SPATIAL ANALYSIS FOR NEIGHBORHOOD SUSTAINABILITY ASSESSMENT

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ABSTRACT

Increasing the energy efficiency of the built environment, in the buildings, transportation and other sectors, and reducing harmful emissions of greenhouse gases are rapidly becoming important components of community planning processes. The effectiveness of planning decisions can be greatly enhanced by providing planning professionals, policy makers, and other stakeholders with methods and tools to evaluate the different impacts of proposed planning decisions on urban sustainability at different scales. This paper describes the methodology and preliminary results from a study to develop a neighborhood sustainability assessment model for the City of San Antonio using the INDEX PlanBuilder GIS-based tool, and to implement this model throughout the city's neighborhoods. The paper will describe the methodology, tools, and information sources used in the study, and will present a brief summary of the study's preliminary findings and the potential impact these findings can have on improving the sustainability of the city's neighborhoods and the city as a whole.

1. INTRODUCTION AND STUDY BACKGROUND

Increasing the sustainability of the built environment, through more efficient use of resources and reduced environmental impact, is a major component of urban sustainable development. Consequently, increasing the energy efficiency of the built environment, in the buildings, transportation and other sectors, and reducing harmful emissions of greenhouse gases are rapidly becoming important components of community planning processes. The effectiveness of planning decisions can be greatly enhanced by providing planning professionals, policy makers, and other stakeholders with methods and tools to evaluate the different impacts of proposed planning decisions on urban sustainability at different scales. Such methods should rely, as much as possible, on quantifiable metrics and indicators that can be easily measured and tracked over time. Developing such metrics and indicators at the neighborhood scale will provide planners, policy makers, neighborhood associations, and other stakeholders with the means to assess the current sustainability of their neighborhoods, and to compare and evaluate potential future plans based on quantifiable objective metrics.

In this context, the City of San Antonio's Sustainability (formerly called the Office of Environmental Policy or OEP) engaged a team of researchers from the College of Architecture, the University of Texas at San Antonio (UTSA) to explore the implementation of a Neighborhood Sustainability Assessment tool across the city, and to use this tool to identify and measure different neighborhood-level sustainability performance indicators for all the city's neighborhoods. These indicators were then to be used to develop a neighborhood-level sustainability assessment model, which would inform planning decisions at the neighborhood scale. The results of this study were intended to assist planners, policy makers and neighborhood associations across the city in making informed decision that would lead to improving San Antonio's overall sustainability. These results were also intended to fulfill the city's comprehensive and ambitious sustainability objectives illustrated in the SA2020 plan (City of San Antonio, 2011), and the City of San Antonio's Mission Verde Plan (City of San Antonio, 2009).

The objectives and activities of this study also coincide with the objectives of the US Department of Energy, which place increasing emphases on quantifiable metrics, as well as the objectives of the "Partnership for Sustainable Communities" developed between the Department of Housing and Urban Development (HUD), the Environmental Protection Agency (EPA), and the US Department of Transportation (USDOT). The six livability principles developed by the partnership provide the bases for the neighborhood sustainability indices developed within this study.

2. GIS AND SUSTAINABILITY ASSESSMENT

GIS software allows for the visual representation and manipulation of information for a specified geographic area. Data such as census demographics can be linked to geographically bound data and maps can be quickly be altered or manipulated to show different scenarios to visually represent the information in the form of pictures and maps instead of tables and text to make interpretation more meaningful. De Candido (as cited in Adkins & Sturges, 2004) contended that GIS systems "*allow problem solving to happen in a new and different way, by the visual inclusion of spatial data in the analysis of spatial problems*." GIS provides a visual image of the specified areas and allows for the implementation of community specific information that will allow for a more informed decision making. Additionally, GIS is a vital technology for dealing with demographics, zoning and land use planning by bundling time and efforts to enhance information infrastructure with and interactive form of decision making influenced by the availability of spatial data and digital geo-information, progress in technology (Saleh & Sadoun, 2006). Shiffer (in Carsjens & Ligtenberg, 2007) noted that the progress and availability in geographic and spatial digital technology has led to the assumption that an increase in available information and the user-friendliness and sophistication of the software such as extensive database management and display capabilities will produce a greater number of alternative scenarios. Consequently, GIS can be used to visualize different situations using indicators of sustainability and eventually lead to a better informed public participation.

Results show that applying GIS in each stage of urban planning and design is not only a means of aiding design, but an important tool that supports planning and a public information integration platform by being able to modify data at any given time, therefore saving time and effort while providing a solid operational base (Zhan et al, 2008). Zhan et al further contend that traditional planning methods are no longer adequate for current urban planning practices, and that GIS has a superior capability for spatial analysis, statistical analysis and simulation while also increasing emphasis on public participation in the urban planning process and providing new ideas and experience for further developing the theory and practice of urban planning. Harris and Elmes (1993) also argue that the use of GIS can address some of the complications of traditional non-automated decision making processes such as inefficiency and lack of documentation.).

With regard to sustainability, GIS could prove very useful in determining urban sustainability as we progress towards more sustainable cities. GIS has the capability to display and evaluate urban sustainability by linking quantitative location data while performing spatial analysis (Alshuwaikhat & Aina, 2006). They also suggests that the assessment of sustainability is developing into a holistic approach that will integrate the different aspects of spatial planning into the appraisal. As the evaluation of the planning process and the appraisal of the outcome becomes integrated, understanding towards how planning could foster sustainable cities will improve. Achieving this, however, will require environmental policies to be integrated early in the planning process, and planners need to have appropriate tools to help them identify potential impacts of their plans on specific sustainability indicators (Carsjens & Ligtenberg, 2007). According to (Vehbi & Hoşkara, 2009), sustainability indicators are "*the numerical tools used to measure changes in the physical, economic and social structures of an urban area*". Indicators should be integrated and specific to a site, thus making some indicators measuring sustainability appropriate in some cases while others are not. Vehbi and Hoskara further argue that useful indicators should communicate current conditions, improved or otherwise, and the general direction of the community, and that using a set of criteria and targets, indicators should offer "*links between trends and spatial structure, urban organization and lifestyles*".

The largest groups to have adopted GIS are municipal, county and metropolitan planning authorities which allow them to possess the greatest potential to thrive through the continued expansion of GIS assisted planning, as provincial and state planning policy is heavily politicized (Harris & Elmes, 1993). In this respect, GIS is seen as a single, high-tech solution to multiple planning problems by many state legislators. While GIS is increasingly being used by local governments and planning agencies as a support tool, limited collaboration between departments limit "comprehensive multipurpose GIS operations" (Harris & Elmes, 1993). Additionally, most GIS applications do not provide some of the functions urban planners are looking for because they were not developed with city planning in mind and the complexity of urban results combined with the complexity of urban planning limits the integration of GIS and urban planning (Mao, et al., 2008).

3. STUDY OBJECTIVES AND DESCRIPTION

3.1. Study Objectives

As noted previously, the objectives of the San Antonio Neighborhood Sustainability Assessment study aim to build on the principles and objectives included in the SA2020 and Mission Verde plans and to enable the achievement of the comprehensive vision of San Antonio illustrated in these plans. To achieve this, the Neighborhood Sustainability Assessment project encompasses the following objectives:

- To explore the use of the INDEX PlanBuilder GIS-based planning software in the City of San Antonio as a means of identifying and measuring neighborhood-level sustainability performance indicators.
- To use the INDEX PlanBuilder software to develop a neighborhood sustainability assessment model for the city that can be both measured and tracked overtime.
- To develop an "existing conditions" sustainability assessment for the city's neighborhoods.
- To explore the capabilities of the tool in evaluating alternative future planning scenarios and assess the impact of these plans on improving a neighborhood's sustainability performance.

3.2. The INDEX PlanBuilder Tool

At the beginning of the study, a survey was conducted to identify the best available methodologies and tools for this at the national level. Based on this survey, the PLACE3S Planning method was identified as the best method for that purpose. The PLACE3S planning method is a land use and urban design method created specifically to help communities understand how their growth and development decisions can contribute to improved urban sustainability (CEC, 1996). The PLACE3S method, an acronym for PLAnning for Community Energy, Economic and Environmental Sustainability, uses energy as a yardstick to evaluate the efficiency with which we use land, design neighborhoods to provide housing and jobs, manage transportation systems, operate buildings and public infrastructures, site energy facilities, and use other resources. The PLACE3S method uses quantitative performance indicators that measure the energy and environmental impacts of community plans and monitors these indicators over time, thus providing decision makers with quantitative information that strengthens the argument for resource-efficient choices. The PLACE3S method has been implemented as a planning software tool originally developed by the California Energy Commission (CEC) and is currently available as web-based tool (I-PLACE3S), which has been used in several US urban regions and cities . As I-PLACE3S was designed to work more at the regional scale, the project team opted for the use of another tool, INDEX PlanBuilder (Criterion Planners, 2011), which is based on the same planning method and is designed specifically for neighborhood-scale studies. INDEX PlanBuilder is desktop software consisting of an integrated suite of interactive GIS-based planning support tools for assessing community conditions, designing future scenarios in real-time, measuring and ranking scenarios with performance indicators, and monitoring implementation of adopted plans. INDEX PlanBuilder has been used by approximately 175 organizations in 35 states across the US and Canada.

3.3. The San Antonio Neighborhood Sustainability Index

The Neighborhood Sustainability Assessment Study utilized the INDEX PlanBuilder software to develop a neighborhood sustainability model for the City of San Antonio. The model was informed by similar case studies, the available indicators in INDEX PlanBuilder, as well as the available GIS data acquired from different organizations in the city. The model was based on 29 sustainability indicators, and was used to calculate an overall Neighborhood Sustainability Index for each neighborhood within the city. Neighborhoods were identified based on the Neighborhood Associations boundaries map developed by the City's Department of Planning and Community Development. In total, a sustainability assessment was conducted for 275 neighborhoods across the city.

This overall Neighborhood Sustainability Index consisted of seven component indices, six of which are in turn based on the six livability principles developed by the Partnership for Sustainable Communities and discussed previously. A seventh component index was also developed for Environmental Impact, and was primarily aimed at assisting the City of San Antonio in its efforts to reduce energy and water consumption, vehicle miles of travel, pollution emissions, and overall carbon footprint. Each of the component indices was calculated through aggregating the standardized scores of a subset of the 29 indicators calculated within the study, while the overall index was calculated based on a relative weighting of the 7 component indices. A more detailed discussion of the calculation process for the indices is provided in the following section.

Both the overall Neighborhood Sustainability Index and the component indices provide a simplified quantitative evaluation of the sustainability of different neighborhoods in San Antonio. The indices scores were meant to be considered only for comparative purposes between the different neighborhoods or between the existing conditions of a neighborhood and an expected future state. They were not meant to provide an absolute measure of neighborhood sustainability. Such an absolute measure can be found by examining the raw scores of the 29 Individual sustainability indicators, each of which offer a measure of one or more aspects of neighborhood sustainability.

4. STUDY METHODOLOGY

The following sections provide a brief summary of the methodology used in the study. A more detailed description of the methodology and the different data sources and inputs used in it can be found in the study's final report (Rashed-Ali, 2012a).

4.1. Data Collection

The first phase of the project included the collection of relevant data for the project from a variety of organizations and sources within the City of San Antonio and Bexar County. This process aimed to determine the availability of data for calculating different sustainability indicators within the study. The collected data included GIS data as well as other required inputs and values for the assessment model.

4.2. Neighborhood Sustainability Model Development

The process of selecting the neighborhood sustainability indicators used to develop the Neighborhood Sustainability Index consisted of three phases: 1) a literature review was conducted of similar sustainability assessment studies in a variety of US cities to identify the significant issues and indicators typically used in assessing urban sustainability at the neighborhood level; 2) the sustainability indicators available in the INDEX software were reviewed and compared to the previously-developed indicators set. Based on this comparison, a smaller set of 35 sustainability indicators was selected for the study; and 3) the availability of citywide GIS data and other required inputs for the indicators was investigated, and indicators which did not have all required data were excluded. Based on this process, a final set of 29 sustainability indicators was identified for the project.

Raw scores for selected indicators were calculated using the INDEX PlanBuilder Software. When available, required data and defaults representative of local conditions (San Antonio or Texas) were used. If this data was not available, national level data or INDEX software defaults (also representing national level averages) were used. While these raw sustainability indicator scores provide valuable information about the performance of a certain neighborhood vis-à-vis specific sustainability issues, they do not provide the ability for an overall evaluation of the sustainability of a neighborhood. To achieve such an evaluation, the indicators were combined into seven sustainability indices. Six of those indices were based on the HUD/EPA/USDOT livability principles, while the seventh related to the environmental impact of the neighborhood. Each of the seven indices was based on a subset of the indicators calculated within the study based on the relevance of the issues addressed by each indicator to the focus area of the index. To aggregate the indicator raw scores, scores were standardized so that they all fall on scale from 0-1. The standardization was achieved by comparing each indicator's raw score to a maximum and minimum threshold score for it. Indicators were assigned equal weights in calculating different index scores. However, several indicators were used in more than one index thus resulting in increasing their relative weight. All index scores were calculated on a scale of 1 -100. The approach of relating neighborhood sustainability indices to livability principles was based on a similar study conducted for the Twin City Region (Kaydee Kirk et al, 2010).

Finally, an overall Neighborhood Sustainability Index was calculated based on the seven component indices. Different relative weights were assigned to each component index based on the relevance of the issues it addresses to the environmental performance focus of the project. Accordingly, indices relating to environmental impact, housing equity, and transportation were assigned higher relative weights than other indices. This resulted in further modifications in the relative weight of each indicator in the overall Neighborhood Sustainability Index.

4.3. Pilot neighborhoods

To test the capabilities of the INDEX PlanBuilder software and the effectiveness of the developed neighborhood sustainability model, the model was first applied to two San Antonio neighborhoods with contrasting sustainability characteristics: 1) the Westside Development District, and 2) the Stone Oak Neighborhood. The Westside Development District represented a neighborhood with high urban density, high use mix, high street connectivity, available amenities, and good transportation coverage. Conversely, the Stone Oak neighborhood represented a low-density mostly single use neighborhood with low street connectivity, low public transportation coverage, and low availability of amenities. Through comparing the assessment results for these two neighborhoods, the project team explored the indicators selected for the assessment and identified relevant issues in the processing of GIS data. The results of this initial assessment were consistent with expectations and clearly exhibited the contrasting sustainability characteristics of the two neighborhoods.

4.4. Citywide Implementation

The model was then applied on a city-wide scale. To achieve this, the City of San Antonio was divided into 10 zones based on geographic location and the major highway network (see figure 1). Each of these 10 zones was then divided into its constituent neighborhoods based on the map of all registered neighborhood association in San Antonio. Areas with no neighborhood associations were divided based on major streets. In total, 275 neighborhoods were assessed within this project.

An assessment of existing sustainability conditions was conducted for each of the 275 neighborhoods identified within the city. Results generated for each neighborhood include scores for all indices (the overall Neighborhood Sustainability Index and the seven component indices), raw scores for the 29 indicators used, as well as maps describing the geographical distribution of some of those indicators within the neighborhoods (see figure 2). The detailed neighborhood results (including scores and maps) are published on the study website (Rashed-Ali, 2012b)

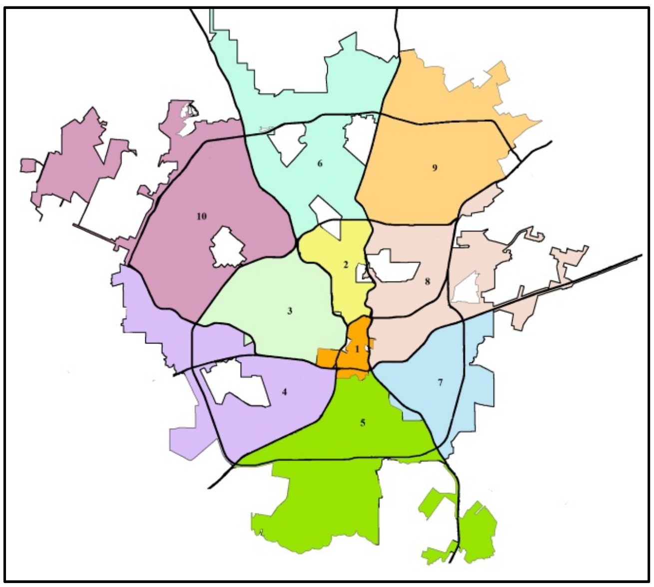

Fig. 1: Geographical zones used in study

4.5. Future Conditions Assessment

To explore the capabilities of the INDEX PlanBuilder software in assessing future planning scenarios and comparing planning alternatives, an assessment was conducted for the Ingram Hill Neighborhood. The assessment was based on the existing neighborhood plan developed in 2009 by the City of San Antonio's planning department for the neighborhood. Three future scenarios were evaluated: 1) scenario 1 reflected the future land use changes proposed in the Ingram Hill Neighborhood plan; 2) scenario 2 reflected a 20% reduction in building energy use (both residential and commercial) which represents the adoption of an energy efficiency program within the neighborhood, combined with an increase of 10% in transit service coverage and density; and 3) scenario 3 combined the impact of scenarios 1 &2.

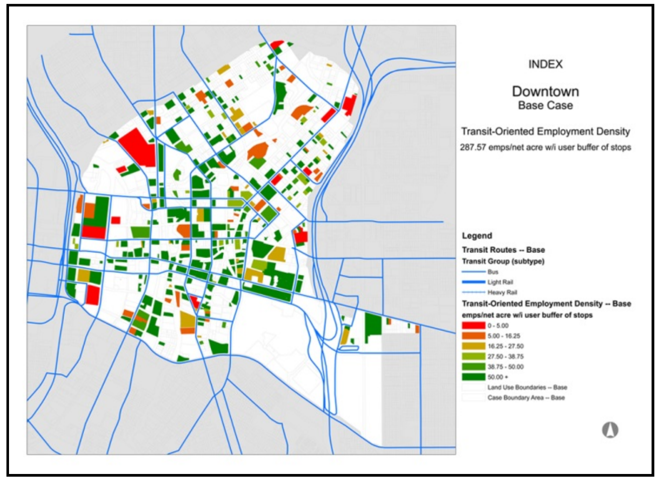

Fig. 2: Example indicator map for downtown San Antonio

4.6. Study Limitations

The following limitations of this study should be considered when interpreting the results:

- The accuracy of the neighborhood sustainability assessment results are based on the accuracy of the input data used, which were collected from different organization in San Antonio.
- While most of the indicators are based on neighborhood level (parcel level) GIS data, some of these indicators also use average values for certain inputs. As much as possible, when parcel-level data was not available or could not be obtained, locally-relevant values were used representing conditions in San Antonio or in specific areas within the city.
- In certain cases, some state and national level average inputs were used when parcel-level data or city/state-level averages were not available. These cases were, however, very limited and do not impact the potential of the tool in achieving a comparative evaluation of the sustainability of San Antonio neighborhoods.

5. RESULTS AND PRELIMINARY ANALYSIS

The following discussion provides a brief summary and preliminary analysis of the results of the neighborhood sustainability assessments conducted within this project. The volume and depth of the results, however, offer considerable potential for more detailed analysis and comparisons. This need for further analysis is elaborated further in the recommendations section.

5.1. Existing Conditions Assessment

(1) The average Neighborhood Sustainability Index score for all neighborhoods was 40.8 (on a 100 point scale), while the median score was 41. The standard deviation for the overall index scores was 11.2. Average index scores for the 7 component indices ranged from 23.4 (for the Supporting Existing Communities Index), to 58.8 (for the Environmental Impact Index). Median scores ranged from 25.6 to 59 for the same indices respectively.
(2) The average scores for the 10 geographical zones used in the study showed an apparent correlation between the proximity of the zone to the down town area and its average Neighborhood Sustainability Index score. The highest average score was achieved by zone 1, followed by zones 2 and 3 (see figure1). Similar correlations can also be seen in the results of the component indices. This result reinforces the opinion that higher density urban areas have higher sustainability performance than lower density areas. A more detailed statistical analysis is needed to evaluate this correlation.
(3) The lowest average scores for the overall index were achieved by zones 6, 9, and 10 which mostly consist of suburban, low density area. This further reinforces the observation made in point 3.
(4) The maximum Neighborhood Sustainability Index score calculated within this study was 74 and was achieved by the Down Town Neighborhood, followed by the Lavaca neighborhood, with a score of 69, Five Points, with a score of 62, then Avenida Guadalupe, Frio, and Highland Park with scores of 60 each. In contrast, the lowest scores were achieved by The Dominion neighborhood, with a score of 14, and the Grey Stone Estates neighborhood, with a score of 18.

5.2. Future Scenarios Results

The objective of the future scenario assessment was primarily to explore the capabilities of INDEX PlanBuilder to assess and compare future planning alternatives for a neighborhood. Figure 3 shows the results of the assessment for the Ingram Hill Neighborhood including the base case and the three scenarios described previously. The following can be concluded from the assessment:

(1) Scenario 1, showing the impacts of the proposed land use changes, resulted in a small increase in the Neighborhood Sustainability Index (increasing it from 40 to 41). Scores for component indices, however, were mixed. Detailed indicator scores show that the proposed changes did result in positive improvements in several indicators including use mix, development footprint, proximity to amenities and transportation, residential water consumption, transit oriented densities, and non-residential energy use and emissions. However, increased neighborhood populations resulting from the land use changes caused decreases in several indicators including wastewater and solid waste generation, imperviousness, and residential energy use and emissions (resulting from the addition of energy intensive single-family housing).
(2) The second scenario, showing the impact of increased public transportation coverage and building energy efficiency programs resulted in an almost equal improvement in the overall index score again increasing it to 41. This was primarily the result of improvements in the travel, energy use, and emissions indicators.
(3) Combining the two scenarios, however, resulted in a larger increase in the overall neighborhood sustainability score, increasing it to 43. In this case, most indicators showed improvement relative to the base case.

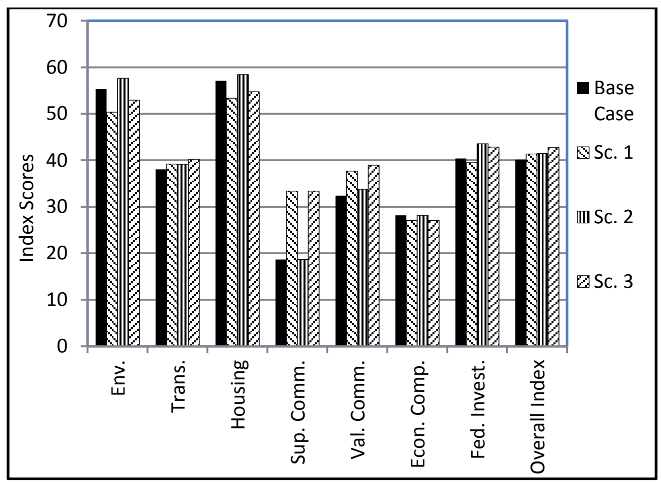

Fig. 3: Future scenarios assessment for Ingram Hill neighborhood

The analysis of these future scenarios illustrates the need for considering issues of energy efficiency and environmental impact when making planning decisions. As shown in figure 3, while the first scenario did result in an increase in the overall index, it also resulted in a drop of 9% in the environmental impact index. The raw indicator scores show that this is caused by a small increase in building energy use and emissions and larger increases in wastewater and solid waste production resulting from the increased neighborhood population. Scenario 3, on the other hand, which adds an energy efficiency program into the mix, resulted in a considerably better situation in which the land use objectives of the proposed plan were still achieved but in the same time, the environmental impact of the neighborhood was reduced compared to the base case. To illustrate this, in the third scenario, residential energy use was reduced from

24.2 MMBtu/yr/capita to 19.9 MMBtu/yr/capita, a reduction of approximately 8%. Non-residential building energy use showed an even larger decrease on a per employee bases dropping from 27.2 MMBtu/yr/employee to 17 MMBtu/yr/employee. This was due to the increase in utilization of commercial land uses in the neighborhood.

6. IMPACT AND POTENTIAL

The above analysis clearly illustrates the value such a tool can bring to the neighborhood planning process. Through having these quantitative metrics, planners, policy makers, and other stakeholders will be able to evaluate the long term environmental impacts of their decisions. Based on this, they can compare available planning alternatives, select optimum ones, develop new alternatives to address issues identified in the analysis, and generally make more informed planning decisions that lead to reductions in energy use, emissions, and other environmental impacts benefiting both the neighborhood and the City of San Antonio. The availability of the tool, the existing conditions assessments conducted within this project, and the expertise developed through it will facilitate this process and provide valuable assistance to neighborhoods in their planning activities. The neighborhood sustainability assessment also provides neighborhood associations and San Antonio residents with a valuable resource to evaluate the sustainability of their neighborhood compared to other neighborhoods in the city. Through this comparison, residents and neighborhood associations can identify potential areas of improvement within their neighborhood and select appropriate projects for implementation. This potential of the project is enhanced by the development of a public website which includes all neighborhood assessment results.

The study also provides the potential for developing a long-term tracking system for neighborhood sustainability in San Antonio. By updating the assessment on regular (e.g., annual) basis to reflect changes in conditions, this tracking system could provide planners and policy makers with the ability to objectively assess the performance of various activities and initiatives within the city. In addition to the assessment and tracking of existing conditions, the project results clearly illustrates the capabilities of the INDEX PlanBuilder tool in evaluating and comparing the effectiveness of proposed future planning alternatives in different San Antonio neighborhoods and areas. Taking advantage of these capabilities can offer a very important resource to all stakeholders which will enable a more informed planning decision making process. This will assist in achieving the city's sustainability objectives of reducing energy and water consumption, vehicle miles of travel, pollution emissions (including greenhouse gas emissions), and the overall carbon footprint of the city. Having a system in place to benchmark and track neighborhood sustainability performance can also facilitate the process of applying for state and federal grants, most of which now require some form of performance evaluation and tracking based on measurable criteria.

The website developed to publicize the results of this project to the general public (Rashed-Ali, 2012b) can also have a positive impact on San Antonio residents by increasing their interest in neighborhood sustainability issues, educating them regarding important indicators and how they are typically measured, and potentially creating a competitive environment between different neighborhood residents about the sustainability of their neighborhood relative to surrounding ones or the city as a whole.

7. RECOMMENDATIONS AND FUTURE WORK

As previously discussed, the results of the neighborhood assessments conducted in this project are in themselves very valuable for different stakeholders in San Antonio including planners, policy makers, neighborhood associations and the general public. However, these assessments also offer considerable potential for future work that would further build on the advantages offered by having such an assessment system in place. The following is a brief summary of possible future work based on this project:

(1) The results of this study provide a wealth of information regarding sustainability performance across San Antonio's neighborhoods. Further analysis of these results is needed and could provide valuable information for planners and policy makers in the city. This additional analysis can inform the city's sustainability strategies and assist in improving its sustainability performance. Potential types of analysis include, but are not limited to:
   a. A statistical analysis of the results correlating the sustainability scores with other variables such as geographic location, demographics, public health, economic, and other variables,
   b. An analysis of the geographical distribution of the different indices scores across the city to identify areas in need of improvement,
   c. An analysis of the results of individual indicators and their geographical distribution across the city.

(2) Assessments conducted in this study represent the existing conditions of different neighborhoods and are based on GIS data available at the time of conducting the analysis. Repeating this assessment on regular bases would offer the City of San Antonio the ability to track progress towards achieving its sustainability objectives as well the potential for evaluating the

success of different sustainability and other initiatives, at both the city and/or neighborhood levels, in improving sustainability.

(3) The model developed within this project and the data and inputs used in it represent the available data at the time of conducting the project. The comprehensive nature of this model results in it overlapping with several existing models in different sectors (e.g. emissions models, transportation models, etc.). While most of these models work at a higher level of aggregation than the one addressed in this project, comparing the results of the neighborhood sustainability assessment project with those of other existing models can result in further improvements in the accuracy of the neighborhood model.

8. ACKNOWLEDGMENTS

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