Suitability for Infill Development: A multi-criteria and Spatial Assessment Approach

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ABSTRACT: Studies on the capacity of vacant sites for infill development have been limited to the analysis of parcels potential for infill, rather than a systematic measure of the accurate amount of parcels suitable for this type of development. Mostly, central city development has been the locale for potential developable sites, yielding only a very few parcels suitable for infill. Additionally, very limited studies have examined infill development in the context of suburban areas (Wiley, 2009) or small towns. This paper, as part of a broader funded research on unincorporated communities in *Zapata* County, develops a multi-criteria analysis method for parcels' suitability for infill development; this method could further be applied to other areas and regions. A spatial analysis method using Geographic Information Systems (GIS) was utilized to develop the assessment model. Pertaining to the theme of this year's conference, this method extends beyond the institutionalization of the inquiry within the discipline of architecture; it intersects with other disciplines such as urban planning, and housing and land development. The inquiry includes: a review of relevant studies and applications of GIS in sustainable urban planning, the creation of a code system for developable sites through the evaluation of eligible parcels in accordance with eight criteria, and a summing up of parcels' composite scores. A compartmentalization of this final score – using an ordinal scale - is what created each parcel's ranking for suitability. This ranking method, unlike the preceding assessments, retrieved a larger amount of vacant parcels suitable for infill by intertwining GIS with multi-criteria coding. The method is feasible and traceable at both the county and city levels; it creates visual mapping outputs that could easily by adopted by other communities in urbanized and peri-urbanized areas alike. City architects and planners could utilize this method to support future policies for land development, rezoning, and land use that leverage smart growth principles.

KEYWORDS: Multi-criteria Assessment, Infill Development, Spatial Analysis, Site Suitability.

1.0. SPATIAL ANALYSIS AND SUSTAINABLE URBAN PLANNING

This paper reviews an empirical case study application of GIS tools in the assessment of the suitability of vacant sites for infill, a form of sustainable urban planning. The case study represents an application of North American planning forms that promote sustainability principles and healthy communities in land development. Infill development refers to new development of vacant and underutilized parcels within the built-up areas of existing communities that have in-place infrastructures (Maryland Department of Planning, 2001). As a sustainable and urban form of promoting smart growth principles (Downs 2001; Burchell et al., 2000; Cooper 2004; and Downs 2005), infill development conserves environmental resources, economic investments, and the overall social fabric through a strategy of absorbing growth into existing communities, thereby relieving growth pressures on rural areas. This strategy preserves agricultural and natural areas by eliminating developments that have spread too far from the traditional population centers. More importantly, it is a form of planning that impact the community and its residents by enhancing the overall quality of life in older communities. However, only a limited number of studies have addressed a comprehensive quantitative assessment for sites eligible for infill development.

As a spatial analysis tool, GIS has been noted to be very useful in monitoring, appraising, and updating the indicators and metrics used in the assessment of sites and neighborhoods for the suitability of urban sustainability approaches. It also provides flexibility and efficiency as a platform for planning and decision making (Kamal, 2012; Collins et al., 2001; Malczewski, 2004; and Saleh and Sadoun, 2006) for its aptitude at visual and quantitative analysis. Because of GIS's capability of linking location data with multiple attributes – quantitatively coded - and its ability to perform spatial analyses on large amounts of data, it has successfully been used to depict proper sites for minimizing commuting distance, assessing walkability and proximity to major facilities, and mapping vacant parcels. Obtaining useful information and providing effective support for these examples of urban planning applications is a new and increasingly prevalent challenge. Currently, there are several different technological platforms being used to provide support to planners to complete their specific objectives (Anthony et al., 2006; Ning-rui and Yuan, 2005). Incorporating GIS in suitability assessments involves data manipulation, integration, and analysis, all of which could be used to visualize clustered residential developments, rates of vacant units, availability and suitability of parcels for infill development, and overall neighborhood assessments.

For these types of tasks, GIS is valuable especially for the sophisticated and extensive database management tool it offers, which also displays the capabilities of its tools; it is also recognized as quite user-friendly (Malczewski, 2004; Saleh and Sadoun, 2006). Other GIS benefits include the possibility that an increase in access to location-based data might lead to a greater number of alternative scenarios, and thus a better-informed public debate on the topic (Shiffer, 1995). As a newly applied apparatus in rural and peri-urban communities, GIS also has incited the development of geo-technology tools that support planning processes, particularly those where participation is a key element (Geertman, 2002). These participatory GIS tools have been described by the generic term Planning Support Systems (PSS) (Harris, 1989; Brail and Klosterman, 2001; Geertman and Stillwell, 2002; Geertman, 2002). PSS have been applied to urban-rural planning for the past 20 years, particularly in developed countries with advanced economies, societies and technology, and perfected systems and laws. The main idea proposed by Harris (1989) was to combine information technology with the methodology of urban planning to provide decision making at every step of the planning process (Mao et al., 2008).

3.0. THE LOCALE: UNINCORPORATED COMMUNITIES IN *ZAPATA* COUNTY

The overwhelming level of economic distress exists in *Zapata* County, TX (Tangum and Kamal, 2013) has triggered a broader-funded project on economic growth and competitiveness. This economic development project was designed to develop solutions to problems related to current land and economic conditions, and to facilitate a long-term economic and land development plan for the county. It also emphasizes strategic, long-term initiatives that deal with some of the underlying causes of underdevelopment in this county.

Zapata County is predominantly rural and sparsely populated. Its urban portions make up only a small part of the county's total land area. Moreover, all of its communities are located along a narrow strip of land centered on U.S. Highway 83. This highway runs along the western edge of the county, and with the Rio Grande it forms a natural boundary with Mexico. While the county is relatively dry, the Rio Grande and Falcon Lake/Falcon International Reservoir provide a stable supply of water for residents in the area. However, during prolonged droughts that supply can be compromised as water levels in the reservoir may decline. The interior portion of the county is largely devoid of any population centers. However, that portion of the county has enormous oil and gas deposits. These deposits provide the county with a huge natural resource base for the local economy. Equally important to the county's long-term economic growth is its potential tourism base centered at Falcon Lake, and several historical sites located in the Highway 83 corridor. Its two largest communities – Zapata and San Ygnacio – are also located within this corridor.

As part of this economic development and growth management study, an analysis of the county's vacant residential lots was conducted. The analysis aimed to create (1) a systematic method of reviewing available vacant parcels, and (2) a quantitative system of assessment and ranking those sites to prioritize them for types of residential infill development that would be both adaptable and comprehensive. The assessment method was intended to be driven by the principles of smart growth and healthy living principles, including proximity to services and public facilities.

This case study, as part of a broader body of funded research, incorporates a multi-criteria analysis of certain residential vacant parcels. Of the twelve Census Designated Places (CDP) in *Zapata* County, five had a sufficient population and level of economic activity to be explored for potential infill developments. These five communities are: Zapata, Medina, Siesta Shores, Falcon Lake Estates, and Falcon Mesa (see Figure 1).

4.0. INTERDISCIPLINARY METHOD FOR SUITABILITY ASSESSMENT

4.1. Assessment Criteria and Coding System

To identify developable sites for infill development in the five qualified communities in *Zapata* County; all vacant parcels located, in whole or in part, in the 100-year floodplain as determined by the U.S. Federal Emergency Management Administration (FEMA) were omitted. The remaining parcels were evaluated. The methods utilized in the evaluation identified those parcels that emerged from an analysis of the degree of each parcel's suitability to satisfy the assessment criteria (Mokarram and Aminzadeh, 2010*)*. This method entailed developing a spatial model using GIS mapping and incorporating a binary coding system to establish the degree of each parcel's suitability for infill, based on eight assessment criteria. The eight criteria were identified in collaboration with the sponsor organization of this research, and by identifying the available mapped data considered to be significant components of smart growth principles. The assessment of whether or not each parcel met the eight criteria was conducted by utilizing different types of data sets:

1) Land use parcel shapefiles, generated by researchers at the Center for Urban and Regional Planning Research (CURPR) in the College of Architecture, University of Texas at San Antonio. Land use maps were generated from a raw parcel data file obtained through the sponsor organization.
2) Thoroughfare layers and natural environment attributes were obtained from the ArcMap USA libraries available via ArcMap 10.0 (Environmental Science Research Institute [ESRI], 2010).
3) Each community's boundary file was downloaded from the US Census TIGER Files (US. Census, 2010).
4) Field notes and mapping shapefiles for all services and public facilities. These maps were generated by the GIS unit in the sponsor's organization in *Zapata* County.
5) Verification of building coordinates (longitude and latitude), as well as the street addresses obtained as mapped field notes from the GIS unit of the sponsor's organization.

Figure 1: Parcels' suitability for residential infill development in *Zapata County*. Source (Tangum and Kamal, 2013)

Each parcel was evaluated and coded based on a score system assigned for each parcel, according to the following criteria (see Table 1). The binary code was inserted into the tabulation of the multi-layered County parcel's file using ArcMap on ArcGIS for Desktop (ESRI, 2010).

- *Criterion #1*: Vacant parcels in predominantly residential areas were assigned a score of "1," indicating significant potential for infill; all other vacant parcels were assigned a score of "0," indicating little or no potential for infill.
- *Criterion #2*: Distance from major highways. Parcels used for residential developments needed to be located a sufficient distance from the highway due to the noise, pollution, and high traffic volume that accompanies such high-traffic roadways. Desired locations, however, could not be too far away from the highway, either. Parcels located within a range of 0.2 to 2.0 miles from US Highway 83 or within a range of 0.1 to 2.0 miles from Texas Highway 16 were considered appropriate for infill, and thus scored a "1." Parcels satisfying proximity conditions for both highways scored a "2." All other parcels scored a "0."

- *Criterion #3*: Ratio of Improvement Value (RIV) to the Total Market Value (TMV). This ratio is considered a good measure for the potential for development of vacant parcels. A parcel with a RIV of 100% means that it has the maximum potential for development. Conversely, a parcel with zero improvement value would have a ratio of 0%, and thus would have no potential for development. All residential vacant parcels were grouped into four categories: 1) parcels with an RIV of 100%; 2) parcels with an RIV between 50.01% and 99.99%; 3) parcels with an RIV between 0.1% and 50%; and 4) parcels with an RIV of 0%. Categories 1 and 2 scored a “1” because they showed a high priority for infill; categories 3 and 4 scored a “0” because they indicated a low priority for infill.

- *Criterion #4*: Proximity to school. Homes closer to schools are more desirable than homes further away. Vacant parcels were grouped into three categories. Parcels in categories 1 and 2 scored a “1” because they were considered a high priority for infill, while parcels in category 3 scored a “0” as they indicated a low priority for infill. Categories were determined by distance: category 1: up to 0.5 miles, category 2: between 0.6 and 2.0 miles, and category 3: over 2.0 miles.

- *Criterion #5*: Distance from injection wells. These wells have negative environmental impacts on most nearby land uses. Parcels closer to such wells have less value, and are least desirable for potential infill developments due to their relatively lower market values. The parcels' proximity to injection wells were classified into three categories: category 1: up to 0.25 miles, category 2: between 0.26 and 0.5 miles, and category 3: over 0.5 miles. Categories 1 and 2 scored a “0” as they were low priority for infill, while parcels in category 3 scored a “1” as they were a high priority for infill.

- *Criterion #6*: Proximity to utility lines. Vacant parcels closer to existing gas lines are economically more efficient than those further away. Vacant parcels were classified into two categories: 1) parcels immediately adjacent to gas lines scored a “1” as they were of a high priority for infill, and 2) parcels not adjacent to gas lines scored a “0” as they were of a low priority for infill.

- *Criterion #7*: Proximity to commercial land use. A considerable impact on the land value and potential revenue is associated with proximity to commercial land use. In addition to increasing the parcel's potential for mixed-use development, this proximity has a significant impact on a vacant parcel’s potential for infill. Vacant parcels were grouped into the following categories. Parcels located within a 0.25 mile distance from commercial land use scored a “1” as they were of a high priority for infill, while all other parcels scored “0” as they were considered a low priority for infill.

- *Criterion #8*: Neighborhood’s real estate stability. Neighborhood stability was indicated by city blocks with comparatively high ratios of owner-occupied housing that were also free and clear of mortgage. To identify the neighborhood stability of the vacant parcels, a map of the blocks (each containing a number of parcels) was overlaid with a map of the vacant parcels. Vacant parcels were grouped into two categories. Category 1 included blocks with over 50% of the parcels owner-occupied and free and clear of mortgage. These blocks scored a “1” as they were considered to be of a high priority for infill. Category 2 included all other blocks, which were scored with a “0” as they were considered to be of a low priority for infill.

4.2. A Parcel’s Composite Score and Rank

ArcMAp (ESRI 2010) was utilized to code an equal-weight score of identified criteria to each parcel. The incorporated score system permits a high score of nine because certain parcels could gain two points for the proximity to both highways. Nevertheless, the maximum score any parcel achieved was eight. The feasibility of estimating each parcels composite score was made possible by inserting the coding systems for eligible parcels on the ArcMap tabulation (ESRI, 2010) using a separate layer for each criterion. A final table was then generated on a spreadsheet to calculate the composite score.

Table 1: Criteria and Coding System for assessing A Parcel's Infill Suitability (Kamal, 2013)

	Criterion	Coding System	Symbol
1	Location of vacant	1: predominantly residential areas 0: other vacant parcels	
2	Distance from major Highways	2: 0.2 to 2.0 miles from US highway 83, and 0.1 to 2.0 miles from Texas highway 16 1: 0.2 to 2.0 miles from US highway 83, or 0.1 to 2.0 miles from Texas highway 16 0: all other parcels	
3	Ratio of RIV to TMV	1: parcels with 100% RIV/TMV and parcels with 50.01%-99.99% RIV/TMV between 0: parcels with 0.1%-50% RIV/TMV and parcels with 0% RIV/TMV	
4	Proximity to school	1: 0-0.5* miles and 0.6-2.0** miles 0: over 2.0 miles	
5	Proximity to commercial land use	1: over 0.5 miles 0: up to 0.25*** miles, and 0.26 and 0.5 miles	
6	Proximity to utility lines	1: adjacent to gas lines scored 0: Not adjacent to gas lines scored	
7	Distance from injection wells	1: within a 0.25 mile distance from commercial land use 0: all other parcels	
8	Neighborhood's real estate stability	1: blocks with over 50% of the parcels owner-occupied and free and clear of mortgage 0: all other blocks	
	Total possible score	**0 (minimum score) - 9 (maximum score)**	

Table Key

* 0.5 mile = Ten-minute walk

** 2.0 mile = Minimum distance beyond which a required school bus transportation is mandated (required by law in the state of Texas)

*** 0.25 mile = Five-minute walk

To assess the overall potential of vacant parcels in the five selected communities, a semantic differential scale to measure suitability of Good, Moderate, or Fair was adopted. The scale allocated a score of six to eight for a parcel of "Good" quality, a score of four to five for a parcel of "Moderate" quality, and a score of zero to three for a parcel of "Fair" quality (see Table 2 and Figure 2). The method used in allocating the scores was limited to the data available in an ArcMap-compliant format at the time the research procedures were performed. Additional attributes could be incorporated in the future, including environmental, transportation, and food desert elements. Data for these attributes are being prepared for further investigation. A weighted-scale for the attributes could then be developed to permit the use of criterion-specific weights to fine tune the preciseness of the scale and its relevance to the magnitude of importance of each criterion.

Table 2: Ranking and Areas of Available Parcels for Residential Infill Development (Kamal, 2013)

Code/ Score	Rank	Count and Percentage		Area (in acres)		
		#	%	Minimum	Maximum	Average
6-8	Good	592	24	0.03	38.46	0.46
4-5	Moderate	1142	46.4	0.02	36.36	0.4
0-3	Fair	730	29.6	0.02	30.66	0.57
Total		**2464**	**100%**			

5.0. DISCUSSION: ASSESSMENT AND INTERSECTION OF DISCIPLINES

This method of assessment of a parcel's suitability for infill residential development differs from other forms of analysis of land development in central city development. The incorporation of ArcMap software and the coding system into the exclusion process of parcels unable to meet the eight identified criteria occurred at an early stage of the analysis.

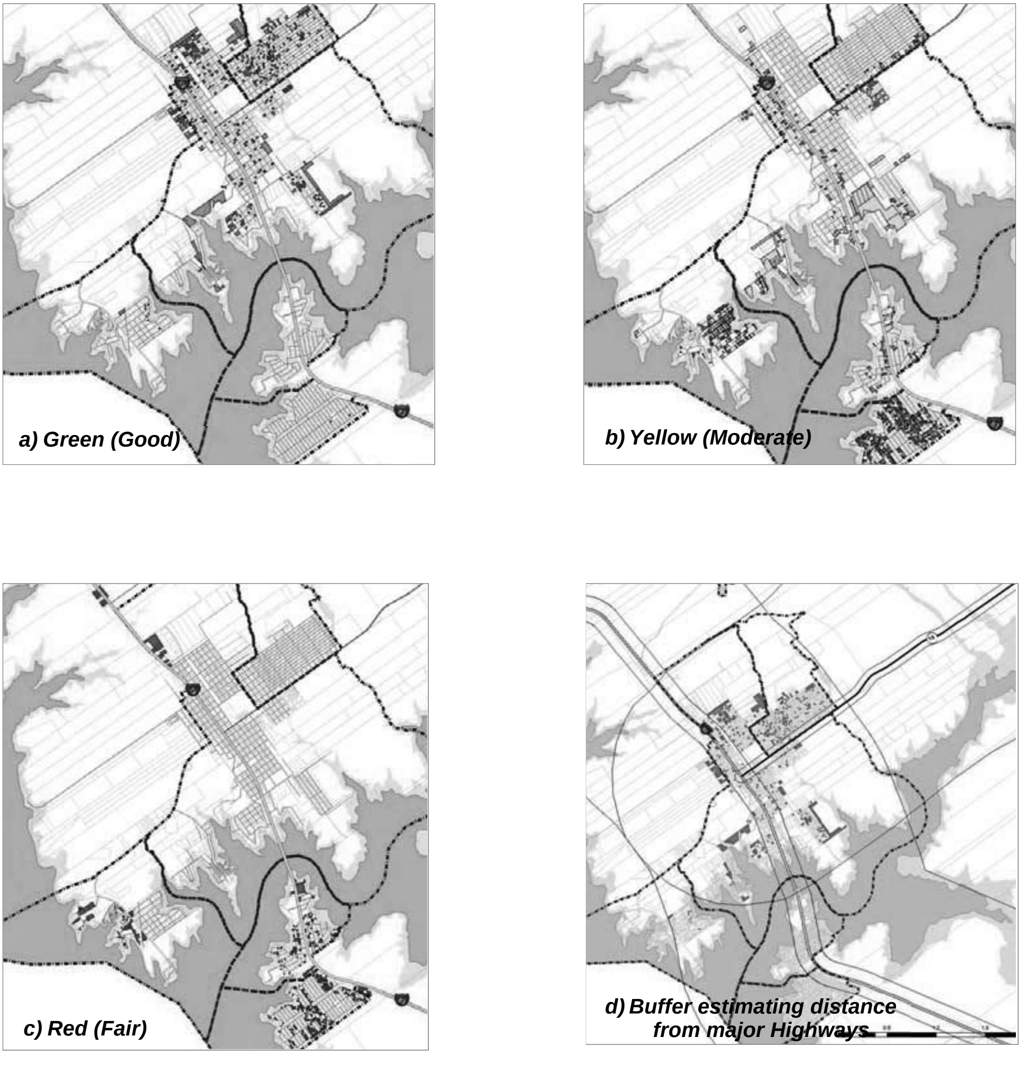

Figure 2 (a, b, & c): Parcels' suitability for residential infill development in *Zapata County*.; **(d):** Sample criteria analysis (Buffers for estimating distance from major Highways). Source (Tangum and Kamal, 2013)

This process retrieved a greater number of available vacant parcels located in primarily residential areas suitable for infill development. By integrating a multi-criteria assessment and through the use of spatial analysis and a binary system of coding, the final scores were feasible for an assessment via the combined tools of ArcMap (ESRI, 2010) and the coding spreadsheet. While no parcels scored nine in the total composite score, thirty parcels received a score of eight. Overall scores and ranks of the eligible vacant parcels were as follows: 592 parcels (24% of the total eligible parcels) received a good suitability score; followed by 1,142 parcels (46.4% of the total eligible parcels) which were regarded as of moderately suitable quality; and 730 parcels (29.6% of the total eligible parcels) were considered to be fairly suitable for infill. In lieu of a review of similar quantitative methods utilized to assess the potential of developable sites for infill development that have appeared in the literature published in the past ten years, this method offers a comprehensive and synthesizing approach that combines all available attributes in peri-urban communities in South Texas. The methods published in the literature reasonably exclude further numerous sites from their assessments due to their uni-variate approach.

6. CONCLUSION

Communities in southern and western Texas, particularly in rural counties, are recognized as outmigration communities; they strive to incorporate sustainable approaches for development, which includes long-term plans for economic and job growth. El Paso, Texas and Odessa, Texas (Andrews, 2013) are examples of local governments working towards healthy community principles through smart growth. Opportunities generated from these efforts not only impact the way we design cities and towns, but the health of both older and younger generations. Adding to this, the benefit of the densification of city centers and urbanized areas in peri-urban communities (i.e., the five communities studied in *Zapata* County crafts a sense of community that is both sustainable and healthy).

The case study of peri-urban communities in *Zapata* County presented in this paper address the invaluable use of GIS and quantitative analysis tools for evaluating land development for infill as a sustainable form of smart growth development. The method used of intertwining GIS mapping with a coding and ranking systems for developable sites was the most appropriate method for processing and projecting quantitatively and visually the *big data* necessary for this type of analysis, and for combining this array of location-based attributes with the planning standards of smart growth. It also provided a useful tool that could both be applied to large amounts of parcel data and be used to create visual mapping outputs for other communities and city center developments. This process would not be possible if these tools were not available. Building on other sustainable development studies (Mokarram and Aminzadeh, 2010; Alshuwaikhat and Aina, 2006; and Maryland Department of Planning, 2001), the challenges urban planner would have had without computer technology and GIS mapping would not make it feasible to incorporate all attributes at once in the assessment and coding system. The elimination of ineligible parcels at the early stage of assessment in traditional – manual- or Computer Aided Design [CAD] maps would have been gigantic, leaving only highly eligible parcels (i.e. parcels close to commercial land use, or schools) for the planning team to offer for the developers. The equal-weight codes assigned to each attribute also helped this approach over other traditional approaches; it increased the number of developable sites (those meeting conditions of distance from injection wells, or far from highway noise and pollution). At the same time, it is a point of research that could further be investigated to study the possible allocation of varied-weight system based on each attribute's contribution to smart growth principles.

The tools used, the results of this assessment, and the expertise developed will facilitate the use of this process in the future, and will provide not only valuable assistance to towns, counties, and regions in their planning for smart growth implementation, but for capacity building and assistance for their staff members. The assessment tool created in this study also provides a beneficial input for decision-making planning at the neighborhood and community levels; the processes was previously challengeable for sites located in peri-urban areas where GIS spatial analysis represented a new trend in data manipulation and decision making. The outputs of this assessment method are time and economically efficient outputs that are feasible, quantifiable, and traceable. This method offers flexibility in the periodic updates of parcels and zoning regulations that the researcher or the planning staff using this method could frequently monitor. Local and state policy makers need to identify a code for sites designated as developable for infill, a code that could be monitored and updated according to the future growth of the community. This process could result in a strategy for allocating resources for an incentive program and a priority zones policy, which would encourage area developers to invest in the designated developable sites. The outcomes of the process could also be used to inform the general public and solicit their involvement in the decision making necessary for sustainable planning. These decisions will flourish from regular updates and the monitoring of the already-established score system which will aid future decisions, assessments, and the allocation of resources. The implementation of this process could also be replicated by creating a score system for other land use policies (i.e., commercial and mixed use development), which in turn could direct further decisions for economic growth and sustainability. The availability of these quantitative attributes and the scoring system to planners, policy makers, and other stakeholders will facilitate their assessment of the long term impacts of decisions regarding real estate equity and the overall condition of neighborhoods, their tracking of population and economic growth, and their re-evaluations of the capacity and amount of infill scores in residential and other forms of development in their communities.

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