Geographic Analysis of LEED-ND for an Existing Neighborhood

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Abstract/Webstract

Problem: The United States Green Building Council Leadership in Energy and Environmental Design for Neighborhood Development (USGBC LEED-ND) rating system integrates the principles of smart growth and green building in a national standard for new neighborhood design. LEED-ND introduces spatial relationships not previously seen in the family of LEED standards. While new neighborhoods can incorporate site design criteria into their plans, existing neighborhoods are challenged with unplanned elements that may not adhere well to predefined measurement protocol.

Purpose: The primary purpose of this paper is to study the benefits and potential obstacles of developing a Geographic Information Systems (GIS) tool for applying the LEED-ND rating system to an existing neighborhood. Spatial data representing physical characteristics, such as transportation and infrastructure, as well as socioeconomic issues, such as diversity and accessibility, were used to measure conditions and calculate points earned on the LEED-ND project scorecard. This article demonstrates the complexity associated with applying LEED-ND measures to existing neighborhoods and discusses how spatial structure and scale can influence LEED-ND certification.

Methods: The Eastown neighborhood of Grand Rapids, Michigan, was used to test the current LEED-ND standards. Using GIS, the physical and social characteristics of a study area within Eastown were documented and compared to the guidelines established in the LEED-ND rating system. Upon completion, we evaluated the potential use of these procedures for other existing neighborhoods.

Results and Conclusions: This research demonstrates that application of LEED-ND standards to existing neighborhoods will require comparative analysis of many neighborhoods. We also conclude that spatial scale and structure of neighborhood design can have a significant influence on LEED-ND certification. Finally, we argue that GIS should be more directly incorporated into future versions of LEED-ND, especially those involving existing neighborhoods.

Takeaway for practice: The LEED-ND certification process provides a unique opportunity for communities and neighborhoods to assess the sustainability of their existing contexts. The review process, using GIS, not only provides a visual review of how a community compares to the standards, but also can be used as a planning tool for managing the growth of a community and achieving sustainability.

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Keywords: USGBC, LEED-ND rating system, GIS, sustainable development, planning support system.

Introduction

The United States Green Building Council (USGBC), the Congress for New Urbanism and the Natural Resource Defense Council collaborated recently to draft the Leadership in Energy and Environmental Design for Neighborhood Development (LEED-ND) asserting that urban design, land use and the environment must function as one piece within neighborhoods (USGBC, 2009a). LEED-ND focuses on "…the design and construction elements that bring buildings together into a neighborhood, and relate the neighborhood to its larger region and landscape (USGBC, 2007, p.1)." New urbanism clearly influenced the LEED-ND Rating System emphasizing priorities, such as sense of community, transit-oriented development, mixed land-use and infill development to revitalize cities. Neighborhood certification design elements include: location, density, conservation of wetlands and agricultural lands, reduced automobile dependence, proximity to housing and jobs, walkability, and energy efficiency. While the standards for a single building can be based on a set of structural components, neighborhoods are more complicated and introduce spatial dynamics to LEED certification. New design is the focus of the current LEED-ND guidelines, but study is underway to adapt LEED-ND to existing neighborhoods, which presents an additional challenge.

We believe Geographic Information Systems (GIS) can be used to study neighborhood spatial relationships in order to better evaluate the existing rating system. We also believe that testing the LEED-ND criteria within an existing neighborhood, again using GIS, will help identify what attributes and features can be refined for future attempts to adopt LEED-ND to existing neighborhoods.

To study these topics we focused our research on the neighborhood of Eastown, located in Grand Rapids, Michigan, a recognized leader in sustainable planning processes and governance (Gamber, 2007). The project study site is comprised of the core commercial district and adjacent residential area (approximately 11.6 acres). Bringing the benefits of LEED to neighborhoods where people already live, work, and play is a key goal of this initiative, and one that has not been widely explored thus far in the LEED-ND program.

History of LEED-ND

In 1993, the United States Green Building Council (USGBC) was founded to expand sustainable building design practices and education (USGBC, 2009c). The Leadership in Energy and Environmental Design (LEED) Green Building Rating System was originally written for new building construction. It now includes credit rating systems for both new and existing commercial buildings, commercial interiors, single-family homes and schools. Recently, USGBC recognized a need to expand the rating system beyond individual buildings, and thus initiated the LEED-ND pilot study. Two hundred and thirty eight (238) registered projects in thirty-nine (39) states were evaluated and the 1st Public Comment Draft of LEED-ND was released in October, 2008. LEED-ND incorporates the principles of smart growth that limit the environmental impacts of urban sprawl and provide transportation alternatives to promote communities that are physically connected (USGBC, 2009b). Greatly influenced by new urbanism, LEED-ND was transferable to new neighborhood plans, but it was unclear if the criteria being developed for LEED-ND were well-suited for existing neighborhoods. Existing neighborhoods can't necessarily be judged by the same standard, nor should they be if indeed they inherit more physical restrictions and attract different types of community support. Over 5,000 public comments were received during the second response and revision period followed by release of the 2nd Public Comment Draft of LEED-ND in May, 2009. This time USGBC included the statement that, "…while the LEED-ND rating system can help guide improvements and infill development within an existing neighborhood, *the rating system was also not designed* *for existing neighborhoods*. An adaptation of LEED-ND in the future to better responds to the design of social and infrastructure improvements and operations of existing neighborhoods is likely (USGBC, 2009c, p.3, emphasis added)." Our project applied the criteria established in the second release of the rating system, using GIS to assess LEED-ND for existing neighborhoods. We believe that such an approach will not only demonstrate the utility of GIS for LEED-ND certification, but also analyze the inherently spatial dynamics of applying LEED-ND to new neighborhoods and identify the specific challenges in adapting LEED-ND to existing neighborhoods.

The Current LEED-ND Rating System

The rating system has three categories of prerequisites and credits and two categories for bonus credits. Projects must meet all prerequisites to be certified, while credits are optional. Each credit, however, contributes to necessary project point totals for obtaining certification.

The three core categories are:

1. *Smart Location and Linkage (SLL)* – Prerequisites and credits for neighborhoods that minimize adverse environmental impacts and avoid urban sprawl.
2. *Neighborhood Pattern and Design (NPD)* – Prerequisites and credits for compact, mixed-use neighborhoods with connections to surrounding communities.
3. *Green Infrastructure and Buildings (GIB)* - Prerequisites and credits for reducing the environmental impacts of buildings and infrastructure.

The two bonus categories are:

4. *Innovation and Design Process (IDP)* - Credits awarded for exceptional performance above the requirements or innovative performance not addressed by the rating system.
5. *Regional Priority Credits (RP)* – Credits awarded for projects located within areas identified by USGBC as being "regionally important."

Each prerequisite or credit begins with a brief description of the *intent* of the credit. The intent is followed by a description of the *requirements* for each credit. The requirements section often contains and/or statements and indicates the number of points awarded for each credit. A brief glossary of important terms and simple graphics are provided to help users interpret the criteria. Projects qualify as Certified, Silver, Gold or Platinum LEED-ND according to their level of compliance with the rating system (USGBC, 2009d).

GIS and Planning Support Systems

The LEED Rating Systems released to date require an object-oriented analysis of a project. Buildings are objects and the criteria for them can be measured based on the components of the building and site itself. LEED-ND, however, introduces spatial relationships to the criteria. LEED-ND criteria based on transportation systems, land use, utility infrastructure, natural environmental features and connectivity are all geographic components of neighbourhoods. We believe that these criteria are best suited for analysis using GIS. Spatial datasets can be combined to produce maps, tables or graphs that allow people to visualize the way things are or the way they could be. Measurement and analysis can be verified, monitored, and updated when new data are made available.

Another important element of GIS is that it better integrates context. Neighbhorhoods, both new and existing are elements of broader settlement systems, and GIS allows users to measure the spatial relationships of a neighborhood with its surrounding cultural and environmental context. It is also iterative and dynamic. Once a model or concept is developed for calculating a prescribed measurement within the GIS, the individual components of the neighborhood designs can be modified by the user. The model can be run again to view the revised result. Because of this, a GIS tool for LEED-ND can serve multiple purposes. The system can be developed to assist with obtaining and storing information referenced in the rating system, provide an environment for evaluating existing and proposed alternatives, and provide a sophisticated means for visual communication of results. Uniquely paired with LEED-ND, GIS can be used as both an analytical tool and as a planning tool.

The dynamic use of GIS, *i.e.*, as a component of Planning Support Systems (PSS), is widely documented. PSS, "…combine computer based methods and models into an integrated system that can support spatial decision making (Geertman & Stillwell, 2003, p.6)." A PSS brings together the three components of traditional decision support systems: information about existing and proposed conditions, models for analysis and visualization of results (Geertman, 2002).

The broad definition of PSS encompasses a variety of tasks and techniques. Klosterman and Pettit (2005, p.477) break down PSS by type in order to evaluate the "advantages and disadvantages of applying different kinds of tools to different tasks in different contexts." One example type of PSS uses a rule-based model determine the relative sustainability of different locations and then analyzes the impact future development will have on them. Three prominent GIS-based models fall into this category; CommunityViz, INDEX and Place^{3}S (1). All three models have been developed for use with the ESRI ArcGIS software platform and are provided as extensions to ArcView.

Even with a variety of PSS models for design and planning currently available, the widespread adoption of PSS by the professional planning community has not yet been realized (Vonk, et.al, 2005). Upon surveying one hundred PSS experts, Vonk, et.al (2005) surmises that although a great emphasis has been placed on the design side of the models, inadequate attention has been paid to the end user. Vonk, et.al (2005) identified several obstacles to the use of PSS within planning projects. The first obstacle noted is that the planning community has little understanding of the purpose of the PSS and how it is to be used. Second, there is a lack of experience among users and they are unaware of the benefits of using the PSS. Third, users find PSS difficult to incorporate into planning processes.

Combining LEED-ND with GIS could be the means through which these obstacles are circumvented, because the process of reviewing a neighborhood's level of potential sustainability will be valuable to submit a project for certification. But if certification is not submitted or achieved immediately, the tool can also be used to support an in-house review of the LEED-ND rating system and adapting it to neighborhood design. Finally, because USGBC is trying to qualify the LEED-ND rating system as an American National Standards Institute (ANSI) standard (Lambert, 2009), it is a system that can be repeatedly measured and applied, regardless of location or time. Therefore, GIS combined with LEED-ND not only offers a reliable basis for evaluating sustainability, it can also be incorporated into local planning ordinances.

In order to evaluate the benefit of combining GIS with LEED-ND, our project focuses on applying the specific criteria of the LEED-ND rating system to an existing neighborhood with limited room for expansion. The process of interpreting the extensive rating system in written form can be overwhelming. In a survey of registered LEED-ND pilot projects (Garde, 2009, p.6), respondents commented that "…the criteria used in the rating system are rigid and that the documentation required is burdensome." A GIS tool will provide communities with a better understanding of a rating system by applying it to a local and familiar project area. As a mapping and database application, GIS will allow users to see where credits are being missed and how close they are to obtaining them. The results will help the community weigh the possible outcome of pursuing LEED-ND certification and its benefits before committing to the costly application process.

The City of Grand Rapids and the Eastown Neighborhood

Grand Rapids has a well-documented interest in sustainable building practices by having the most LEED-certified buildings per capita, in the nation, including the first double-gold building. Additionally, new policy requires that all new city facilities and school buildings be built to LEED standards (West, 2008). Although Grand Rapids was not registered with USGBC as a LEED-ND pilot project, the city is supporting the USGBC West Michigan Chapter's LEED-ND Member Circle study of the rating system as it applies to the mixed-use neighborhood of Eastown (figure 1). Eastown is at the heart of the Grand Rapids sustainable planning because of its diverse population, mixed-use character, and growing number of "green" businesses. It is a highly walkable neighborhood, actively promoting a healthy lifestyle, infill development, and use of alternative transportation. Developed prior to World War II, Eastown is an historic development that follows the model of "old urbanism." The Eastown Community Association (ECA) has successfully revived Eastown with an artistic flair, and it is currently home to a vibrant population of professionals, artists and students who welcome an opportunity to integrate changes that foster community health and well-being as they plan for the future. The entire Eastown neighborhood, 385 acres in area, was originally considered as a potential study area by the Member Circle. However, it was determined that the area was too large to feasibly obtain all the necessary information to adequately review the LEED-ND criteria. An 11.6 acre mixed-use project area was selected for the study (figure 2) (USGBC WMC, 2009b). The construction of a proposed LEED certified commercial/residential apartment building served as an anchor for the study area (Grand Rapids, 2009).

Insert here Figure 1- City of Grand Rapids and Eastown.
Insert here Figure 2 - Project Area.

Methodology

To explore the practicality of developing a LEED-ND GIS tool for existing neighborhoods, we built a set of GIS procedures for the Eastown project using ESRI ArcInfo and ArcView geoprocessing tools. We selected the spatial aspects of the criteria and tested our ability to measure them based on the LEED-ND definitions and intent. In the process, we imported or created the features that were necessary to calculate measurements and map design elements. Upon completion, we evaluated the potential use of these procedures for other existing neighborhoods.

Our project reviewed the first two LEED-ND categories, Smart Location and Linkage (SLL) and Neighborhood Pattern and Design (NPD), as they are the two categories that include geographic components of the community and its relationship with the surrounding area. In his survey of LEED-ND registered pilot projects in the United States, Garde (2009, p.18) reported that, "…the rating system has placed a heavy emphasis on projects' location related characteristics," and that, "…the majority of location-related criteria were among the most utilized." Although the remaining three categories, Green Infrastructure and Buildings (GIB), Innovation and Design Process (IDP) and Regional Priority (RP), contribute to a project's sustainability, we determined that they do not contain sufficient spatial elements to require GIS analysis at this time (2).

First, the narratives of the SLL and NPD categories were converted into a matrix of credit topics along with the requirements and options for each section. Design elements, such as infrastructure, transit and connectivity, represent characteristics of the site used to describe the project. We identified the spatial features, or data, required to define and measure the design elements as shown in tables 1 and 2.

Insert here Table 1 – Data matrix of SLL.

Insert here Table 2 – Data matrix of NPD.

GIS data layers were obtained from Grand Rapids and the REGIS agency (3) for the Eastown project area. REGIS has an extensive GIS data warehouse that includes high resolution aerial photography, parcels, topography, utility infrastructure and public transit routes.

Additional data sets, such as soils, wetlands, ecological, and demographic data were acquired through Michigan Geographic Data Library (4) and federal agencies.

An ArcView file geodatabase was used to store the data layers we digitized, imported or processed for use in this project. The geographic extent required for each layer is defined by its use in the LEED-ND criteria as a distance from either the project perimeter or project geographic center. For example, the feature class "*project site*" includes the variety of ways in which the study area is described within the SLL and NPD standards (figure 3).

Insert here – Figure 3 Project site definitions.

The first prerequisite, SLL P1: Smart Location, illustrates the spatial complexity of LEED-ND and the challenges to applying the rating system to existing neighborhoods. It includes several "and/or" statements. The project must be in an existing or proposed water/sewer service area *and* it must meet the requirements for infill site *or* connectivity *or* transit corridor *or* neighborhood assets. Submittal requirements vary from basic maps of existing utility services to more sophisticated maps that demonstrate that a site meets a host of geospatial conditions. Fortunately, many of the design elements evaluated in this first prerequisite are used repeatedly in the remaining prerequisites and credits. The GIS user will reap the rewards of adhering to a data processing method and storage structure that allows them to access design elements throughout the remainder of the analysis.

The Eastown project provided a valuable exercise in working through a GIS analysis using the typical data layers and spatial characteristics of a traditional neighborhood. Based on this experience, a preliminary LEED-ND GIS Toolkit Workflow was drafted and is shown in figure 4. The proposed GIS Toolkit would assist users in evaluating projects based on the intent of LEED-ND and preparing the submittals required to attain credit.

Insert here Figure 4 - GIS Tool Workflow.

Project Results

While developing the GIS based LEED-ND tool and applying this tool to an existing neighborhood, we identified two key observations. First, and perhaps most importantly, existing neighborhoods exhibit unique challenges for future attempts to adapt LEED-ND within existing neighborhoods. Conversely, we believe that identifying how to adapt new design standards to existing neighborhoods is the most important next step for LEED-ND. Second, we observed some uniquely spatial challenges when adapting the LEED-ND criteria to geospatial datasets. Whether it is data quality or measurement standards, scale or spatial structure, the newly introduced spatial elements of LEED-ND will likely require criteria refinement and monitoring. We organized our specific observations three categories: design parameters of existing neighborhoods vs. new/infill developments, scope and scale selected for the project area, and availability of consistent data resources used to measure credits**.**

Existing neighborhoods differ from new/infill neighborhood design.

An urban infill site is a proposed redevelopment project, removing much of the existing structures to allow for a new design within a specific project site. The project boundary for an existing neighborhood can be flexible within a community, but its boundary will be restricted by existing structures. Existing neighborhoods, however, do not always have such firm physical boundaries. They also contain many smaller parcels with a mix of uses. Infill development contains well defined boundaries and may only have a few larger parcels. Simply, the physical location of structures and streets within an existing neighborhood cannot be easily influenced by planners in this “as-built” site plan. For example, houses with porches, decks and auxiliary structures, are not always placed in alignment and exist independently of what lies nearby. Digitizing building footprints from high-resolution aerial photography will not provide the total square footage of the building or identify the type of use. This can be done easily in the planning and design stage of the infill project, but how do we accomplish this without a complete door to door survey in an existing neighborhood?

The architecture represented may be typical of a historic time period, but individual modifications made over time often make it incompatible with a prepackaged set of measurement procedures. For example, **NPD Prerequisite 1- Walkable Streets** (USGBC, 2007, p. 37) requires a building-height-to-street-width ratio. The width of the street is defined as the distance from building façade to façade. The measurement becomes tedious when nearly every building has a unique set back distance. In the pilot study area, Hurd Street has a right of way width of 25 feet yet it is not considered to be an alley because it provides primary access with sidewalks to the front of houses on the south side of the street (figure 5). The north side of Hurd Street does not have a sidewalk. It provides back lot access only to homes on the north side of street. Therefore, the building-height-to-width ratio should be determined using only the south side of Hurd Street and remove the north side from building frontage. The rating system allows this interpretation for bordering streets, but does not currently accommodate it within the project site. A new infill site design could be modified to attain the credit whereas changes to an existing site would be much more difficult.

Insert here Figure 5- Residential units front on south side of Hurd Street.

Scope and scale of the project area

LEED-ND relies heavily on an established project boundary to measure the criteria of the rating system. Many of the criteria focus on elements that surround the site rather than the current development within an existing site. Several analysis area definitions are used throughout the rating system based on the intent of the criteria. Analysis areas include the project site perimeter, border parcels, parcels adjacent to border parcels, area within specified buffer distance of border, walking distance from project site geographic center and walking distance from dwelling units within the site.

GIS can be used to document and store these defined areas and can also be used to run scenarios for criteria using modified distances or definitions. Results would reveal the effect the analysis area, or scale, has on a project. **NPD Credit 3 Mixed-Use Neighborhood Centers** (USGBC, 2007, p. 49) includes criteria for locating 50% of dwelling units within one quarter mile walk of diverse uses whereas **NPD Credit 13 Local Food Production** (USGBC, 2007, p. 68) includes criteria for a community garden or farmer's market located within one half mile walk distance of the project geographic center shown in figure 6. The geographic center of a project site does not consider the location of residential uses in a neighborhood. Interpreted as the centroid of the polygon shape that describes the project site, the centroid of an "L" shaped project may not even lie within the site. It is possible that a project could have a community garden within one half mile walk distance of its dwelling units that is not also within one half mile walk of its geographic center. If the intent of the credit is for the dwelling units to have access to the community garden, then running a scenario using only the residential component may reveal that it has achieved this goal and that the geographic center is not relevant for all projects.

How, then, does a community select the boundary for an existing neighborhood for submittal to LEED-ND when, "…what constitutes a neighborhood remains a matter of dispute

(Song & Knapp, p. 222)?" Our study area is just a piece of a larger neighborhood as defined by the neighborhood association. Project boundaries may run along streets, back lot lines, natural features or political boundaries. These jagged edges make it difficult to perform even the most basic measurements, such as the distance between access points used to measure connectivity (USGBC, 2009). In the current version of LEED-ND, it is unclear whether the measurement should be made along lot lines, as the crow flies, or only along sidewalks (see figure 7). By revealing such complexities, GIS may actually allow communities to work backward from the rating system criteria and then define project areas more likely to pass certification, but that do not representative of the actual neighborhood boundaries.

Insert here Figure 6- Distance to community garden based on project geographic center.
Insert here Figure 7- Multiple distances between access points.

Evaluation is limited by availability of resources

The availability of data resources for input into the GIS will vary by project. While larger communities commonly have a wealth of digital mapping and tabular data available for use, others will need to rely on publically available data that may not be provided in the best scale or perhaps have not been updated to present conditions. Importantly, the integrity of locally produced data sets can significantly influence the results of the analysis. Whether it is mapping existing wetlands or measuring the distance between buildings, data quality has not been addressed in the LEED-ND criteria.

SLL Prerequisite 5 Floodplain Avoidance (USGBC, 2007, p. 16), for example, refers to the location of the 100-year high or moderate risk floodplain as identified by FEMA or state or local floodplain agency. The FEMA floodplain map modernization project is currently a work in progress; some counties are ahead of others in their mapping status. Eventually, there should be full coverage for floodplain mapping throughout the country, but many locations are not yet available in a GIS format. This demonstrates the need to default to best data available at the time of certification submittal, even if the accuracy and completeness of the data layer varies based on location.

The site design may also change over time due to socioeconomic conditions. This is noticeable when identifying diverse uses in **SLL Prerequisite 1 Smart Location Option 4 Neighborhood Assets** (USGBC, 2007, p. 3) and employment centers in **SLL Credit 5 Housing**

and Jobs Proximity (USGBC, 2007, p. 29). The project owner or planner does not control the future of a diverse use, such as a grocery store or school, yet the location and type of use is critical to the analysis of the project site. The GIS analysis to identify uses that currently meet criteria can be reversed to identify potential replacements if assets are lost. If a grocery store or employment center closes, the tool can be used to identify the locations within the one-quarter mile walking distance of the project that would make good candidates for replacing this required asset.

Conclusion

LEED-ND establishes criteria for evaluating the level of sustainability for neighborhood design. We have argued that a GIS tool based on these standards provides a way to not only measure the design elements of project sites and compare the results to LEED-ND standards, but also provides an opportunity for improving the criteria. The interactive nature of GIS allows the user to make adjustments to design input, run scenarios to view the output and initiate the discussion of planning goals that will direct a community toward a path of greater sustainability. Used this way, the GIS tool becomes more than a tool to evaluate existing conditions; it becomes a tool for looking ahead and managing the growth of a community. The existing neighborhood within a larger community is not a blank slate and does not necessarily have a definitive boundary. Planners are required to work within an existing framework, implementing change that will enhance and grow the community while accommodating inherited design elements.

LEED-ND uses the principles of new urbanism and smart growth to evaluate and recognize green communities. However, the certification process can strain the limited resources available to smaller, existing communities. Recognition for a neighborhood's efforts to become green is well-deserved, but the real value comes from actually living it. Whether or not the community decides to pursue full certification with LEED-ND, conducting the review process using GIS will provide a visual review of how their community compares to the proposed standards. The tool will not accommodate all project scenarios, especially given the unique characteristics of existing neighborhoods. It will require a knowledgeable user who is open to interpretation of the standard and willing to provide rationale for the data sets used and created for a particular project. The results can then be used to guide and support planning efforts toward more sustainable design.

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Notes

(1) Additional information on these models can be found on their websites.

CommunityViz: http://www.communityviz.com

INDEX: http://www.crit.com

Places^{3}S: http://www.energy.ca.gov/places

(2) While these categories do not contain sufficient spatial elements presently, we believe there are spatial elements that should be evaluated in future research.

(3) Base data used for all figures was provided by the REGIS agency of the Grand Valley Metropolitan Council, http://www.gvmc-regis.org . © 2004 REGIS All Rights Reserved. Maps do not represent a legal document. They are intended to serve as an aid in graphic representation only. Information shown on maps is not warranted for accuracy and should be verified through other means. Any duplication is restricted under copyright laws and the Enhanced Access to Public Records Act, PA 462 of 1996, as amended.

(4) The Michigan Geographic Data Library serves as the state's repository of digital geographic information. It is maintained by the Michigan Department of Information Technology Center for Shared Solutions & Technology Partnerships, http://www.michigan.gov/cgi .

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Table 1. Smart Linkage and Location (SLL) Conversion of Rating System Narrative to Data Matrix.
Design elements represent the characteristics of the site used to describe the project.
Design elements are comprised of spatial features that are used to define and measure the design element.
"X" indicates that the spatial feature is required to analyze the prerequisite or credit.

		PREREQUISITE					CREDIT								
Design Element	**Spatial Feature**	**P1**	**P2**	**P3**	**P4**	**P5**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**
Study Area	perimeter	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	streets	X	X	X	X	X	X	X	X	X		X	X	X	X
	buildings	X		X	X					X	X	X		X	X
	project site parcels	X		X	X	X	X								
	right of way	X			X										
	geographic center										X				
Infrastructure	existing water	X													
	existing sewer	X													
	water service area	X													
	wastewater service area	X													
Infill Site	border parcels	X			X	X	X				X				
	adjacent parcels	X			X	X	X				X				
	adjacent intersections	X			X	X	X				X				
	waterfront other than stream	X			X	X	X				X				
Connectivity	border parcels	X					X								
	project site intersections	X					X								
	adjacent intersections	X					X								
	border streets	X					X								
	non motorized ROW	X					X								
Transit Corridor	bus stops	X			X				X		X				
	streetcar stop	X			X				X		X				
	bus rapid stop	X			X				X		X				
	rail station	X			X				X		X				
	ferry terminal	X			X				X		X				
	building entrance	X			X				X						
Neighborhood Assets	diverse uses-shops/services	X								X					
Imperiled Species/ Ecology	natural features inventory		X										X		
	biological field survey		X										X		
	habitat buffer		X										X		X
	conservation easement		X										X	X	X
Wetland/Water Conservation	wetlands			X									X	X	
	water bodies			X									X	X	
	ecological impairments			X									X		
	bicycle/pedestrian pathway			X											
	topography			X											
	clearings			X											
	tree removal			X											
	brownfields			X											
	minimal impact structures			X											
Agricultural Lands	preservation district				X										
	soils				X										
	transfer development rights				X										
	mitigated prime soil sites				X										
	buildable land				X										
Floodplain	floodplain					X									
Preferred Location	high priority location						X	X							
Brownfield Redevelopment	brownfileds							X							
Reduced Auto Dependence	transportation analysis zone								X						
Bicycle Network	bike paths									X					

Table 2. Neighborhood Pattern and Design (NPD) Conversion of Rating System Narrative to Data Matrix
Design elements represent the characteristics of the site used to describe the project.
Design elements are comprised of spatial features that are used to define and measure the design element.
"X" indicates that the spatial feature is required to analyze the prerequisite or credit.

		PREREQ			**CREDIT**														
		P1	**P2**	**P3**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**
Design Element	**Spatial Feature**																		
Study Area	perimeter	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	streets	X	X	X						X								X	
	buildings	X	X		X	X	X	X	X			X		X	X		X		X
	project site parcels		X		X	X													
	right of way	X	X	X	X					X					X				
	geographic center																X		
Walkable Streets	public spaces	X		X									X	X					
	sidewalks	X			X							X						X	X
	building entrance				X								X	X					
	parking				X				X										
	street curbs				X														
Transit Corridor	bus stops		X				X				X	X							
	streetcar stop		X				X												
	bus rapid stop		X				X												
	rail station		X				X												
	ferry terminal		X				X												
	building entrance		X				X												
Open Community	slope			X															
	waterbodies			X															
	wetlands			X															
Neighborhood Assets	diverse uses						X										X		X
Street Network	bicycle/pedestrian pathway									X									X

Figure 1- City of Grand Rapids and Eastown

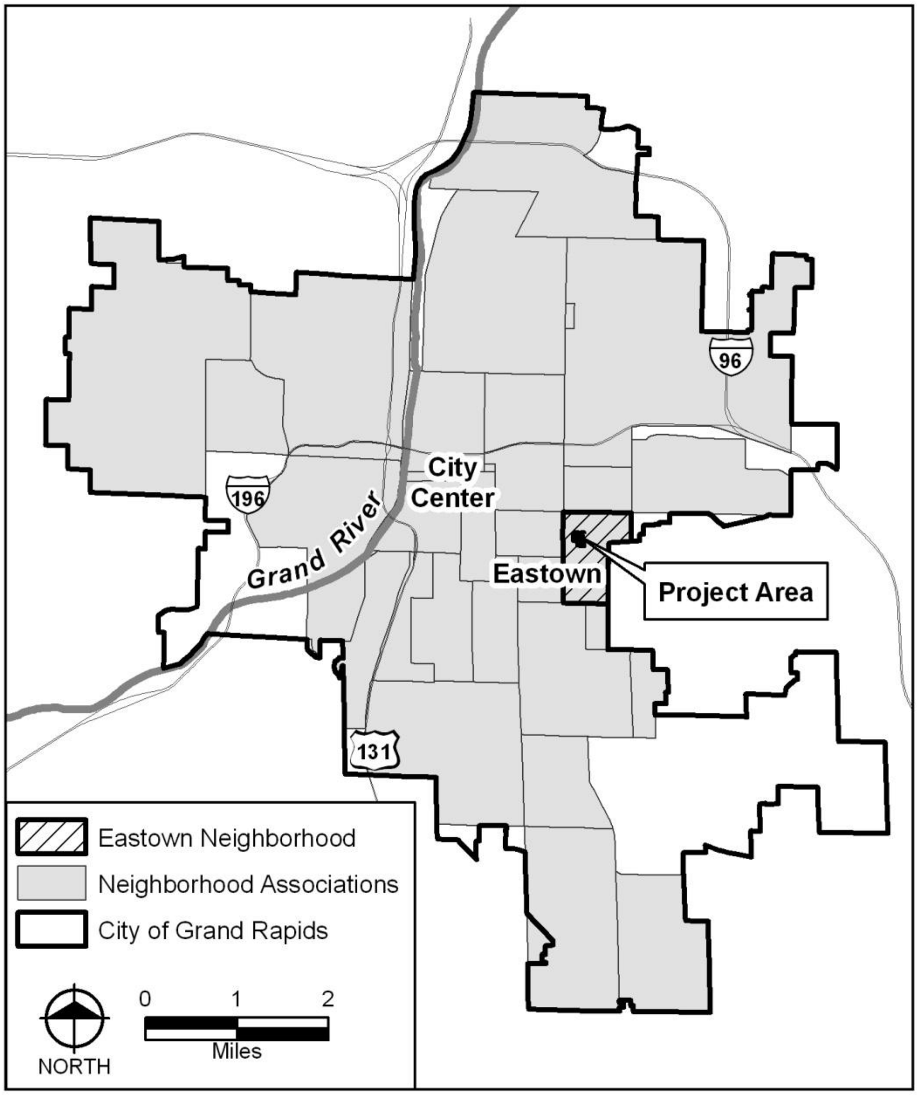

Figure 2- Project Area

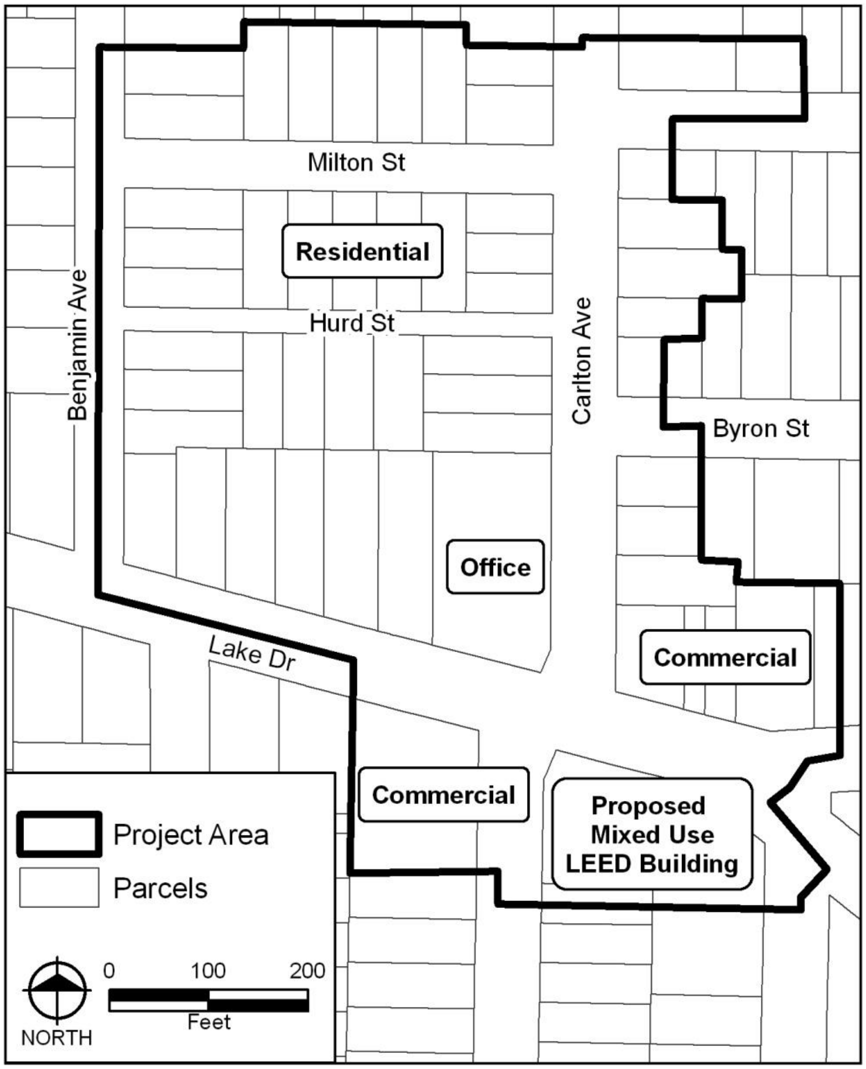

Figure 3- Project site definitions.

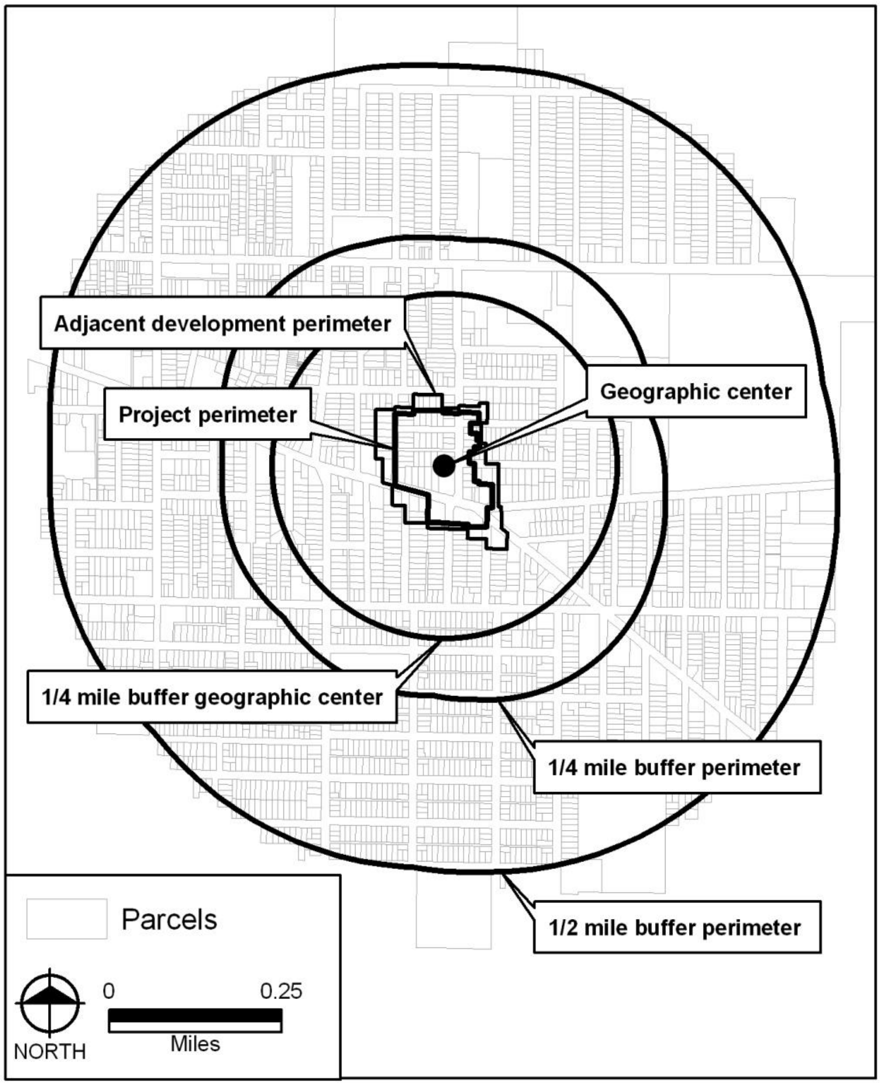

Figure 4- GIS toolkit workflow.

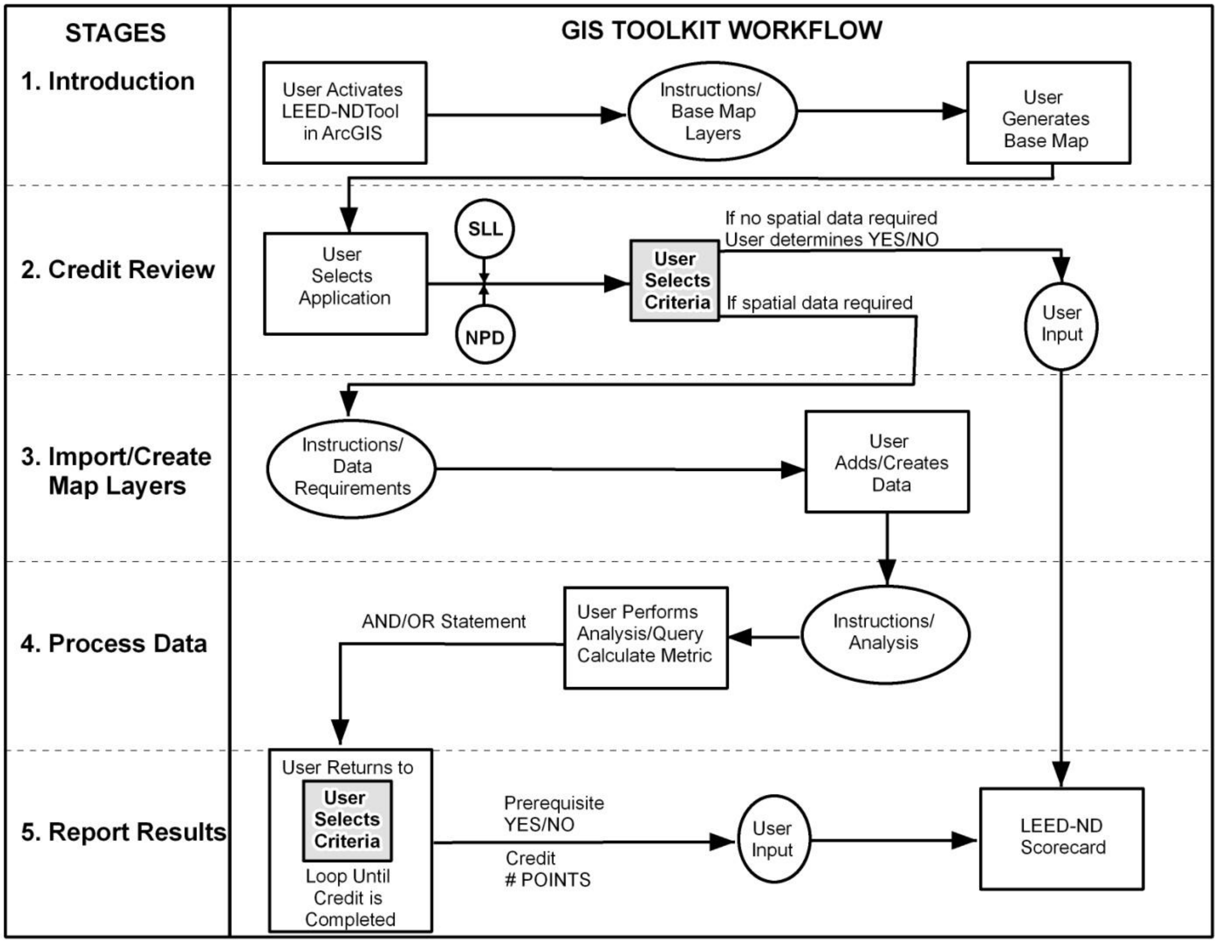

Figure 5- Residential units front on the south side of Hurd Street. Site design of existing neighborhood cannot be easily changed.

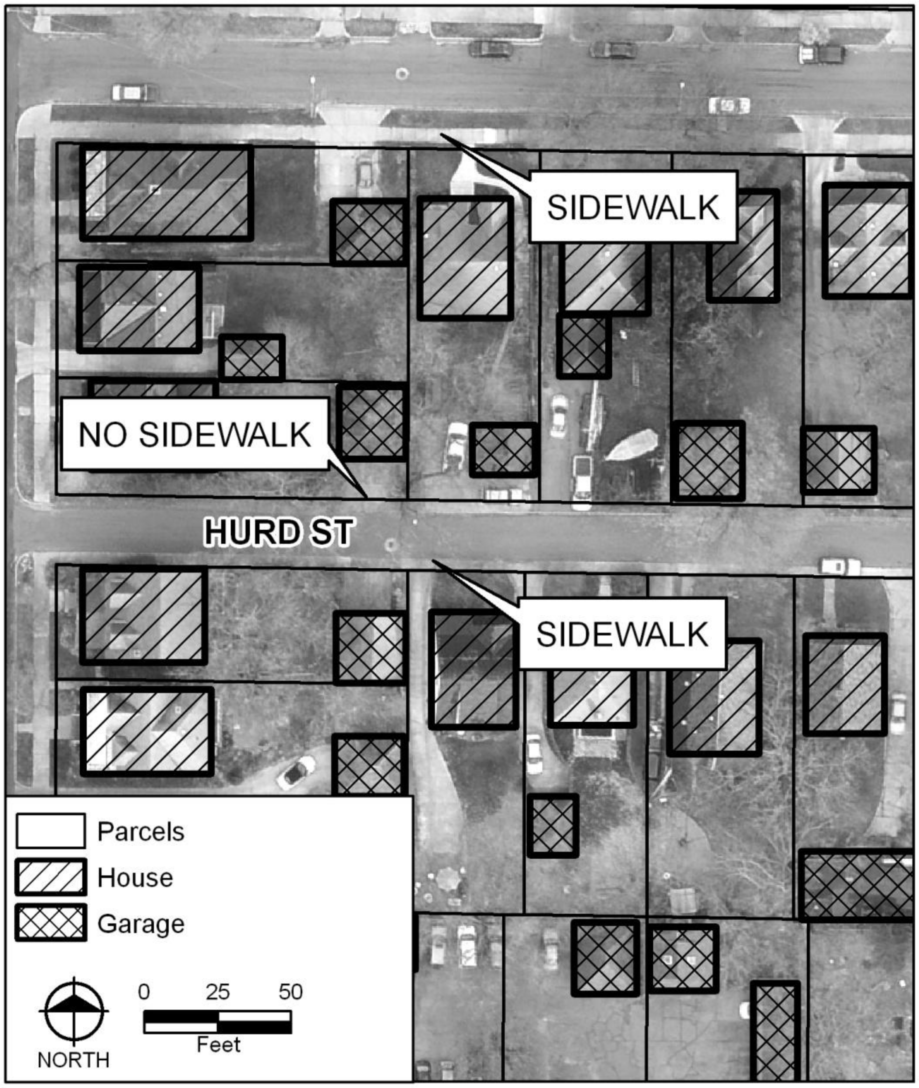

Figure 6- Distance to community garden based on project geographic center. Residential units are mostly located in north half of project area.

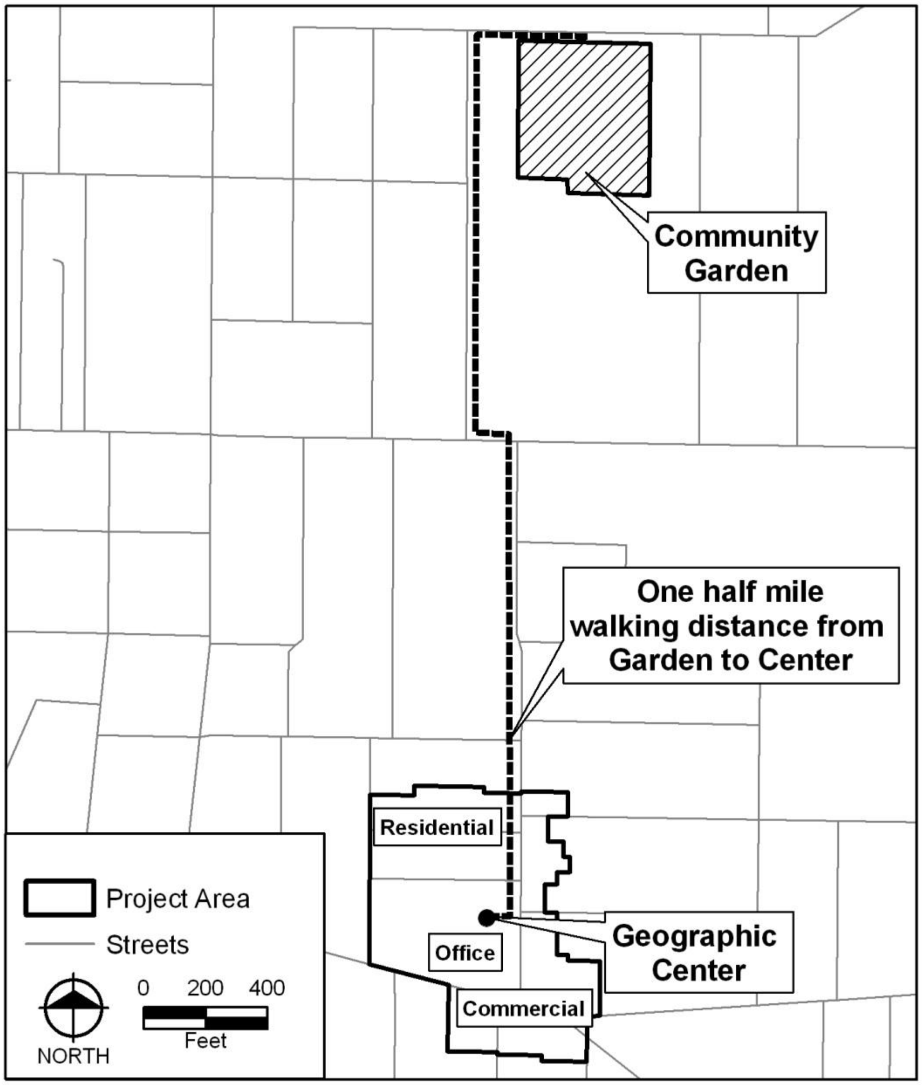

Figure 7- Multiple distances between access points.