URBANIZATION & THE SEARCH FOR SUSTAINABLE DEVELOPMENT
POTENTIALS ALONG THE IH-35 GROWTH CORRIDOR

Prepared by Sarah Simpson
Masters of Architecture II - Post Professional Degree in Urban Design

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I. EXECUTIVE SUMMARY

The central Texas region, anchored by the cities of Austin and San Antonio, has been experiencing rapid growth over the last ten to twenty years. Although linked by IH-35, a heavily trafficked vehicular corridor, there is little dialogue or concerted planning efforts between the various municipalities that are located along this connecting vein, and as a result, the region has suffered from low-density, sprawling development patterns that perpetuate fossil-fuel dependency and are actively degrading the natural value of the surrounding hill country. Plans for a regional rail system that would connect the study area, Lone Star Rail (LSTAR), lack the appropriate structural support and public momentum for implementation. In order to better understand how future development could help build support and demand for this regional connectivity, land use trends over the last decade between 2001-2011, including where high concentrations of urbanization and natural land loss are occurring, are analyzed using GIS in the eight counties along the IH-35 growth corridor, including Travis, Williamson, Bastrop, Hays, Caldwell, Comal, Guadalupe and Bexar. This mapping then provides the basis for identifying suitable locations for new sustainable TOD urban design and development studies along the proposed LSTAR route that could possibly serve as catalysts for increased endorsement of future regional planning efforts.
II. INTRODUCTION

CONTEXT
The Central Texas region, anchored by the cities of Austin and San Antonio, has been experiencing rapid growth over the last ten to twenty years. Simultaneously divided and connected by a heavily trafficked stretch of IH-35, this area is home to over 4 million people and expected to grow to 5-7 million people by 2030. Situated along the seam of a national divide that separates heavier eastern US development and historic deforestation patterns from somewhat lighter development patterns of the western US (Clement, 2015), this location also coincides with sensitive ecoregions, including both the aquifer recharge and contributing zones of the Edwards Plateau which provides drinking water for a large portion of the area, and the rich prime farmland soils of the Blackland Prairies.

The scenic value of the area alone generates considerable tourism that greatly benefit the region’s economy, and it is also home to many unique plant and animal species, as well as geological formations. However, sprawling development patterns and the impending effects of climate change threaten to damage this natural character as lands are given over to development throughout the entire region at unstudied rates to keep up with the growing population.

Efforts of varying degrees to encourage smart growth (compact, pedestrian friendly) strategies and discourage suburban sprawl exist within individual jurisdictions, such as downtown revitalization efforts and the adoption of ‘smart codes’ in Austin and San Marcos. Intermittent neighborhood development projects are peppered throughout the area, as well, most of which are driven by a new urbanist agenda that in its ‘Texan implementation’ places high priority on private automobile ownership and fails to acknowledge the importance of maintaining/improving ecological function and the integration/bolstering of biodiversity within urban development. Transit oriented development (TOD), bona fide smart growth, is also unlikely to occur without the execution of effective transit. Thus, with anemic, unbalanced sustainability goals being promoted as best practices for the small percentage of larger development projects actually implemented under often elective smart growth agendas in the area while low-density business-as-usual settlement patterns continue to spread outwards from peri-urban edges and into unregulated county land, there is no denying that Central Texas has a lot of ground to gain in order to ensure the preservation of its unique character in the long-term.

IH-35, the primary transit conduit, can see over 200,000 cars daily and is a significant hub for international trade as a result of NAFTA (The Greater Austin-San Antonio Corridor Council, 2015). An asset in its provision of connectivity between several growing towns and cities anchored by the highway itself, there is the potential to embed within this conveyance network a unionizing, catalytic regional effort that launches a more sustainable future for the region. Given the area’s rapid population growth, the rise of a number of bedroom communities, and the high rates of commuting that occur within the area, there is an acute need for a forward-looking regional strategy to improve access between housing, jobs and tourism opportunities amongst the adjacent municipalities and to support more sustainable lifestyles for central Texas residents and visitors alike.
There has been much discussion about implementing a serious regional transportation network in the last twenty or more years but there is little to show for it. Existing Amtrak service in the region is extremely limited and undependable, running only once a day between Austin and San Antonio; similarly, Capitol Area Rural Transportation Systems (CARTS) Interurban buses offer a more regular (once an hour or less) service between Austin and municipalities directly adjacent but only go half the distance of a regularly trafficked corridor.

Planning efforts for a regional rail system, as promulgated by the Lone Star Rail District and the Greater Austin-San Antonio Corridor Council, that propose reusing existing freight lines parallel to IH-35 have been ongoing since the 1990s but have not yet delivered any tangible outcomes or benefits beyond feasibility studies and proposed routes. This is attributed largely to a lack of non-road funds at the state and local level, a lack of county planning authority and a disconnect between land-use and transportation planning (Zhang, Steiner & Butler, 2007). Also, when the cities in question have difficulty providing dependable bus services, let alone pass funding for inner-city light rail just within their own boundaries, it is not surprising that a more far-reaching public transit scheme would also prove challenging.

These challenges have been widely acknowledged by both the larger Austin and San Antonio metro areas, but have resulted in disparate responses. Envision Central Texas, an all-encompassing effort to address future land use, transit and environmental within a unified vision, does not extend to the counties surrounding San Antonio. Similarly, San Antonio has utilized its energy to protect its own immediate interests, focusing on securing the future of its aquifer-dependent water supply by protecting related lands from urbanization and promoting sustainability within its existing neighborhoods but has not accomplished much in the way of discouraging an outward spiral of low-density, placeless sprawl.

This pattern of disconnected leadership within a shared region speaks to not only issues of bureaucracy and perceived feasibility but also a long-lived cultural divide between Austin and San Antonio. Characterized by a legacy of Spanish settlement and in 20th century, significant military operations, San Antonio has undergone a more conservative history than Austin, the latter of which was founded to serve specifically as the state’s capitol and has been dominated by both a governmental and academic economy, flavored by a long-standing liberal environmentalism spurred by unique assets such as Barton Springs pool and more recently a surging tech boom. As all the cities in the area vie for both jobs and cultural amenities (Rivard, 2014), San Antonio and Austin have a lot at stake to secure a sustainable future for their respective citizens that goes beyond political currents.

So, given the current uncoordinated state of urban planning, instead of IH-35 serving as the backbone for exemplary transit or urban agendas, it has earned the reputation for being one of the most congested and deadly stretches of highway in the country (LSTAR, 2015), lined with strip malls, ample big box outlets, Texas-sized parking lots and sprawling, low-density housing developments. And yet, although there is a growing to-do list to rectify the recent past, current leadership shows promise for inspiring a more unified approach to the regional situation. At a recent transportation summit held in San Marcos, area representatives discussed a need for
comprehensive planning efforts. Mayor Taylor of San Antonio was quoted as saying “It’s no longer San Antonio versus Austin, but San Antonio and Austin” (Rivard, 2015).

But what this means, no one is quite sure. The only thing that is certain, however, is that the area population will continue to grow. A recent analysis of projections from the Texas Water Development Board, estimated that the regional population of currently 4.27 million will increase by over 34% to 5.71 million in 2030 and result in an apparent merging of population densities along the corridor (Lawnstarter, 2015). Now is the time to dig into that future and make sure it is to the benefit of the longevity of residents, non-human species and the natural habitat, function and character of the region.

**PROPOSED RESEARCH**

In order to support the implementation of regional transit and sustainable growth, as well as preserve the integrity of sensitive bioregions, I propose establishing a framework that endorses development demand through progressive social and ecological development goals, not just within Austin and San Antonio but along the entire length of the proposed route. By investing in more integrated and responsive neighborhood development along IH-35 and the proposed LSTAR route, a growing need and well-situated density will gradually embed itself along this transit route to support alternative transit options. Not only would this give the transit strategy more legitimacy, it would also help to prevent sprawling development within more pristine landscapes and agricultural lands while inventing a new identity for the region, unified through shared concern for the Central Texas environment and social vitality.

An initial step in building this narrative is to study the existing condition in the counties between Austin and San Antonio. Using the National Land Cover Dataset, developed by USGS and based on Landsat thematic mapper satellite imagery (Auch, Taylor, & Acevedo, 2004), this project undertakes an investigation of current land use and population trends within the Central Texas region to determine the spatial relationship between high land use change and transit futures. Analysis of land use change intensities throughout the region will then form the basis for a suitability analysis to determine sites linked by regional transit systems for further sustainable, urban design study. Through this exercise, I hope to build an understanding of growth characteristics along this spine and identify how this already supports or should shift to support a more socially and ecologically cohesive vision throughout the region.
III. RESEARCH QUESTIONS & HYPOTHESIS

The following questions are posed to the research:

1. What areas in the eight counties along IH-35 between Austin and San Antonio have experienced greater urbanization* in the past decade?
2. Do current growth trends appear to support clustering of development along the IH-35 corridor and proposed LSTAR route that could be targeted as a way to transition to more socially and ecologically comprehensive growth patterns? Or do they exhibit primarily conventional post WWII patterns of low-density, suburban growth in peri-urban edges and otherwise rural areas?
3. What sites would be appropriate for further sustainable design studies that could possibly help guide the location of LSTAR stops and other future transit routes?

Based on my general knowledge and understanding of the study area, I hypothesize that within the research time frame, there has been considerable aggregation of growth along IH-35 itself and within a buffer zone of one to two miles. That being said, the diffusion of growth into less urban areas of the hill country is expected to be prevalent, as well, supporting a need to prevent diffuse development patterns that require extended infrastructural support and detract from building a critical mass to support regional transit.

*Semantic Note: For the purpose of this investigation, the term “urbanization” has been interpreted as a process rather than an indication of development intensity. The term’s use refers to land that has been modified for human use, typically increasing the amount of impervious land cover. Although much of this land use change has occurred in what would be deemed rural or suburban areas, this process of land change to facilitate human development and colonization is understood as a process that occurs at all scales of the rural to urban transects.
IV. METHODS

ArcGIS (ArcMap and ArcCatalog) is the primary software system utilized for data accumulation, preparation and analysis in service of the research questions as outlined previously. Using integrated spatial analysis tools, data sets from the National Land Cover Database, Texas Natural Resources Information Systems, Capital Area Council of Governments, Comal and Bexar Counties, Texas Parks and Wildlife, and the City of San Marcos were manipulated and analyzed to carry out the investigation. A brief description of procedures taken to complete the research are provided in this section, with a more detailed list of steps provided in the Appendix.

DATA COLLECTION

Data from the Texas Natural Resources Information System, including state and county boundaries, major road networks, and railroads (as it relates to proposals for future rail) were downloaded to prepare the base geographic structure. City boundaries were downloaded from Capital Area Council of Governments and Comal and Bexar Counties. Hydrological networks, including water bodies, streams and rivers, as well as Texas Natural Subregions were downloaded from TNRIS and TPWD respectively to provide an understanding of the natural context. More detailed building footprint data and parcel information was also downloaded for reference from the City of San Marcos.

Appropriate sections relating to the research site were downloaded from the 2001 – 2011 National Land Cover Database raster databases, including 2011 Land Use and 2001 – 2011 Land Use Change. These serve as the foundational data sets for analysis on land use trends. Census data at the block level already embedded with population attributes for 2010 was gathered from the U.S. Census Bureau to measure population trends against land use change trends in a similar time period.

DATA PREPARATION

With the collected geographic boundary data sets, a framework was first established upon which to layer data. This was comprised of the eight counties along IH-35 between Austin and San Antonio, including Travis, Williamson, Bastrop, Hays, Caldwell, Comal, Guadalupe and Bexar counties. Because a majority of these counties lie within State Plane Zone 4, all of the base data was projected to State Plane Texas S Central FIPS 4204 (US Feet). After matching projections, the analytical data downloaded as outlined previously were then clipped to the aggregated county boundary.

DATA PROCESSING & ANALYSIS

Using datasets from the National Land Cover Database, including Land Cover 2011 and Land Cover Change 2001-2011, the eight county study area was analyzed for urbanized land cover between 2001-2011. Pixels representing urban land use in the two raster datasets (values 21, 22, 23, 24 based on the NLCD land classification system) were isolated and given values of 1 using the Spatial Analyst Conditional tool. Next, the Spatial Analyst Zonal Statistics as Table tool was used to quantify the total urban pixels in each dataset, the results of which were then exported to external spread sheets. This data was then manipulated to calculate the total percentage of urban
land conversion in each county between 2001 and 2011 and the resultant total urban land percentage.

Next, the NLCD Land Cover Change 2001-2011 dataset, as analyzed by the Conditional tool, was converted to points, where one point represented every pixel that was converted to an urban use. Average nearest neighbor analysis was run on the dataset within the eight county region, revealing significant clustering with a z-score of over 1,000. Thus, the urban land use change point dataset was then joined to a 2010 census block shapefile, upon which a Hot Spot Analysis was run. This resulted in a new shapefile highlighting areas of identified urban land use change clustering which were assigned confidence percentages in a heat map – “hot spots” with 99% confidence signifying confirmed cluster patterns of urban land use change versus “cold spots” with 99% confidence signifying confirmed lack of cluster patterns of urban land use change.

An analysis of urban land use change as it relates to the IH-35 corridor and the proposed LSTAR route was conducted. 2-mile buffers (based on studies looking at the extent of TOD influence) were made based on both of the aforementioned transit networks, both of which were then analyzed using the two methods described above, including use of the Spatial Analyst Zonal Statistics as Table tool to identify the percentage of urban land use change in each buffer, as well as the Hot Spot Analysis tool to identify hot spots at the 2010 census block level within each buffer based on a point-conversion of urban land use change pixels.

The cluster analysis information then factored into a suitability analysis to identify appropriate sites for a future design study to investigate sustainable urban design models along the LSTAR route. First, an overall “build zone” was created, consisting of areas within existing city limits, 1-mile buffer zones around 99% confidence hot spots, and the 2-mile buffer zone around the LSTAR route that were combined using the Intersect tool. Next, an overall “no-build zone” was created by combining the 100-year flood plain and the Edward’s Aquifer Recharge and Contributing zone. The “no-build” areas were then erased from the “build” areas, which revealed a series of suitability zones.

This layer was then qualitatively analyzed based on my knowledge of the region, the relationship of the suitable areas to municipalities, the intensity of existing development and parcel size in any given area, as well as the growth characteristics and development agendas of each respective municipality. Through this process, a new San Marcos district targeted for future growth, The South End, was identified as the first site for a future design study.
V. FINDINGS

STUDY AREA CHARACTERISTICS
The following maps describe the area’s geographic, ecological, urbanized and population characteristics of the IH-35 corridor as bounded by Austin and San Antonio.

- **Regional Networks:** This map introduces the study area, including the location of municipalities, road networks, rail networks and significant water systems.
- **2011 Land Use:** This map provides a snapshot of land use in 2011 based on the NLCD 2011 land use cover dataset.

STUDY AREA ANALYSIS
The following maps represent an analysis of the land use cover changes and resultant trends between 2001 and 2011, and the spatial relationship between urbanization, IH-35 and the proposed LSTAR regional rail route.

- **Population Density 2010:** This map overlays urbanized land pixels between 2001 to 2011 and population density at the end of this time period as available by the 2010 census to better understand and compare where urbanization is occurring as it pertains to population.
- **Urbanization Rates in Natural Bioregions:** This map looks at urbanized land between 2001 to 2011 in the natural bioregions of the 8-county area.
- **Urbanization 2001 - 2011:** This map isolates urbanized land pixels between 2001 to 2011 and quantifies land urbanization in each county.
- **Urbanization Clustering 2001-2011:** This map analyzes patterns of land use change using ArcGIS spatial statistics tools to highlight occurrences of clustering and greater accumulative change, priming further detailed studies in these identified zones of greater urbanization.
- **Urbanization Clustering Along LSTAR Route 2001-2011:** This map draws relationships between urbanization and the proposed LSTAR route using ArcGIS spatial statistics tools to confirm its measure of influence on land use change, and facilitates the drawing of conclusions on the potential of utilizing this corridor as a planning catalyst for the future of the region.
- **Suitability Analysis for Future Site Study:** This map identifies zones of suitability for future urban design studies in the region based on layering of “build” and “no-build” zones, including the regional hot spot analysis, existing city limits, the LSTAR route, as well as the 100-year flood plain and the Edward’s Aquifer Recharge and Contributing zones respectively.
- **Identified Site for Future Design Study:** This map locates the first identified site for further study (based on qualitative investigation of the previous suitability analysis areas and knowledge of regional characteristics and the unique municipality agendas).
DATA TABLES
The following tables were compiled based on the findings of the above maps.

Table 1 (Refer Map: Population Density 2010)

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<tr>
<td>County</td>
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<tr>
<td>--------</td>
</tr>
<tr>
<td>Total Population</td>
</tr>
<tr>
<td>Population Density (Person per Square Mile)</td>
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<td>Population Density (Person per Acre)</td>
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Table 2 (Refer Map: Urbanization in Natural Bioregions)

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<tr>
<td>Natural Bioregion</td>
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<tr>
<td>% Land Urbanized Relative to Region Itself</td>
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<tr>
<td>% of Total Urbanization Occurring in Region</td>
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Table 3 (Refer Map: Urbanization 2001-2011)

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<tr>
<td>County</td>
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<tr>
<td>% Land Urbanized</td>
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<tr>
<td>% Total Urban Land 2011</td>
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<td>Acres Urbanized</td>
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<td>Total Urban Acres 2011</td>
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Table 4 (Refer Map: Urbanization Clustering Along LSTAR 2001 – 2011)

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<td>Buffer Zone</td>
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<tr>
<td>% Land Urbanized Relative to Buffer Itself</td>
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<tr>
<td>% Land Urbanized Relative to 8-County Area</td>
</tr>
</tbody>
</table>
**URIANIZATION RATES IN NATURAL BIOREGIONS**

**GRAPHIC LEGEND**
- LSTAR Stops
- IH-35
- LSTAR Proposed Route
- Land Developed Between 2001 and 2011
- City Limits
- Edwards Aquifer Contributing Zone
- Edwards Aquifer Recharge Zone

* Percentages reflect Urban Land Use Change in each Bioregion / Total Land in each Bioregion within the study area.

% OVERALL URBANIZATION BETWEEN 2001-2011 CAPTURED IN EACH BIOREGIONS

- Edwards Plateau: 4.6% Land Use Change
- Blackland Prairie: 3.5% Land Use Change
- Oak Woodlands: <0.1% Land Use Change
- Brush Country: <0.1% Land Use Change
- Edwards Aquifer Contributing Zone: 43%
- Edwards Aquifer Recharge Zone: 55%
- City Limits: 1.5%

Prepared By: Sarah Simpson, Dec 2015
Projection: Texas S Central FIPS 4204 (US Feet)
Data Sources: CAPCOG, Comal & Bexar Counties, TNRIS, TPWD, NLCD
URBANIZATION CLUSTERING 2001 - 2011

GRAPHIC LEGEND

- LSTAR Stops
- LSTAR Route
- IH-35

URBANIZED LAND HOT SPOT ANALYSIS

Gi BIN

- Cold Spot - 99% Confidence
- Cold Spot - 95% Confidence
- Cold Spot - 90% Confidence
- Not Significant
- Hot Spot - 90% Confidence
- Hot Spot - 95% Confidence
- Hot Spot - 99% Confidence

GiZScore

- No Hot Spots
- 1.76 to 5.54
- 5.55 to 10.40
- 10.41 to 17.43

Prepared By: Sarah Simpson, Dec 2015
Projection: Texas S Central FIPS 4204 (US Feet)
Data Sources: CAPCOG, Comal & Bexar Counties, TNRIS, TPWD, NLCD
URBANIZATION CLUSTERING ALONG LSTAR ROUTE 2001 - 2011

GRAPHIC LEGEND

- LSTAR Stops
- LSTAR Route
- IH-35
- CityLimits

URBANIZED LAND HOT SPOT ANALYSIS

Gi BIN

Cold Spot - 99% Confidence
Cold Spot - 95% Confidence
Cold Spot - 90% Confidence
Not Significant
Hot Spot - 90% Confidence
Hot Spot - 95% Confidence
Hot Spot - 99% Confidence

URBANIZATION IN IH-35 ROUTE BUFFER

9.1% Urbanization in IH-35 Route Buffer

URBANIZATION IN LSTAR PROPOSED ROUTE BUFFER

9.9% Urbanization in LSTAR Proposed Route Buffer

% URBANIZED LAND IN TRANSIT CORRIDOR 2-MILE BUFFER ZONES

Prepared By: Sarah Simpson, Dec 2015
Projection: Texas S Central FIPS 4204 (US Feet)
Data Sources: CAPCOG, Comal & Bexar Counties, TNRIS, TPWD, NLCD
THE IH-35 GROWTH CORRIDOR

SUITABILITY ANALYSIS FOR FUTURE SITE STUDY

GRAPHIC LEGEND

- LSTAR Route
- IH-35
- LSTAR Stops
- Suitable Study Sites

SUITABILITY FACTORS: DESIRED ZONES

- 1-Mile 99% Confidence Hot Spot Buffer
- 2-Mile LSTAR Buffer
- Existing City Limits

SUITABILITY FACTORS: UNDESIRABLE ZONES

- 100-year Floodplain
- Edward's Aquifer Recharge & Contributing Zones

Prepared By: Sarah Simpson, Dec 2015
Projection: Texas S Central FIPS 4204 (US Feet)
Data Sources: CAPCOG, Comal & Bexar Counties, TNRIS, TPWD, NLCD
THE IH-35 GROWTH CORRIDOR
IDENTIFIED SITE OF FUTURE DESIGN STUDY

GRAPHIC LEGEND

- IH-35
- LSTAR Route
- LSTAR Stop (General, TBD)
- Suitable Study Sites
- 1-Mile 99% Confidence Hot Spot Buffer
- 2-Mile LSTAR Buffer
- Existing City Limits
- 100-year Floodplain

STUDY SITE: THE SOUTH END

SAN MARCOS, HAYS COUNTY

Prepared By: Sarah Simpson, Dec 2015
Projection: Texas S Central FIPS 4204 (US Feet)
Data Sources: CAPCOG, Comal & Bexar Counties, TNRIS, TPWD, NLCD
VI. DISCUSSION OF FINDINGS

The results of the mapping studies provide an interesting picture of the eight-county region, one with highly variable conditions. As would be expected, more intensive growth and population density is highest in urban cores of both large and small cities. Within Travis county, this more intensive density tends to occur more or less concurrently along IH-35, unlike in Bexar county, where much urbanization has occurred along beltlines that encircle the city and has led to more concentric expansion and radial population densification. Smaller towns between the two major cities of Austin and San Antonio, similar to Austin, exhibit density and the most intensive urbanization adjacent to or relatively near IH-35.

However, when looking at overall distribution, it was found that considerable population is dispersed throughout the eight county area exhibiting no evident pattern tied to the transit corridor, revealing that considerable residential land use is dispersed throughout both urban and rural areas.

Urbanization as a process studied at the larger bioregional level shows that a majority of development (55%) is occurring westward of IH-35 in the Edwards Plateau bioregion, which is an incredibly sensitive region that directly impacts the health and functioning of the Edwards Aquifer, an important water supply for the entire region’s hydrology, as well as San Antonio’s municipal water source. Despite this issue, areas of north San Antonio show considerable urban land use change within the Edward’s Aquifer Recharge zone. The remainder of growth (43%) is occurring east of IH-35 in the Blackland Prairies, which is largely fertile land with soils appropriate for agricultural use.

Most of the apparent urbanization between 2001 and 2011 occurred at the peri-urban edges of San Antonio and Austin and within bedroom communities, such as Selma/Schertz and Round Rock/Pflugerville respectively, with more focused local growth in the smaller towns along IH-35, such as San Marcos and New Braunfels. Almost all counties experienced urbanization within or adjacent to existing incorporated municipalities. However, Comal county, and to some extent Bastrop county, exhibited considerable uncontrolled urban land use change outside of city limits in rural areas. (This is largely attributed to Comal county’s lack of a county environmental conservation plan up until 2010 (SWCA Environmental Consultants, 2010). This effectively created a conservation gap during the analyzed period of time amidst other regional conservation efforts in the other seven counties, such as proposed regional habitat conservation plans for Williamson county, Hays county and the Edwards Aquifer Authority, as well as Travis county’s Balcones Canyonlands Conservation Plan (Koone, 2008).)

Overall, as would be expected the counties that house the major metropolitan municipalities experienced the highest rates of urbanization between 2001 to 2011: Bexar county urbanized at a rate of 6.8%, with Travis county following behind at 5.8%, Williamson at 3.6% and Comal and Hays at 2.2% and 1.8% respectively.

ArcGIS spatial statistics hot spot analysis in the eight county region highlighted confirmed areas of clustered urbanization ranging from 90% to 99% confidence, and many of the identified hot spots correspond with the easily observable trends of peri-urban land use change in the NLCD.
dataset. In contrast, most existing urban areas, such as municipal downtowns were mapped as “cold spots” with 90% to 99% confidence, confirming a lack of clustered urban land use change at the heart of most cities, which is to be expected since there is less opportunity to urbanize in already developed areas. More interesting, however, were the areas of clustering that appeared along the IH-35 corridor, particularly as it relates to the proposed LSTAR regional rail route. This correlates to smaller but steadily growing towns like San Marcos and New Braunfels, which are situated in the middle of the growth corridor and have more of a buffered immunity to the direct bedroom community growth that towns like Kyle/Buda and Selma/Schertz are subjected to in response to growth in the major urban centers of Austin and San Antonio, respectively.

Isolated hot spot analysis in a 2-mile buffer zone along the proposed LSTAR route, an accepted radius that can be influenced by transit oriented development (Jaffe, 2015), revealed similar results to the overall eight county hot spot results with clusters forming at smaller towns that are currently situated along IH-35 in and outside the urban cores of Austin and San Antonio. Given that these smaller towns are urbanizing at noticeably and measurably significant rates reveals an opportunity to guide this growth in a manner to help support transit oriented development along the transit corridor between Austin and San Antonio and lessen growth in disconnected peri-urban zones.

The suitability analysis for future urban design study sites within a 2-mile buffer zone of the LSTAR route and a 1-mile buffer of 99% confidence hot spot zones narrowed these hot spot areas into existing city limits and reveals six primary areas of potential. These include the majority of Selma and Schertz, north and south New Braunfels, south San Marcos, most of Kyle and Buda, south Austin, and parts of Round Rock and Hutto.

Qualitative assessment of each unique zone’s characteristics, including existing built-environment, development agendas in place within each municipality, and issues of autonomy, highlighted factors more difficult to quantify in the land assessment and helped to identify the first site of investigation. Based on a prioritization of municipal autonomy (versus serving as a bedroom community to one of the larger metropolitan anchors), robust leadership at the city level for sustainability goals, and relative proximity to both Austin and San Antonio, the area in south San Marcos will serve as the primary area of more detailed investigation.

Further refined assessment of parcel size, existing built environment, and specific city-led growth agendas in the south San Marcos area found that within this initial suitability zone exists a city-identified future growth district, The South End, an area of approximately 120 acres, which consists of large, primarily undeveloped parcels at a transition zone between the downtown, several historic neighborhoods, an aging industrial zone, and a growing Medical district. This area is also located in an area where both the LSTAR route and IH-35 converge, separated by approximately one quarter mile, making for interesting relationships between both important corridors and the land that lies between. Based on the gathered data and the suitability analysis results, The South End, as linked to this larger regional context, was identified as the site for a detailed urban design study.
VII. CONCLUSIONS

The findings as previously discussed confirm the two hypothesized growth patterns, including significant clustering of urbanization at the fringes of major cities, as well as considerable urbanization along IH-35. When comparing these two models of growth, one is not necessarily seen as superior to the other since both likely involve the removal of regional habitat and necessitate car-dependency given the state of local municipality-driven and regionally-connected transit networks. Also, the evidence does not necessarily suggest a densification of population in these more recent areas of urbanization. Nevertheless, the growth along IH-35 carries by far greater potential to efficiently tap into regional networks as they are brought online to service the municipal anchors of San Antonio and Austin, such as the LSTAR, and has more potential to be located within existing city limits, rather than requiring intensive extension of service resources.

Focused evaluation of urbanization from 2001 to 2011 in the raw raster state as well as in hot spot cluster analysis reveal the latent potential that exists in the communities adjacent to IH-35 and the LSTAR proposed route. As these smaller towns grow within this period of accelerated maturation, there is an opportunity to redirect conventional low-density growth patterns to support the creation of sustainable networks as it pertains to transit, such as the LSTAR, as well as environmental conservation, housing and commerce before they expand outwards in a similar fate of San Antonio or Austin. In doing so, there is the possibility to rebrand the region and lessen or prevent long-term development in the rural and environmentally valuable lands of the rest of the region that can continue instead to serve as ecological habitat or productive, local agricultural lands.

Each of the six identified suitability zones, while not located in existing urban cores, offer the opportunity to develop within a regional context. While each needs to be assessed individually to find potential areas to implement a new sustainable model of growth, each does exhibit similar traits of being less intensely developed but bordered by areas of rapid land use change. By investigating areas that may also include natural pieces of land, there is the potential to incorporate natural ecological features and function into urban design, subverting what has historically been the typical status quo of clear cutting development sites. And on the other end of the spectrum, in areas that have already been heavily disturbed, there is the possibility at the larger neighborhood or district scale to build frameworks that look to reinvent the ecology of a site and enrich the existing condition.

It is hoped that this first investigation in the South End, San Marcos will lay the groundwork for a new regional strategy as manifest by unique points of urban design intervention.

LIMITATIONS & RECOMMENDATIONS FOR FUTURE RESEARCH

Given that the period of study as defined by the available NLCD datasets does not include the most recent data including the period of 2011 – 2015 and also spans the economic recession of 2008-2009, the research provides an understanding of recent trends but may not accurately reflect the most current trends. It would be beneficial to conduct this study again once NLCD...
releases datasets for 2016 or 2021 to get a more concrete depiction of post-recession area growth. However, for the purpose of this study, the few year gap is not understood to diminish the findings, which were supportive of recent growth reports in the eight county region.

The NLCD dataset is also limited in its distinction of urbanized land use itself, scaling only by intensity and does not distinguish between residential, commercial, institutional use. A more detailed study of urban land use utilizing different datasets that could furbish this information would add a more complete understanding of the type of development that is occurring.

Because this study region was comprised of eight counties, data was compiled primarily at the state level rather than individual jurisdictions to maintain consistency across all counties. More factors could have been considered for the suitability analysis, such as parcel size and the presence of existing buildings, however, gathering this across multiple counties revealed gaps and inconsistencies in the datasets. Thus, for the more detailed design study, more factors should be included in the assessment of the site characteristics since the data source (City of San Marcos) will be consistent.

It is also recommended that further investigations consider the potential land use effects of the LSTAR and how the transformation of this line could incorporate not just regional rail but also other regional amenities, such as a hike and bike trail or agricultural uses. Paying attention to land use adjacencies could influence and guide the amplification of LSTAR’s potential impact.
VIII. SOURCES

LITERATURE


Clement, M.T. (June 2015). Local Growth and Land Use Intensification (Dissertation). Department of Sociology, University of Oregon.


**DATA**


IX. APPENDIX

DETAIL STEPS TO DEVELOP DESCRIPTIVE & ANALYTICAL MAPS

Data Preparation

1. Data sets obtained from Texas Natural Resources Information System (TNRIS) are defined in GCS North American 1983; projected to Texas S Central FIPS 4204 (US Feet) for accuracy at the regional study area.
2. Eight county boundaries forming study area from TNRIS data sets are isolated and copied to a new layer to serve as project extents.
3. Roads and railroads clipped to the project extents.
4. Data sets obtained from the National Land Cover Database are defined in NAD 1983 Albers; projected to Texas S Central FIPS 4204 (US Feet) to match chosen projection and clipped to project extents.
5. Data sets obtained from Texas Parks and Wildlife are defined in NAD 1983; projected to Texas S Central FIPS 4204 (US Feet) to match chosen projection and clipped to project extents.
6. Data sets obtained from Texas Water Development Board are defined in NAD 1983; projected to Texas S Central FIPS 4204 (US Feet) to match chosen projection and clipped to project extents.
7. Data sets obtained from US Census Bureau are defined in GCS North American 1983; projected to Texas S Central FIPS 4204 (US Feet) to match chosen projection and clipped to project extents.
8. Data sets obtained from CAPCOG are defined in Texas Central FIPS 4203 (US Feet); projected to Texas S Central FIPS 4204 (US Feet) to match chosen projection and clipped to project extents.
9. Data sets obtained from Comal County are already defined in Texas S Central FIPS 4204; clipped to project extents.
10. City boundaries obtained from Comal County and CAPCOG are merged using merge tool. Attribute data is edited to collapse equivalent fields with different names.
11. Utilize select by query to isolate IH-35 corridor from TNRIS road dataset and create new layer.
12. Utilize manual selection to select proposed LSTAR route from TNRIS railroad network dataset and create new layer.

Data Processing – Urbanization in Counties Analysis

1. Use Spatial Analyst Conditional Con tool to convert NLCD 2011 Land Use Change to values of 1 (equal to raster pixels with values 21, 22, 23, or 24 that represent developed pixels) or 0 (all other raster pixel values).
2. Use Spatial Analyst Zonal Statistics as Table tool to calculate statistics on urban pixels in NLCD 2011 data set (value 1) within county polygons; export dbf file of table results and calculate % urbanized land and total urbanized acres for each county.
3. Use Spatial Analyst Conditional Con tool to convert NLCD 2001-2011 Land Use Change to values of 1 (equal to raster pixels with values 21, 22, 23, or 24 that represent urbanization) or 0 (all other raster pixel values).
4. Use Spatial Analyst Zonal Statistics as Table tool to calculate statistics on urbanized pixels in NLCD 2001-2011 Land Use Change dataset (value 1) within county polygons; export dbf file of table results and calculate % urban change and total urbanized acres for each county.
5. Join Zonal Statistics as Table output fields to IH-35 counties shapefiles, including counts for total urbanized pixels and total pixels overall.

**Data Processing – Urbanization Cluster Analysis**

1. Field added to 2010 Census Block dataset attribute table; field populated with calculated geometry for area (square miles).
2. 2010 Census block dataset symbology manipulated to show population density (total 2010 population normalized over area for each census block).

**Data Processing – Urbanization Cluster Analysis**

1. Use raster to point conversion tool to convert NLCD 2001 - 2011 Land Use Change dataset to points; create nlcd2001_2011_point.
2. Add “Count” short integer column in attribute table of nlcd2001_2011_point; calculate field value as “Count = 1”.
3. Use Spatial Analyst Tool Average Nearest Neighbor to analyze patterns in nlcd2001_2001_point dataset.
5. Run Spatial Statistics - Mapping Clusters Hot Spot Analysis (Getis-Ord Gi*) Tool on feature class [2010CB_NLCDJoin] dataset and input [Count_] to analyze significant areas of hot and cold clustering.
6. Symbolize both Gi_bin and GiZscore outputs.

**Data Processing – Urbanization along IH-35 & LSTAR Route Analysis**

1. Create 1 and 2 mile buffer zone of isolated IH-35 layer using buffer tool.
2. Create 1 and 2 mile buffer zone of proposed LSTAR route using buffer tool.
3. Use Spatial Analyst Zonal Statistics as Table tool to calculate statistics on urban pixels in NLCD 2001-2011 Land Use Change dataset (value 1) within LSTAR buffer polygons; export dbf file of table results and calculate % urbanized land and total urbanized acres within the buffer zones.
4. Use intersect tool with 2010 Census Blocks with LSTAR 2 mile buffer datasets to isolate census blocks along LSTAR buffer.
5. Join nlcd2001_2001_point dataset with isolated 2010 census blocks along LSTAR buffer dataset to form 2010CB_LSTAR2MBuf_NLCDJoin with new field Count_(total points of urbanized land in each census block).
6. Run Spatial Statistics - Mapping Clusters Hot Spot Analysis (Getis-Ord Gi*) Tool on feature class [2010CBLSTAR2MBuf_NLCDJoin] dataset and input [Count_] to analyze significant areas of hot and cold clustering along LSTAR route.

**Data Processing – Suitability Analysis of Future Design Sites**

1. Select by attribute cluster zones with Gi-bin values greater than 2 (99% confidence rating) of the eight county hot spot analysis layer. Dissolve the layer using the Gi-bin attribute to create a single polygon. Create a 1 mile buffer from the dissolved 99% confidence cluster zones.

2. Using the intersect tool, create a layer comprised of overlapping zones from the 1-mile hot spot buffer created in the step above, existing city limits, and the 2-mile LSTAR buffer zone. This will serve as the desired site area.

1. Select by attribute 100-year flood zones from the FEMA dataset and dissolve into a single polygon to define a no-build zone.

2. Select by attribute recharge and contributing zones of the Edward’s Aquifer; dissolve the layer using the zone type attribute to create a single polygon and define a no-build zone.

3. Using the union tool, combine the two no-build 100-year flood and Edwards aquifer recharge/contributing zones.

4. Erase the united no-build zones from the desired site area to create a layer of overall site suitability within the 8-county area.