to the ATUS participants who were aged 18 or older and lived in the 326 identifiable counties with family members (i.e., spouse, unmarried partners and/or children under 18) during the time of the survey—resulting in a total of 23,759 individuals. Table 1 describes the percentage distributions of various population groups in the final sample, which confirms the sample's diversity and representativeness in demographic and socio-economic terms.

[insert Table 1]

Figure 2 summarizes how the ATUS participants in the final sample on average spent their leisure time. Based upon the ATUS's three-tier activity lexicon code system, leisure activities are categorized into 6 groups: socializing (code 1201, 1202), relaxing (code 1203), arts & entertainment (code 1204), active leisure (code 1301), religious activities (code 14), and volunteer activities (code 15). As shown in Figure 2, the participants on average spent 3 hours and 20 minutes per day (about 2 hours with family and the rest away from family) on relaxing and passive leisure activities such as watching TV, playing video/computer games, and listening to radio/music. Note that the ATUS data include both weekday and weekend samples and as a result the numbers presented in

Figure 2 are mean values averaged over both weekdays and weekend days. Compared to time spent on passive leisure, ATUS respondents spent much less time on socializing activities (44 minutes per day) and far less time on active leisure such as exercise and sports (19 minutes per day), indicating impoverished and sedentary lifestyles within American families. Moreover, the level of family-engaged active leisure is extremely low: only six out of the 19-minute active leisure time was family-engaged. With so little time spent on active leisure and with family members, many US families have created sedentary family environments and negative reinforcement that are unhealthy for both adults and (especially) the vulnerable child population (Timperio, et al., 2008; Zaborskis, Zemaitiene, Borup, Kuntsche, & Moreno, 2007).

[insert Figure 2]

Measuring Urban Form: Ground-Based Census and Remotely-Sensed Imagery

Although both satellite and Census data have been proven to be useful resources to map urban areas (Imhoff, Lawrence, Stutzer, & Elvidge, 1997), to measure sprawl (Galster, et al., 2001; Sutton, 2003), and to assess land-use and land-cover changes (Parker, Manson, Janssen, Hoffmann, & Deadman, 2003), they both have their own known limitations. For Census datasets, they are not a substitute for direct observations of the land surface. For remote sensing data, coarse resolution data sets have inadequate spatial and spectral resolution for reliably determining urban infrastructure, while the higher resolution data present problems of analysis due to the vast data volume required for processing. In addition, remote sensing data with coarse resolution are known to overestimate the actual size of human settlements due to the large pixel size and possible geo-location errors. As a result, remote sensing data often require the use of thresholding techniques to map boundaries more accurately (Elvidge, et al., 2003). This research uses both Census datasets and remote sensing imagery to generate county-level urban form measures. This allows comparison and cross-validation of the usefulness of the two different types of data in measuring urban form and its impact on family-engaged active leisure.

Out of the many remote sensing image datasets, this research uses nighttime satellite imagery for at least three reasons:

1) Theoretically, the nighttime imagery may be more suitable than other remote sensing data (e.g., land cover datasets) for measuring urban form because urban systems are essentially aggregations of human activities and nighttime lights intensity serves as a good proxy measure of human activity intensity. There has been research evidence suggesting linear relations between nighttime city lights data and social-economic variables such as population and Gross Domestic Product (Elvidge, et al., 2003).

2) The nighttime imagery has additional advantages given its temporal continuity and spatial coverage. The nighttime imagery dataset available at the National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Center is a time series of annual global nighttime lights products at an approximately $1km^2$ resolution extending from 1992 to 2003. The time series provide high contrast between lit and unlit lands and covers large area per scene, making them an innovative and appropriate choice for classifying and mapping urban development at large regional scales (See Figure 1). Given these characteristics of nighttime imagery, remote sensing researchers have increasingly used NOAA's global images of nighttime lights in generating population density estimates (Sutton, Roberts, Elvidge,

& Meij, 1997); as well as in modelling environmental and ecological impacts of urbanization including urban heat island effects (Gallo, Tarpley, McNab, & Karl, 1995), the impact of coastal development on sea turtle nesting activities (Salmon, Witherington, & Elvidge, 2000), and impacts on greenhouse gas emissions (Doll, Muller, & Elvidge, 2000). Interested readers are referred to Elvidge, et al. (2003) for a detailed review of the applications that have been developed or proposed for nighttime lights imagery.

3) When compared to other remote sensing datasets, application of nighttime imagery in mapping urban area is relatively recent. Little research exists comparing the urban form measures generated from the dataset with those generated from other datasets such as the Census datasets. The field of remote sensing is in need of more research that helps to advance the application of nighttime imagery and more analyses that lead to better understanding of the limits of such satellite data.

Three types of nighttime images are available as geotiffs for download from the NOAA's Version 2 DMSP-OLS Nighttime Lights Time Series: (1) Cloud-free coverages that tally the total number of observations that went into each 30 arc-second grid cell (approximately 1 km*1 km at the equator) during each calendar year; (2) Nearly raw raster data that contain the average of the visible band digital number (DN) values of each calendar year; and (3) The cleaned-up raster data that contain the annual average of the visible band DN values calculated with background noise and ephemeral lights from events such as fires being removed from the coverages. This research uses the third image type (i.e., the cleaned-up stable lights images) and adapts an approach developed by Sutton (2003) to generate urban form measures out of nighttime satellite imagery. Sutton's approach involves three general steps: 1) select light intensity thresholds to characterize the urban extent in each spatial analysis unit (e.g., county or metropolitan area), 2) estimate "sprawl lines" to describe the relationship between the population and areal extent of these urban areas, 3) estimate the residual percentage based upon the "sprawl lines" and use the residual percentage as a measure of urban sprawl. A spatial unit with a positive residual percentage means higher-than-expected population and lower-than-expected land consumption per capita in that spatial unit, thereby represents less sprawling urban form. A negative residual percentage represents a higher extent of sprawl.

Setting light intensity thresholds inevitably involves making assumptions and simplifications. This research uses Census-defined urbanized area boundaries as a check when setting urban thresholds on the nighttime images. To increase the robustness of the measurement, two thresholds are used and analyzed separately. The orange area in Figure 3 represents the lower threshold (average visual band digital number value >= 15) and measures larger urban extents. The red area in Figure 3 represents the higher threshold (average visual band digital number value >= 45) and captures urban areas more strictly. The 2003 nighttime satellite image is used in this research given its apparent relevance to the 2003-2008 time use data.

[insert Figure 3]

Using the 2003 nighttime lights image, two different boundaries are created to describe the urban extent in each of the 326 study counties, including a low-threshold urban boundary and a high-threshold urban boundary. The two urban boundaries, coupled with a block group-level population dataset from the Census, are used to derive both area and population size of the urban parts in each county. The area and population size information is further used to estimate the regression parameters for the following log-log relationship:

$$\ln(Population) = \beta_0 + \beta_1 * \ln(Area) + \varepsilon$$

Where ε represents the error term—that is, the residuals to help us determine whether each county has an urban population smaller or larger than its expected size. As the log-log format produces residuals that are more normally distributed, the format is preferred over the simple linear format. The scatterplots of the log-log relationship using high- and low-thresholds are respectively shown in Figures 4 and 5. The regression lines, which present the average relationship between the areal extent and population of urban areas in the 326 study counties, are also shown in Figures 4 and 5. Each point in the scatterplot represents one of the study counties. The points above the regression line (also referred as sprawl line) represent counties with a higher-than-expected population, which implies lower-than-expected per capita land consumption. These counties can be viewed as experiencing less sprawl than the counties that fall below the line.

The log-log relationship shows a strong correlation for the area and population data generated using the high threshold (R-Square=0.77) and a moderately strong correlation for the data generated using the low threshold (R-Square=0.37). This indicates that larger variation exists in the residuals estimated using the low threshold than those estimated using the high threshold.

[insert Figures 4 and 5]

Table 2 reports both the raw scores and rankings for the top 10 least sprawling counties. As shown in Table 2, the raw scores in the high-threshold column are generally smaller than those in the low-threshold column, indicating smaller residual variations when estimating the high-threshold sprawl line. The rankings in Table 2 suggest that the sprawl index generated using the low threshold is largely consistent with that of the high threshold. Counties ended up with high rankings using the low threshold do not differ much from the top-ranking ones using the high threshold. The consistency between the two sprawl indices to some degree reflects the reliability of this scale-adjusted measure of sprawl.

[insert Table 2]

The second approach exclusively uses ground-based Census data and is built upon Galster, et al. (2001)'s measurement of sprawl. This approach is intended to capture the multi-dimensionality of the sprawl phenomenon. Four county-level urban form measures are created and termed as 3C+P indicators (i.e., compactness, continuity, centrality, and proximity).

- Compactness measures land-use density/intensity. In this research, it is simply defined as population per square mile in the county.

- Continuity measures the degree of connected versus "scattershot" land use. It is defined as the percentage of census block groups showing patterns of continuous development. Given such a definition, the continuity dimension is concerned with density only as a means of determining whether a block group contains enough housing units to consider it part of a continuous pattern or skipped over. In this research, a threshold of two housing units per acre is used to distinguish continuous from leapfrog development. In addition, a threshold of 0.2 housing units per acre is used to exclude the rural parts of each county from the continuity calculation.

- Centrality measures the strength of central cities/downtowns. It is defined as the weighted average distance from block groups in the county to their nearest principal cities. According to the Census, the largest city in each metropolitan statistical area is designated a "principal city." Additional cities qualify if specified requirements are met concerning population size and employment. The principal city concept is intended to identify cities that contain the primary population and/or the primary economic centers of a metropolitan area.

- Proximity measures relative closeness of residences to complementary land uses (e.g., shopping and recreation). In this research, it is defined as the weighted average distance from block groups in the county to their nearest parks, shopping centers, churches/religious institutions, recreation areas, and schools. Factor analysis is used to create a composite index out of the multiple proximity indicators.

Formal operationalization of the 3C+P measurement is shown below.

$$Compactness(i) = \frac{P(i)}{A(i)}$$

$$Continuity(i) = \frac{\sum_{n=1}^{N(i)} \mathrm{I}\{H(i,n) > 2\}}{\sum_{n=1}^{N(i)} \mathrm{I}\{H(i,n) > 0.2\}}$$

$$Centrality(i) = \sum_{n=1}^{N(i)} (Dis(n,p) \times \frac{P(i,n)}{P(i)})$$

$$\mathrm{Pr}\,oximity(i,j) = \sum_{n=1}^{N(i)} (Dis(n,j) \times \frac{P(i,n)}{P(i)})$$

Where

i represents county index;

$N(i)$ represents the total number of block groups in County i;

$P(i)$ represents the total population in County i;

$A(i)$ represents the total area size in square miles in County i;

n represents block group index;

$P(i,n)$ represents total population of Block Group n in County i;

$H(i,n)$ represents housing density of Block Group n in County i, measured by number of dwelling units per acre;

$Dis(n, p)$ represents the linear distance from Block Group n to its nearest principal city; and

$Dis(n, j)$ represents the linear distance from Block Group n to its nearest activity center j ($j = 1, ..., 5;$ representing parks, shopping centers, churches, recreation areas, and schools).

Since the 3C+P measurement allows a finer-grained categorization of the built environment, large variation is expected across the four dimensions. Raw scores and rankings of the measurement in Table 3 confirm this expectation. Counties with high rankings on some dimensions do not necessarily have high rankings on other dimensions. For example, Norfolk, VA is ranked as the top one on the Centrality dimension but is only ranked as the 26th on the Continuity dimension. Surprisingly, when adding the rankings up across the four dimensions and then ranking the counties based upon the add-up, most counties appeared in Table 2 are included in Table 3 as well. This indicates some level of consistency between the scaled-adjusted sprawl index approach and the 3C+P approach.

[insert Table 3]

Regression Analysis

The dependent variable in this research is the total amount of time that the respondent spent on family-engaged active leisure during the ATUS diary day. Like many other time use variables, the family-engaged active leisure variable contains many zero observations and represents a two-stage decision structure: an individual must decide whether to participate in family-engaged active leisure, and if so, how much time he/she would like to allocate. Given the nature of the dependent variable, Tobit regression is used in this research. Tobit is a discrete/continuous modelling procedure that first models a discrete choice of passing the zero threshold, and second (if it is passed) models a continuous choice regarding the value above the zero threshold. By incorporating the discrete model of passing the zero threshold into the continuous model of actual time use, Tobit models are able to address the zero-value clustering issue associated with the family-engaged active leisure variable: Out of the 23,759 respondents in this analysis, 22,166 respondents (93%) did not conduct family-engaged active leisure activities on the survey day. The Tobit model's form is presented in the following equation:

$$y = \begin{cases} y^* = \beta \cdot x_i + \varepsilon & if \quad y^* > 0 \\ 0 & if \quad y^* \leq 0 \end{cases}$$

where, y^* is a latent unobservable variable that linearly depends on independent variables x_i via a parameter (vector) β. ε is a normally distributed error term that captures random influences on the relationship between y^* and x_i. y is the observable variable defined to be equal to the latent variable whenever the latent variable is above zero, and to be equal to zero if otherwise. In our analysis, y represents the family-engaged active leisure variable measured by minutes spent with family members on active leisure activities per person per day. x_i is a set of explanatory variables including urban form indicators, personal/family attributes, temporal contexts, and social environmental factors.

Three Tobit models are estimated (see Table 4). In Models 1 and 2, the low- and high-threshold sprawl indices generated from nighttime satellite imagery are respectively used to predict family-engaged active leisure. Besides the sprawl indices, the simple county-level population density measure (persons per square mile) is also included in

Models 1 and 2. Adding the simply density measures to Models 1 and 2 is expected to improve the performance of the two models, as the sprawl indices are measured using residual percentage—a measures of how each county's land consumption stands out relative to others—and the indices themselves do not capture the absolute land consumption or density scale of the county. In Model 3, the 3C+P urban form measures generated from Census data are used. According to the chi-squared tests reported in Table 4, all three models are statistically significant.

Unlike traditional regression coefficients, the Tobit coefficients cannot be interpreted directly as estimates of the marginal effects of changes in the explanatory variables on the expected value of the dependent variable. In a Tobit equation, each marginal effect includes both the influence of the explanatory variable on the probability of adoption as well as on the intensity of adoption. Stata provides a 'dtobit' command for calculating the marginal effects of the estimated Tobit model. The marginal effects of our Tobit models are presented in Table 4 as well, which translate the Tobit coefficients into ordinary least squares (OLS) regression equivalents.

[insert Table 4]

Results from Tobit models indicate a significant association between urban form and family-engaged active leisure. Coefficients in Models 1 and 2 suggest that both low- and high-threshold sprawl indices are positively associated with daily time spent on family-engaged active leisure. The results suggest a negative relationship between sprawl and family-engaged active leisure, as higher values on the sprawl indices imply lower-than-expected land consumption rates. When comparing Model 1 with Model 2, Model 2 performs slightly better than Model 1, as shown by a lower log-likelihood value and a higher pseudo R-square. This indicates that the high-threshold sprawl index is a better predictor than the low-threshold sprawl index of family-engaged active leisure. In other words, the negative relationship between sprawl and family-engaged active leisure can be more accurately estimated by imposing a stricter classification of the urban extent. Another interesting finding from Models 1 and 2 is that after taking into account the sprawl index, the simple density indicator (total county population divided by the total area size of the county) shows a negative relationship with family-engaged active leisure. This is consistent with previous empirical evidence that simple density measures are inappropriate and insufficient delineation of urban form (Fan & Khattak, 2009) and that the importance of density has been overemphasized in the war on sprawl (Gordon & Richardson, 1997).

Model 3 uses the 3C+P measurement to estimate the urban form and active leisure connection, which performs slightly better than Models 1 and 2. However, the differences in model performance are rather minimal: The log-likelihood value in Model 3 (-14516.8) increased by one from that of Model 2 (-14517.8). This indicates that the multiple county-level urban form indicators derived from detailed ground-based Census data may not necessarily generate a more accurate representation of urban form than the scale-adjusted sprawl index derived from nighttime satellite imagery at an approximately 1km^2 resolution. Despite the relatively little difference in model performance, Model 3 provides more informative results than Models 1 and 2. As shown in Table 4, the compactness indicator, as measured by the simple density indicator, has a negative relationship with family-engaged active leisure. This is consistent with the negative relationship found in Models 1 and 2. The centrality indicator, as measured by weighted average distance from block groups in the county to their nearest principal cities, also shows a negative relationship with family-engaged active leisure. As higher values on the centrality indicator represent weak central cities/downtowns in the region, the result suggests that people who live in regions with predominant central cities are more likely to be engaged in active leisure with family members.

The regression coefficients of the urban form variables in Model 3 are also more meaningful and easier to interpret than those in Models 1 and 2. Although we know higher values on the sprawl indices suggest less sprawl, the indices are measured in less "meaningful" units as residual percentage. To some extent, the indices are similar to variables with arbitrary values on a scale, and as such it is difficult to explain the meaning of a one-unit increase in these indices. This issue may be partially addressed by applying the concept of standard deviation (SD) in the result interpretation. The low-threshold sprawl index has a SD of 6.5 and the high-threshold sprawl index has a SD of 5. Along with the regression coefficients in Models 1 and 2, it can be calculated that a one-SD increase in the low-threshold sprawl index is associated with a 0.6-minute increase in family-engaged active leisure (0.09*6.5=0.6) and a one-SD increase in the high-threshold sprawl index is associated with a one-minute increase in family-engaged active leisure (0.19* 5=1). The effect sizes of the sprawl indices are on par with those of the 3C+P measures. Based upon the standard deviation values of the 3C+P measures and the regression coefficients in Model 3, a one-SD increase in population density is associated with a 0.64-minute decrease in family-engaged active leisure and a one-SD increase in the centrality indicator is associated with a 0.6-minute decrease in family-engaged active leisure.

In terms of other explanatory variables than urban form, older age is associated with less family-engaged active leisure. African Americans on average spent five minutes less everyday on family-engaged active leisure than other racial groups. Both education level and family income are positively associated with family-engaged active leisure. Adults who held a bachelor's degree or higher on average spent about three minutes more per day on family-engaged active leisure than high school graduates and about four minutes more per day than those who did not complete high school. Both weekends and holidays are associated with longer time spent with family members on active leisure. People on average spent four minutes more on family-engaged active leisure during weekends than weekdays.

Family-wise, single parents have the lowest level of engagement in active leisure with family members. Results in Table 4 show that daily time spent on family-engaged active leisure by single parents on average is four minutes less than that of regular couples. As expected, dual-earner couples spend less time on family-engaged active leisure than non-dual-earner couples. Presence of young children (age <=12) is associated with a two-minute gain on daily family-engaged active leisure time.

Discussion and Conclusions

For people with families, activity decisions are often created and experienced in the context of family togetherness rather than of isolated individuals. Yet the standard analyses of the built environment and activity engagement overlook the "with whom" dimension of activity participation. This research attempts to close the gap by focusing on individuals with families and focusing on examining factors contributing to these individuals' engagement in active leisure with family members. Evidence found in this research suggests a significant and negative association between sprawl and family-engaged active leisure. Centrality, strength of central cities/downtowns, is found to be associated with higher level of engagement in active leisure with family members. These findings imply negative impact of urban sprawl on social capital and public health, which have practical implications for both urban planners and public health practitioners. The ongoing “active living by design” movement has illustrated that individual well-being can be improved by creating places possible for people to be active. With a family-centered approach, this research provides empirical evidence that such places may contribute to family well-being by promoting family-engaged active leisure. Stronger family ties, in turn, are expected to encourage family-oriented social activities (Eyler, et al., 1999). Thus, the social and health benefits associated with such places are likely to be reinforced through its positive impact on observational social support from family (e.g., joint engagement in active leisure).

Researchers interested in measuring urban form and/or in exploring the urban form-activity engagement link may also find this study useful. The study employs both the ground-based Census data and remotely-sensed imagery to generate urban form measures. Results show that both measurement approaches produce robust representations of regional urban form. The scale-adjusted sprawl index derived from the 1 km^2-resolution nighttime satellite imagery is on par with the multi-dimensional 3C+P measurement generated based upon various Census datasets in measuring sprawl and in predicting family-engaged active leisure. As the nighttime satellite images are publicly available, longitudinal, and global, researchers who are interested in countries or historical periods where spatial Census data are not readily available could use this remotely-sensed imagery as a reasonable (if not ideal) substitute.

Table 1: Demographic Distribution of the Study Sample (N=23,759)

	Distribution Statistics	Study Sample	Census 2000
Individual Characteristics *N=209,128,094 in Census 2000	Female	56.3%	51.7%
	White	82.8%	77.4%
	Black	10.5%	11.4%
	Hispanic	19.0%	11.0%
	Age 65 or older	11.1%	16.7%
	Employed	70.2%	70.0%
	Have no high school degree	14.2%	20.3%
	Bachelor's degree or higher	35.4%	22.3%
Family Characteristics N= 71,787,347 in Census 2000	Single parents	17.6%	**19.1%
	Dual-earner couples	43.3%	**44.8%
	Family income lower than $15,000	8.1%	10.1%
	Family income higher than $40,000	67.5%	61.3%
	Family income higher than $75,000	37.9%	27.7%

Note:
*With the publicly available Census data, it is practically impossible to calculate distribution statistics of various population groups within the universe of people aged 18 or older and living with family members. The best comparable universe in Census with the final sample comprises people aged 18 or older (N=209,128,094).
**Census data do not offer sufficient family structure to distinguish single-parent families and dual-earner families from other families. 2000 March CPS is used here to estimate the prevalence of single-parent and dual-earner families in the U.S.

Table 2. Raw Scores and Rankings of the Scale-Adjusted Urban Sprawl Indices

		Low-Threshold		High-Threshold		Total	Final
County Name	**State**	**% of Error**	**Rank**	**% of Error**	**Rank**	**Rank**	**Rank**
New York	NY	25.8	1	25.2	1	2	1
Bronx	NY	22.3	3	20.7	2	5	2
Kings	NY	22.7	2	20.5	3	5	2
San Francisco	CA	18.7	5	17.0	4	9	3
Queens	NY	19.3	4	16.1	5	9	3
Hudson	NJ	16.1	6	14.1	6	12	4
Alexandria	VA	14.0	8	14.0	7	15	5
Philadelphia	PA	15.0	7	11.1	11	18	6
District of Columbia	DC	13.9	9	11.2	10	19	7
Richmond	NY	13.6	10	11.4	9	19	7
Arlington	VA	13.0	11	11.8	8	19	7
Essex	NJ	11.6	12	7.6	14	26	8
Union	NJ	10.3	14	6.6	17	31	9
San Mateo	CA	8.8	19	7.0	16	35	10

Table 3. Raw Scores and Rankings of the 3C+P measurement

County Name	State	Compactness		Continuity		Centrality		Proximity		Total Rank	Final Rank
		Value	**Rank**	**Value**	**Rank**	**Value**	**Rank**	**Value**	**Rank**		
New York	NY	58,457	1	0.98	2	0.00	2	-1.21	4	9	1
San Francisco	CA	16,873	5	0.98	4	0.00	5	-1.29	2	16	2
Bronx	NY	32,033	3	0.97	5	0.00	1	-1.12	9	18	3
Arlington	VA	7,782	11	0.95	8	0.00	1	-1.30	1	21	4
Philadelphia	PA	10,342	7	0.95	7	0.00	1	-1.12	8	23	5
District of Columbia	DC	8,657	9	0.94	9	0.00	1	-1.20	5	24	6
Alexandria	VA	9,074	8	0.91	13	0.00	1	-1.27	3	25	7
Richmond	NY	8,314	10	0.92	11	0.00	1	-1.10	10	32	8
Denver	CO	3,739	17	0.91	12	0.00	1	-0.94	21	51	9
Norfolk	VA	4,218	15	0.82	26	0.00	1	-1.04	11	53	10

Table 4. Tobit Models of Family-Engaged Active Leisure

Variable	Model 1		Model 2		Model 3	
	Coef.	**Marginal**	**Coef.**	**Marginal**	**Coef.**	**Marginal**
County-Level Urban Form Indicators Derived From Nighttime Satellite Imagery						
Low threshold sprawl index	1.347**	0.090				
High threshold sprawl index			2.837***	0.190		
County-Level Urban Form Indicators Derived From Ground-Based Census						
Compactness (1000persons/sqml)	-1.778***	-0.119	-2.711***	-0.182	-1.389**	-0.093
Continuity					14.764	0.990
Centrality					-44.871**	-3.008
Proximity					2.780	0.186
County-Level Social Environments						
% of black population (0-100)	-1.119***	-0.075	-0.950***	-0.064	-1.053***	-0.071
Per capita income ($1,000)	0.500	0.034	0.745	0.050	1.172*	0.079
Personal and Family Characteristics						
Male	4.939	0.331	4.954	0.332	4.843	0.325
Age	-0.877***	-0.059	-0.873***	-0.059	-0.861***	-0.058
Family income	2.023*	0.136	2.032*	0.136	2.172**	0.146
Black	-78.384***	-5.256	-78.586***	-5.269	-77.690***	-5.209
No high school degree	-23.863**	-1.600	-24.264**	-1.627	-23.344**	-1.565
Bachelor degree or higher	39.819***	2.670	39.688***	2.661	39.497***	2.648
Unemployed	28.986***	1.943	29.040***	1.947	29.082***	1.950
Single Parent	-62.427***	-4.186	-62.459***	-4.188	-62.540***	-4.193
Presence of children (age<=6)	27.749***	1.861	27.869***	1.869	28.445***	1.907
Presence of children (age 7-12)	30.269***	2.029	30.295***	2.031	30.679***	2.057
Presence of children (age >13)	6.303	0.423	6.414	0.430	7.389	0.495
Dual-earner family	-15.737**	-1.055	-15.625**	-1.048	-16.024**	-1.074
Temporal Factors						
Weekend	60.493***	4.056	60.533***	4.059	60.527***	4.058
Holiday	48.363**	3.243	48.177**	3.230	48.740**	3.268
Constant	-372.462***		-377.711***		-389.964***	
Summary Statistics						
Log-likelihood	-14519.9		-14517.8		-14516.8	
Chi-squared test (p value)	0.0000		0.0000		0.0000	
PseudoR2	0.0155		0.0156		0.0157	
Left-censored N	22166		22166		22166	
Uncensored N	1593		1593		1593	
Total N	23759		23759		23759	

Note: *** p<=0.01; **p<=0.05; *p<=0.1

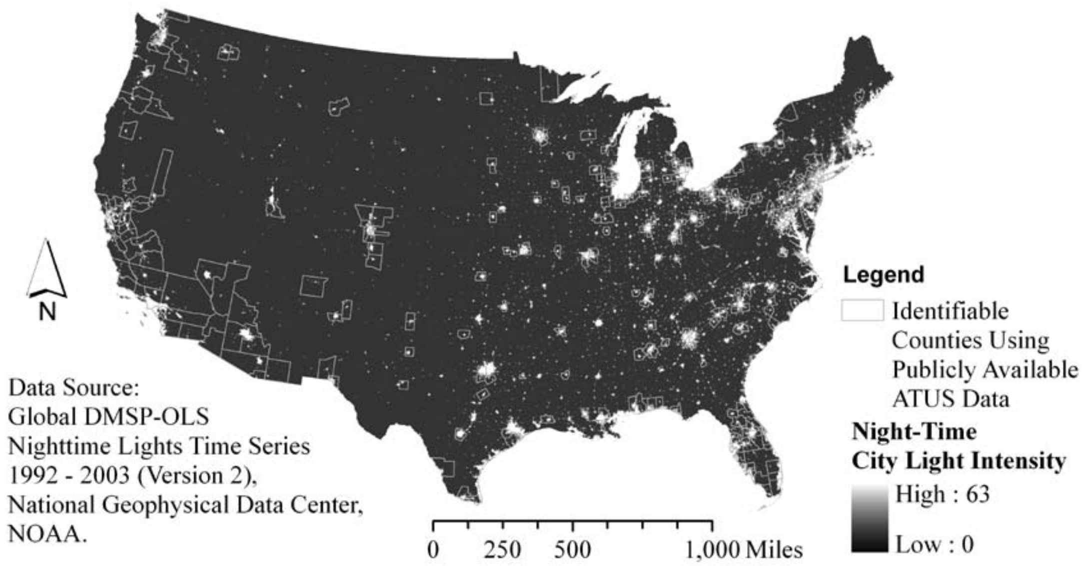

Figure 1. Map Showing Nighttime City Light Intensity in the Study Counties

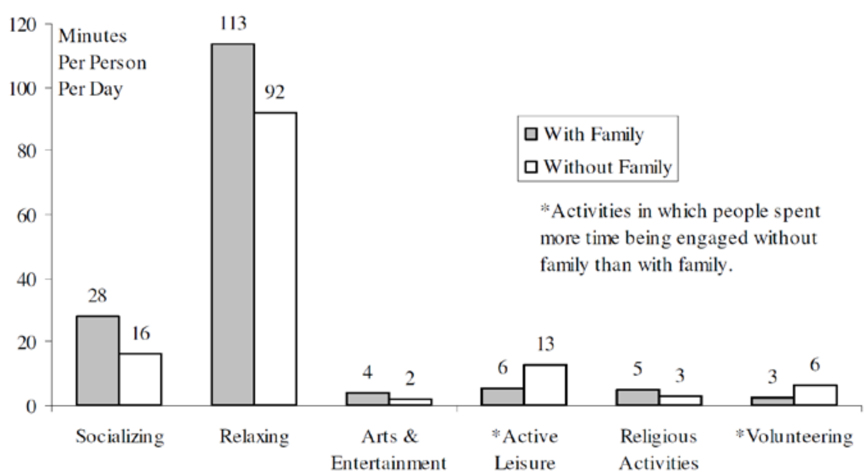

Figure 2. Average Time Spent on Leisure Activities by Individuals with Families

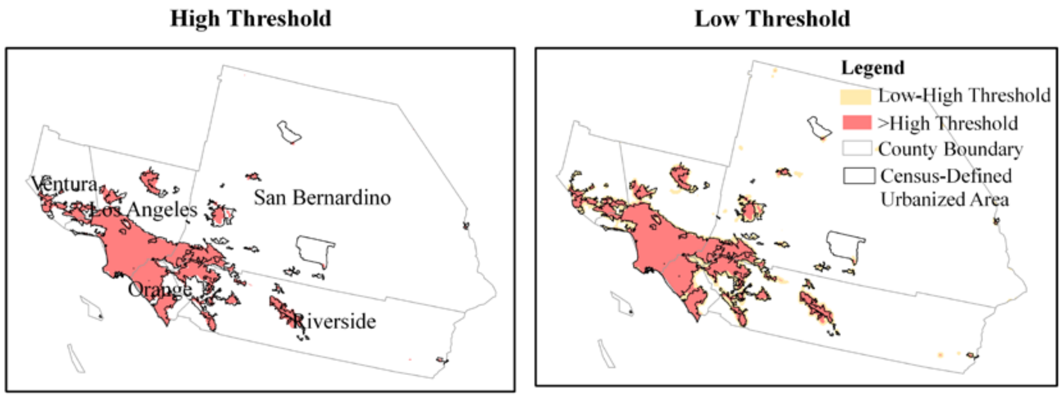

Figure 3. Urban Extents in the Greater Los Angeles Area Using High (Right) and Low (Left) Thresholds

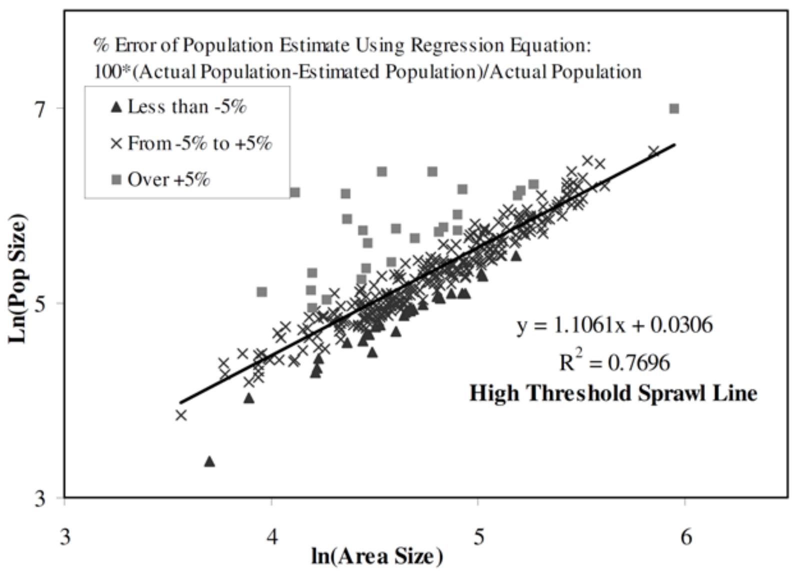

Figure 4. The High-Threshold Sprawl Line

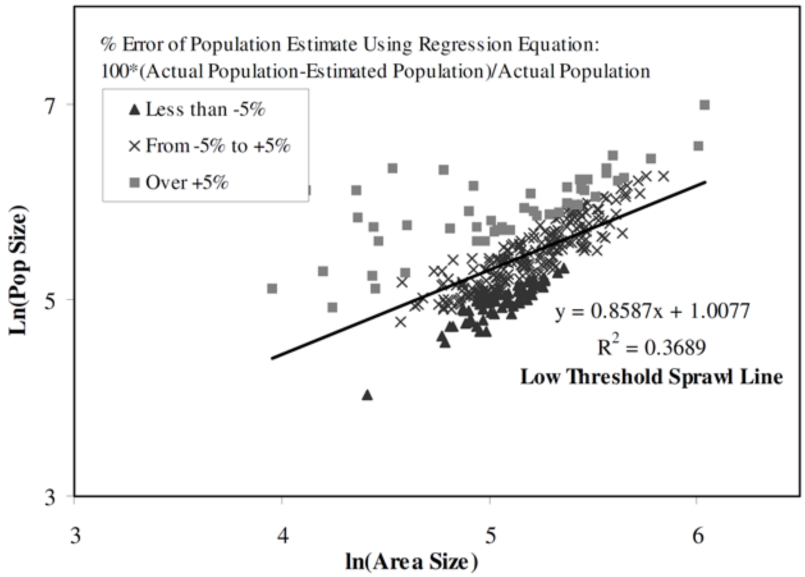

Figure 5. The Low-Threshold Sprawl Line

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