CHAPTER 6 UTILIZING GIUS MEASURES FOR ASSESSING CORRELATED FACTORS OF SPRAWL

I. Introduction:

Searching for the Realities of Rural Sprawl

Measuring spatial characteristics of urban sprawl provides a means of objectively quantifying an elusive and rhetorical concept. However, the GIUS measures hold promise beyond simple quantification of sprawl characteristics. GIUS measures hold potential for gaining perspectives on underlying mechanisms involved in the process of urbanization. This concluding chapter reaches back to the themes of all the preceding chapters by scaling the GIUS measures to alternate geographic spatial extents in Hunterdon County in search of socioeconomic factors related to sprawl. The GIUS measures are utilized to explore the correlation between spatial components of urban sprawl and; (1) large versus small subdivisions, (2) the New Jersey State Development and Redevelopment Plan (SDRP), (3) sewer service infrastructure, and (4) per capita impervious surface creation. The chapter concludes with a discussion of the utility and limitations of the GIUS measures both as a tool for landscape analysis as well as land management, and the potential for further research.

II. Scaling GIUS to Alternate Geographic Spatial Units

Chapter 4 scaled the GIUS measurements from the individual tract to the municipality illustrating that the spatial characteristics of residential development could be differentiated from town to town in Hunterdon County during the period of analysis. Summarizing the GIUS measures to different geographies has the potential to illuminate relationships between sprawling development patterns and underlying geopolitical factors. Four factors were selected for analysis including major versus minor subdivision, the New Jersey State Development and Redevelopment Plan, sewer service areas and impervious surface. Each factor provides a different angle of insight into the patterns and processes involved in sprawling urban growth.

Major versus Minor Subdivisions

In New Jersey land use practice there is an important distinction between major and minor subdivision. A subdivision is the dividing of a tract of land into two or more pieces, together with certain on-site and off site infrastructure improvements that support the proposed use of those pieces (Barnes 1997). By definition, a minor subdivision is "a Subdivision of land for the creation of a number of lots specifically permitted by ordinance as a Minor Subdivision provided that such Subdivision does not involve (1) a Planned Development, (2) any new street, or (3) the extension of any off-tract improvements, the cost of which is prorated among nearby properties" (NJ MLUL, 40:55D-5). A major subdivision is "any subdivision not classified as minor" (NJ MLUL, 40:55D-5). While this legal definition provides considerable local discretion to the distinction between major and minor subdivision, in practice a minor subdivision typically occurs when a parent lot is divided into no more than three new lots. Minor subdivisions that conform to local zoning codes are relatively easy to enact requiring no notification of adjacent property owners and often approved within a single evening of planning board activity. Conversely, major subdivisions typically require a more rigorous review of the planning board and official notification of all property owners within 200 feet of the requesting parcel. Minor subdivision are often advanced by the private landholder for sale as a single building lot whereas major subdivisions are often carried out by professional developers with interests in creating tracts of new housing.

The question arises to the comparable impact of each of these two categories of development. This is an especially significant issue in a fringe rural region such as Hunterdon County which is experiencing ubiquitous single lot development throughout it's environs while simultaneously undergoing major subdivisions in a number of high-growth areas. Summarizing GIUS measures by development patches with 3 or less housing units versus patches with greater than 3 housing units, provides a reasonable proxy for analyzing the spatial characteristics of major and minor subdivisions.

Table 6-1 summarizes the GIUS countywide for major versus minor subdivisions. The results indicate that minor subdivisions were substantially more sprawling than major subdivisions for most of the GIUS measures including *density, leapfrog, segregated land use, regional planning incongruency, transit inaccessibility, community node inaccessibility, open space encroachment* and *impervious surface*. One of the most distinguishable characteristics between major and minor subdivisions is the highway strip index. While minor subdivisions accounted for only 26.4 % of the total number of new residential units, they accounted for 45.6 % of the highway strip units built.

Table 6 -1 Average GIUS Measures by Major and Minor Subdivisions.
[UD = urban density], [LF = leap frog], [SL = segregated land use], [RPI = regional planning inconsistency], [HS = highway strip], [RI = road inefficiency], [TI = transit inaccessibility], [CNI = community node inaccessibility], [LR = land resource consumption], [OSE = sensitive open space encroachment], [IS = impervious surface inefficiency] and [= GT growth trajectory]

TYPE	*HOUSING UNITS*	UD	LF	SL	RPI	HS	RI	TI	CNI	LR	OSE	IS	GT
major	*6872*	*0.729*	*1493*	*4.63*	*2.92*	*0.043*	*93.9*	*8537*	*12073*	*0.426*	*0.889*	*0.117*	*264.2*
minor	*2467*	*1.131*	*3547*	*6.06*	*5.02*	*0.100*	*93.4*	*15065*	*17165*	*0.384*	*1.038*	*0.142*	*182.7*

Table 6-2 provides a measure of percentage impacts attributable to major and minor subdivisions. The results indicated that minor subdivisions were responsible for proportionately more landscape impact than major subdivisions in Hunterdon County during the study period. Minor subdivisions accounted for 26.4 % of new housing units but consumed 35.8 % of the total land developed, generated an estimated 33.8 % of the vehicle miles traveled and created 30.4 % of the new impervious surface acres. Minor subdivision imparted substantially more impact on a per capita basis than did major subdivisions.

Table 6 – 2 Impacts by major and minor subdivision

TYPE	*%UNITS*	*% Ac dev*	*% Hwy strip*	*% VMT*	*% LRI*	*%imperv*
major	*73.6%*	*64.2%*	*54.4%*	*66.2%*	*75.5%*	*69.6%*
minor	*26.4%*	*35.8%*	*45.6%*	*33.8%*	*24.5%*	*30.4%*

This finding runs counter to common perceptions of minor subdivisions, which generally do not raise the same negative response to new growth that often accompanies a major subdivision. This is due to a number of factors including the perceived low impact of a few new individual homes versus the perceived high impact of a tract of multiple new homes. There is also the perception that minor subdivisions are the private business of local residents whereas major subdivisions are imposed by outside developers at the detriment of the community. What the GIUS analysis suggests is that minor rural subdivisions, in aggregate, impart a significant impact on the efficiency and accessibility of the resulting pattern of growth. Major subdivisions may be more visible and generated more contention but GIUS analysis indicates the combined impact of minor subdivision is also of significant concern.

Sprawl and the State Plan

The New Jersey State Development and Redevelopment Plan (SDRP) is a statewide growth management plan established by the New Jersey Office of State Planning in an effort to address the problems of continuing sprawl and protection of the environment. The SDRP was envisioned as a mechanism in which to guide urban growth toward a more efficient pattern and in doing so protect important lands. The plan is not regulatory but rather recommendatory providing a statewide map of planning regions and principled goals for mitigating sprawl. Municipalities retain land use decision control at the local level.

The SDRP delineates five zones of land use; 1) PA1 Metropolitan Planning Area, 2) PA2 Suburban Planning Area, 3) PA3 Rural Planning Area, 4) PA4 Rural Planning Area, 5) PA4B Rural/Environmentally Sensitive Planning Areas [labeled PA42 in the dataset], 6) PA5 Environmentally Sensitive Planning Area. Summarizing the GIUS by each of the SDRP planning areas provides an indication of growth patterns in each Planning Area. Table 6-3 provides growth summaries for each planning zone. The suburban and fringe planning areas PA 2 & PA 3 demonstrated low sprawl measurements across all 12 GIUS variables whereas growth that has occurred in the rural/sensitive planning areas PA 4, PA45 & PA 5 have incurred substancially higher GIUS measures.

Table 6 –3 Average GIUS Measures by New Jersey State Planning Areas

SDRP PA	*HOUSING UNITS*	UD	LF	SL	HS	RI	TI	CNI	LR	OSE	IS	GT
PA 2	*1397*	*0.24*	*536*	*3.37*	*0.056*	*50.69*	*3489*	*8502*	*0.051*	*0.67*	*0.079*	*33.52*
PA 3	*3212*	*0.62*	*1169*	*4.48*	*0.048*	*87.20*	*7988*	*11609*	*0.513*	*0.92*	*0.109*	*56.40*
PA 4	*1436*	*1.31*	*3712*	*6.13*	*0.084*	*127.67*	*14723*	*18910*	*0.782*	*1.06*	*0.150*	*96.20*
PA 4B	*1770*	*1.11*	*3106*	*5.82*	*0.062*	*103.46*	*13912*	*15240*	*0.321*	*1.18*	*0.148*	*130.37*
PA 5	*1488*	*1.06*	*2344*	*5.60*	*0.052*	*103.59*	*12888*	*14405*	*0.300*	*0.71*	*0.141*	*128.45*

Evident in the summation table of impacts (table 6-4) is the substantial amount of development that did not comply to the SDRP. More than half the housing units developed in Hunterdon County during the study period occurred in the sensitive planning areas PA 4, PA 5 and PA 4B. Since the zoning density of growth was lowest in these sensitive planning areas they required more consumption of land per unit of new housing. The result was that 70% of the land developed, 60% of the estimated vehicle miles traveled, 55% of the land resources consumed and 60% of the impervious surface created occurred in PA 4, PA 45 and PA 5. Considering that the delineation of these planning regions is intended to discourage development and protect the land resources, this analysis confirms that the SDRP has been ineffective in accomplishing these goals.

Table 6 – 4 Impacts by New Jersey State Planning Areas

SDRP PA	*%UNITS*	*% Ac dev*	*% Lane Mi*	*% VMT*	*% LRI*	*%imperv*
PA 2	*15.0%*	*4.3%*	*8.1%*	*9.5%*	*1.8%*	*9.5%*
PA 3	*34.4%*	*25.4%*	*32.0%*	*29.8%*	*42.6%*	*30.2%*
PA 4	*15.4%*	*24.1%*	*20.9%*	*21.7%*	*29.0%*	*18.7%*
PA 42	*19.0%*	*25.2%*	*20.9%*	*21.5%*	*14.7%*	*22.7%*
PA 5	*15.9%*	*20.3%*	*17.6%*	*17.1%*	*11.5%*	*18.2%*
PA 8	*0.4%*	*0.7%*	*0.5%*	*0.5%*	*0.4%*	*0.6%*

The results of this GIUS analysis of the SDRP in Hunterdon County imply that the conditions leading to rural sprawl, in particular, are more prone to exist in the Sensitive and Rural planning areas. To a degree, the sprawling nature of growth within the sensitive planning areas is tautological. The sensitive areas of the New Jersey landscape as delineated by the SDRP planners will be delineating areas that have “the most to lose.” Therefore it is understandable that the delineation of these zones would capture the dispersed extent of the sensitive lands needing management. The findings suggest that land management policy for guiding urban growth within sensitive planning areas has not been effective and needs to be substantially adjusted to mitigate the propensity for growth to occur in an inefficient and highly impacting pattern within these regions.

Sewered Versus Non-sewered Area

The question of the relationship between sewer service and urban sprawl often arises. While sewer service allows for higher densities of housing than what is possible on septic and often spurs new growth, there is debate over whether the type of growth that occurs within sewer service areas is actually more sprawling or less sprawling. To answer this question the GUIS measure of new urban growth were summarized by sewer service area. Table 6-5 provides the results of average GIUS measure by sewered and nonsewered areas. Sewered areas exhibited lower GIUS measures across the board for all variables compared with non-sewered areas. On average non-sewered residential units consumed three times the amount of land, leapfrogged three and a half times the distance, consumed two and a half times the important land resources and created nearly twice the impervious surface as new housing units that occurred within sewered areas.

Table 6 -5 Average GIUS Measures by Sewered Versus Non-sewered Areas

	HOUSING UNITS	UD	LF	SL	RPI	HS	RI	TI	CNI	LR	OSE	IS	GT
SEPTIC	5513	1.17	2866	5.9	4.6	0.0731	115.3	13623	16364	0.551	0.963	0.149	352.33
SEWER	3826	0.36	840	3.7	1.8	0.0361	62.7	5418	9174	0.218	0.879	0.087	94.53

Table 6-6 demonstrates the degree of per unit impact of housing in sewered versus non-sewered areas. While 59.0% of new residential units occurred outside of sewered areas they accounted for a far greater landscape impact consuming 82.6% of the land developed; contributing 72.6% of the new road lane miles paved, consuming 78.5% of wetlands, prime farmland and natural heritage lands lost; and producing 71.2% of the impervious surface acres created.

Table 6 – 6 Impacts by Sewered Versus Non-sewered Areas

	%UNITS	% Ac dev	% Lane mi	% VMT	% LRI	% Imperv
SEPTIC	59.0%	82.6%	72.6%	72.0%	78.5%	71.2%
SEWER	41.0%	17.4%	27.4%	28.0%	21.5%	28.8%

It should be noted that growth within a sewer service area did not necessarily mean that the growth was hooked up to the treatment system. A portion of the growth that occurred within sewered areas was, in spite of its location, still on private septic due to the limited capacity of treatment facilities (personal communication Hunterdon County Planning Department). Nevertheless, there was a substantial difference between the sewered and non-sewered areas dramatically illustrating the connection between infrastructure and the efficiency of development patterns.

Impervious Surface and Sprawl

There is a growing interest within planning, geography and environmental sciences for exploring the impacts of impervious surface created by urbanization. Impervious surface coverage is showing broad implications for the water quality and flooding potential for urbanizing watersheds. Impervious surface is increasingly being used as a comprehensive environmental indicator for planning purposes (Arnold and Gibbons 1995). However, research has yet to focus on the relationship of urban sprawl to impervious surface. An analysis on the Hunterdon County data was performed by grouping the new residential housing units into classes of the amount of impervious surface created per housing unit. Five classes were created on the natural breaks of impervious surface contribution with each class containing roughly 20% of the housing units developed.

Table 6-7 illustrates the strong relationship between classes of impervious surface and average GIUS measures within each class. Particularly noteworthy is the lowest impervious class of <= 0.020 acres per unit. This class was dramatically less sprawling than the higher class bins suggesting a substantially more compact and clustered form of development. The low GIUS *density* value (indicating a small lot sizes for each unit), indicates that this category of impervious surface housing is occurring in areas serviced by sewer infrastructure.

Table 6 -7 Average GIUS Measures by Impervious Surface Categories

IMPRV_CAT	*HOUSING UNITS*	UD	LF	SL	RPI	HS	RI	TI	CNI	LR	OSE	GT
<= 0.020	*2251*	*0.031*	*922*	*3.3*	*2.0*	*0.0689*	*31.9*	*6063*	*9467*	*0.05*	*0.83*	*5.1*
0.020 - 0.065	*1345*	*0.268*	*2106*	*5.0*	*3.5*	*0.0625*	*72.2*	*9777*	*13172*	*0.31*	*1.15*	*31.1*
0.065 - 0.135	*2097*	*0.813*	*2539*	*5.5*	*3.9*	*0.0696*	*110.2*	*11225*	*14465*	*0.50*	*0.99*	*118.7*
0.135 - 0.215	*2402*	*1.250*	*2309*	*5.7*	*4.0*	*0.0458*	*128.1*	*11865*	*14862*	*0.63*	*0.86*	*151.0*
> 0.215	*1244*	*2.139*	*2600*	*5.9*	*4.5*	*0.0370*	*135.1*	*13664*	*16285*	*0.62*	*0.90*	*140.9*

Table 6-8 illustrates the impacts of housing units within the various classes of impervious surface. While a quarter of the new housing units occurred on lots with the lowest amount of impervious surface, the amount of land consumed by these units totaled less than 1%. Examination of the data points within this class against orthophotoquads revealed that many of the units were highly clustered townhouses and condominiums. The second tier of impervious surface also exhibited a reasonably efficient profile of GIUS measures while the top tiers of impervious surface came in far less efficient. The least efficient tier, [> 0.215 acres of impervious surface per unit], also demonstrated the least efficiency and most highly impacting residential development from the perspective of sprawl. The results suggest that per capita impervious surface holds promise as an overall indicator for urban sprawl.

Table 6 – 8 Impacts by Impervious Surface Categories. Category bins were created by natural breaks in the per unit impervious surface value.

IMPRV_CAT	%UNITS	% Ac dev	% Lane Mi	% VMT	% LRI
<= 0.020	24.1%	0.9%	8.2%	14.2%	17.0%
0.020 - 0.065	14.4%	4.6%	11.1%	13.7%	14.1%
0.065 - 0.135	22.5%	21.9%	26.4%	24.6%	24.2%
0.135 - 0.215	25.7%	38.5%	35.1%	29.7%	28.5%
> 0.215	13.3%	34.1%	19.2%	17.7%	16.2%

III. Discussion

The preceding four alternate GIUS summaries make evident the utility of GIUS measures for providing insight into the underlying relations between geopolitical factors and patterns of sprawling urban growth. The analysis demonstrates the connections between the characteristics of sprawl subdivision size, the State Plan, sewer services and per unit impervious surface. Minor subdivisions, on average, contributed to a more sprawling pattern than major subdivisions. The rural and environmentally sensitive areas of the State Plan experienced the most sprawling forms of development. Sewer infrastructure is highly correlated to urban efficiency. Per unit impervious surface is a promising overall indicator for sprawl.

The analysis of the state plan in particular demonstrates the potential of GIUS to provide insight into the problematic qualities of urban growth associated with sprawl. The dysfunctional qualities of sprawling development are illuminated in that half the development was in conflict with the guidance laid out by the State Development and Redevelopment Plan and growth within the sensitive planning areas was substantially more impacting. This finding does not suggest that the SDRP was actually contributory to the sprawling pattern of growth that occurred but conversely that the lands within the sensitive planning areas are more susceptible to the impacts of sprawling growth. It also suggests that the common zoning tool of down-zoning to larger lot sizes actually contributes to sprawl on a per housing unit basis. The SDRP did a good job of delineating sensitive lands but a poor job in protecting them as more than half the units and 70% of the developed land occurred in PA's 4, 4B, and 5.

IV. Conclusion

This dissertation has set out to bring a better understanding of the processes of urbanization occurring in New Jersey at the turn of the 21st century. In order to accomplish this goal the research has explored the contemporary socioeconomic setting and land management initiatives shaping development New Jersey (Chapter 1), and the magnitude of change that urbanization is imparting on the New Jersey landscape (Chapter 2). The dissertation has developed a set of tools for analyzing the spatial characteristics of sprawl (Chapter 3), and utilized these measures at several spatial scales and geographical configurations to characterize and shed insight into important underlying patterns and processes related to the sprawling nature of urban growth (Chapters 4, 5 and 6).

The thesis has demonstrated that Geospatial Indices of Urban Sprawl developed in this research provide a substantive suite of measures for landscape analysis and management. The measures provide empirical information about patterns of land use that is potentially useful for academic research in addition to planners in the field making land management decisions. The ability to quantifiably characterize the realities of the term *sprawl* can lead to better identification and understanding of the patterns of urban growth which are more costly, wasteful and damaging on both a social and environmental basis. One could envision the potential for planning boards in the future to require calculation of GIUS measures for the construction of a proposed development. The sprawl indices could conceivably evolve into sprawl standards by which a proposed development must comply or perhaps a *sprawl tax* for development that is demonstrably wasteful or highly impacting as revealed by the sprawl indices.

The strength of the GIUS measures is that they quantify spatial characteristics of sprawl in substantially different aspects. A number of the GIUS measures are geographically universal in that the characteristics would be the same for a tract of similar development regardless of the position within a landscape. For example *low density* is *low density* regardless of where it is located. Other GIUS measures are geographically dependant on the configuration of land use in which the development is positioned. A *leapfrog* patch would be less *leapfrog* if it were situated closer to previous settlement. There is also a temporal component as GIUS values calculated for recent development will change over time for that development as future changes occur to the surrounding landscape. Lastly, some GIUS measures are site and design specific. A development that consumes prime farmland might be moved or reconfigured to mitigate the landscape impact.

A key component to the geospatial sprawl indices is the temporal aspect. The measures are designed to characterize urban growth that occurs over a particular period of time thereby demonstrating the efficiency and impact on landscape functionality imparted by new urban patches for a particular cycle of development. The appropriate temporal scale is important for capturing the underlying processes of urbanization. While every landscape is constantly in a state of flux, a sufficient period of time is necessary to capture the temporal scale necessary for completion of a development tract without lasting that individual new tracts would be indistinguishable from on another within a growing locality. Such temporal resolution would likely range from a year to a decade. The temporal scale is also greatly limited by data availability. For example the land use/land cover data set used in this thesis depicts urban change from 1986 to 1995 resulting in a temporal resolution of 9 years. Other potentially usable data includes U.S. Department of Agriculture census which is compiled ever 5 years as is the Natural Resources Conservation Service's nation-wide Natural Resource Inventory. U.S. population census data is generated on a 10 year basis. Along with appropriate temporal scale land use change data, the GIUS measures require concurrent demographic change data for the concurrent spatio/temporal scale. Datasets that fulfill these requirements are becoming more available. However at the site-level scale the GIUS measures are heavily dependent on high-accuracy land use/land cover data and digital parcel mapping which is less readily available due to the costs of creation.

Nonetheless, the maturation of geospatial technologies (GIS, GPS and remote sensing) and the exponential increase in available geospatial data such as orthophotography, digital land use data and parcel mapping make the feasibility and practicality of such detailed urban spatial analysis accessible to a growing user base. No doubt continued technological changes and further research will result in these measures evolving to better capture the dysfunctional nuances of sprawling patterns of land development. These advances can have a substantial impact on shaping future land management policy and decisions.

The GIUS measures have the potential for substantially buttressing the principles and application of smart growth planning. Distinguishing between haphazard, wasteful, sprawling patterns of urban growth and more efficient, high quality, less impacting forms of growth will be key in ensuring the highest possible future sustainability of a given landscape. The concept of landscape integrity developed in the theoretical development of the GIUS measures, could evolve into a framework to guide the design of development so that urban growth strives to occur within the domain of landscape integrity. As the New Jersey landscape steadily marches toward build-out, smart growth planners should coordinate and design the impending final landscape to exhibit the maximum degree of landscape integrity. Such landscape integrity design principles must consider both the constraints imposed by the landscape on design of development and the subsequent constraints that a development design will impose on the landscape. In order for future land management efforts to result in a built landscape that maintains the highest level of landscape integrity in both its ecological and social aspects an empirically-based method for delineating the defining characteristics of sprawl needs to be well developed. This type of information is provided by the GIUS measures developed in this research.

Sprawling urban growth as it is exhibited in New Jersey and elsewhere in the United States has significant associated social and environmental costs and represents a major challenge to land use planning and management in the coming century. While many approaches are needed in analyzing the environmental and social consequences of various development patterns, the GIUS measures developed in this research present one set of tools for analyzing significant specific landscape impacts attributable to sprawling urban growth. These indices combine multi-temporal landscape data with demographic data to integrate often separately addressed landscape process with social process. Through identifying quantifiable impacts that can be compared across regions and scales and investigating the corresponding political, economic and geographical context in which the patterns of sprawl are occurring, the GIUS indices presented herein will hopefully add to a better understanding of the impacts and consequences of urban sprawl and perhaps lead to a more sustainable system of land use.