398: Reconciling Housing Density and Housing Diversity in Inner Ring Neighbourhoods

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Abstract

Density plays a complex role in the sustainability of a neighbourhood. For example, higher densities place larger numbers of residents within walking or biking distance of amenities such as stores, parks, or transit stops; allowing for less motor-dependent lifestyles. Conversely, higher densities tend to both limit access to useful solar gain and increase urban heat island effect. Thus, determining "optimal" neighbourhood density involves weighing multiple density-dependent factors against each other in order to understand their relative impacts. In order to be useful to policy makers and designers, it is necessary for such an analysis to provide information in a manner that is easily digestible, allowing for the testing of density propositions through the lens of unequal and sometimes contradictory effects.

Using an American inner ring neighbourhood as its context, this study uses geographic information visualization (GIV) software to analyze and reconcile two density-dependent aspects of urban sustainability, housing density and housing diversity. The relationship between these two factors is played against a third, walking distance to a transit stop. It is proposed that GIV, with its ability to convert quantitative information into images and drive visual analysis, is an effective tool for assessing current conditions, suggesting beneficial interventions, and measuring the effectiveness of these proposals with respect to the to these indirectly linked variables.

Keywords: housing, neighbourhoods, density, diversity, visualization

1. Introduction

Many American cities are ringed by underutilized neighborhoods that were once thriving communities intimately linked with the center city, but which have seen decades of indifference and decline as citizens and policy makers tended to favor car-dependent development on the fringes of the city. Due to their genesis as streetcar suburbs, these neighborhoods possess many characteristics that make them strong candidates for reinhabitation as contemporary green neighbourhoods – proximity to the amenities of the center city, commercial streets that connect and organize nearby residential districts, and an existing building stock and infrastructure that represents a sizeable investment of civic resources [1].

While environmental concerns, unsound lending practices, and steadily rising fuel prices have begun to put strains on the suburban development model, American cultural preferences are simultaneously swinging back toward the center city and its surrounding neighbourhoods [2]. Yet, the most advantageous method of resettling these neighbourhoods is far from clear. Central to this lack of clarity are questions surrounding the issue of density. It would seem that density has a relationship with the overall sustainability of a neighbourhood that is not linear. Furthermore, density itself is related to many density-dependent factors of sustainability in complex and sometimes contradictory ways. For example, lower neighborhood densities might allow for more direct stormwater absorption, better solar access for individual buildings and public spaces, and greater opportunities for natural ventilation, while higher densities might lead to more efficient building forms for heating and reduced transportation energy as walking, biking, and public transport become more viable options [3]. If the inner ring neighborhood is to play its fullest role in the greening of the American city (surely one of the keys to realizing the developed world's responsibilities with respect to sustainability) then built solutions must be developed that maximize as many of the factors as is possible while maintaining some continuity of character [4].

Fig 1. Aerial photograph of North Knoxville, Tennessee, indicating a typical gain and scale of an American inner ring neighbourhood –single family homes punctuated by multifamily, commercial, and civic buildings.

Such complex interplay of environmental and urban design issues can leave even a well informed, well intentioned designer or policy maker unsure as to the best decision with regard to neighbhourhood sustainability. A comprehensive analysis seeking to discern an optimal neighbourhood density by weighing numerous aspects of sustainability against one another is fraught with a myriad of difficulties; not the least of which is settling on a common unit of measure by which issues as divergent as storm water absorption and potential for useful passive heat gain might be compared. Such an analysis, while its ultimate goal, is beyond the current scope of this study. Yet, by examining two related but somewhat divergent aspects of neighbourhood sustainability, housing density and housing diversity, this paper posits that visual analysis driven by Geographic Information Visualization (GIV) software offers an effective tool for understanding multiple density dependent factors of urban sustainability each of which varies with location.

2. Methodology

2.1 Study Area

This study was conducted in North Knoxville, a former streetcar neighbourhood of Knoxville, Tennessee. More specifically an area of 290.51 acres (117.57 hectares) was selected so as to coincide with a recent study by the local planning authority. The study area possesses many of the hallmarks of contemporary American inner ring neighbourhoods. Organized by significant commercial streets and close to the downtown core the area is nonetheless largely separated from the life of the city by a raised interstate highway and functioning cargo rail lines. The neighbourhood is blessed with a robust stock of historic single family housing interspersed with multifamily blocks and deployed in a walkable pattern (Figure 2). Additionally, a subarea was identified for consideration within the study area. This subarea consisted of all locations within a .10 mile walk of an existing transit stop; an area of 181.01 acres (73.25 hectares).

Fig 2. (left) Aerial photograph of the neighbourhood, (right) Diagram indicating the location of the highway system (dark gray) and rail lines (black), outlines of designated historic districts, primary commercial streets, and the limits of the study area (light gray)

2.1 Metrics

Within the study area and the transit subarea, two related factors were considered – housing density and housing diversity. These aspects of neighborhood sustainability were selected for their close but indirect relationship. (Increasing housing density within a given area might easily either increase or decrease housing diversity within the same range. Conversely, as long as no existing housing is removed increasing housing diversity will always result in a related increase in density.) The study assumes that no existing housing will be removed. It is envisioned that, through future investigation, this method will provide a model for the simultaneous consideration of other or more numerous density related factors of urban sustainability such as access to useful solar gain or area of impervious surfaces.

Housing density is measured as number of housing units per acre (and per hectare) within either the study area or the transit subarea.

Housing diversity is measured using a modified version of the Simpson Diversity Index (SDI) as found in United States Green Building Council's Pilot Version of the LEED™ for Neighborhood Development (LEED-ND) rating system [5]. As modified, this index divides housing into sixteen categories (Table 1).

Table 1: LEED-ND housing categories as defined for SDI calculations.

cat.	description
1	detached residential large - (greater than 1200 sq. ft.)
2	detached residential small - (less than 1200 sq. ft.)
3	duplex or townhouse - large (greater than 1200 sq. ft.)
4	duplex or townhouse - small (less than 1200 sq. ft.)
5	multifamily dwelling in a building with no elevator - large (greater than 750 sq. ft.)
6	multifamily dwelling in a building with no elevator - small (less than 750 sq. ft.)
7	multifamily dwelling in a building with elevator four stories or fewer - large (greater than 750 sq. ft.)
8	multifamily dwelling in a building with elevator four stories or fewer - small (less than 750 sq. ft.)
9	multifamily dwelling in a building with elevator more than four stories and fewer than nine stories - large (greater than 750 sq. ft.)
10	multifamily dwelling in a building with more than four stories and fewer than nine stories – small (less than 750 sq. ft.)
11	multifamily dwelling in a building with elevator nine stories or more - large (greater than 750 sq. ft.)
12	Multifamily dwelling in a building with nine stories or more - small (less than 750 sq. ft.)
13	live/work large (greater than 1200 sq. ft.)
14	live/work small (less than 1200 sq. ft.)
15	accessory unit – large (greater than 1200 sq. ft.)
16	accessory unit – small (less than 1200 sq. ft.)

SDI is then calculated according to the expression:

$$(1 - \Sigma (n/N)^2) / ((M-1)/M)$$

Where n = the total number of dwellings in a single housing category, N = the total number of dwellings in all housing categories, and M = the number of housing categories represented. This normalized expression yields values ranging from 0 to 1. LEED-ND awards three points for values ≥ .7, two points for values ≥ .6, and one point for values ≥ .5.

2.2 Analysis

The study began with an inventory of all existing housing units within the study area. This inventory was compiled using both direct observation and publicly available data including aerial photographs, databases, and maps. Each existing housing unit was categorized according to the designations established by the LEED-ND criteria for calculating SDI (Table 2).

Table 2: Existing housing units, (total) number of units within the study area, (transit) number of units within the transit subarea.

housing category	total	transit
1	309	182
2	26	19
3	54	20
4	14	10
5	146	104
6	120	76
10	252	252
16	1	1
TOTALS	922	664

This initial cataloguing revealed a housing density for the entire study area of 3.1737 units / acre (7.8421 units / hectare) and a housing density for the transit subarea of 3.6683 units / acre (9.0648 units / hectare). It should be noted that these densities fall well below those generally considered necessary to support a convenient transit system or significant neighbourhood amenities. By way of comparison, the LEED-ND credit relating to density does not begin to award points until a density of 10 units / acre (24.7105 units / hectare) has been achieved and tops out at seven points for densities ≥ 70 units / acre (172.9738 units / hectare). Initial consideration of the housing data in tabular form also revealed a concentration of large single family homes while several of the multifamily housing categories are not represented in the study area.

2.3 Geographic Information Visualization

CartaVista™ geographic information visualization (GIV) software was used in order to gain a more complex understanding of the geospatial distribution of housing diversity. Using the catalogue of existing housing units to create the initial data set, the location of each housing unit was mapped and assigned a numeric value corresponding to its particular housing category designation (Figure 3).

Fig 3. Locations of existing housing units.

While even this simple mapping of locations begins to reveal certain patterns, particularly with respect to the relationship of housing units to busier commercial streets, the greater potentials of visual analysis are only unlocked through the generation of more complex images that begin to manipulate the information imbedded in the data. To this end, Ambroziak Third Dimension Technologies, developers of CartaVista™, worked to add a Simpson Diversity Index (SDI) calculation function to their software for the purposes of this investigation. This function allows investigators to overlay a grid of regularly spaced points, define a radius within which SDI is to be calculated, and generate an SDI value for each point on the grid. This study used a grid with the points spaced evenly at 250 feet and SDI for each point was calculated within a ¼ mile radius, which matches the calculation radius used in the LEED-ND rating system.

The resulting images reveal relatively high SDI values near the center of the study area with values generally declining as one moves either north or south (Figure 4). The modulation of SDI values was found to be similar in the study area and transit subarea, with the most notable difference being a very sharp decline in SDI values in the northwest corner of the transit subarea, indicating the simple device of using this walking distance as a mask for the data can significantly alter the reading; particularly in specific locations. This hints at the complexities inherent in future development of the work. The highest calculated existing SDI value for the study area was .64911 while the highest calculated existing SDI value for the transit subarea was .63947.

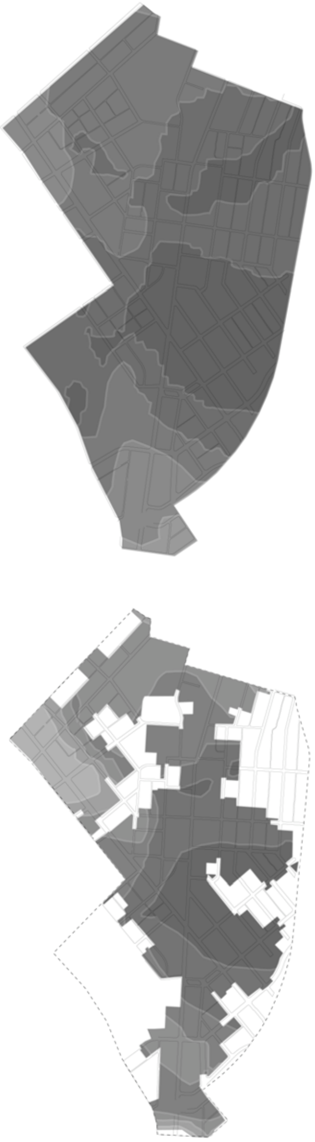

Fig 4. (left) existing SDI entire study area, (right) existing SDI transit subarea; in both images bands indicate areas of .10 SDI and the darkest areas correspond to values ≥ .60 but < .70

Both the study area and transit subarea diagrams are bisected by a swath of significant size running east/west that would receive at least one point under the LEED-ND criteria for housing diversity.

2.4 Development Response

Responding to these preliminary findings, opportunities to intervene in the neighborhood such that housing density and housing diversity would be simultaneously increased were identified. The visual analysis heavily informed this portion of the investigation. However, other concerns were taken into consideration. For instance, as there are only currently two buildings in the study area taller than four stories in height, buildings of this height were suggested sparingly. An effort was also made to remain sympathetic to the existing and traditional patterns of the neighbourhood. For example, housing was not placed on the ground floor along busy commercial streets while on residential streets an effort was made to match the massing of adjacent buildings even if the proposed additions contained housing types that varied from their neighbours. Existing buildings that are either unused or underutilized were also considered for conversion to housing. No wholesale changes were suggested (such as placing an accessory unit behind every single family home.) Rather, opportunities inherent in the existing fabric were considered alongside the deficiencies suggested by the SDI analysis. By using the visual information in conjunction with more subjective concerns to guide the response, it is hoped that this study provides a more accurate model of how GIV analysis might be used by designers and/or policy makers within a complex context.

Within these guidelines, the southern portion of the study area – where there are typically larger contiguous undeveloped lots and where there are far fewer existing small scale structures to which new construction might relate - presented greater opportunity for large scale developments. Meanwhile, response in the northern portion of the study area relied more heavily on strategic use of smaller infill sites. In both the north and the south an effort was made to identify development opportunities fronting the major commercial streets. Such opportunities are seen as serving the urban design purpose of helping to create the street wall along these important arteries while also providing housing that is almost inevitably within walking distance of a transit stop. This design process informed by both the cumulative knowledge and abilities of the design team and the newly generated visual data yielded several effective housing typologies (Figure 5).

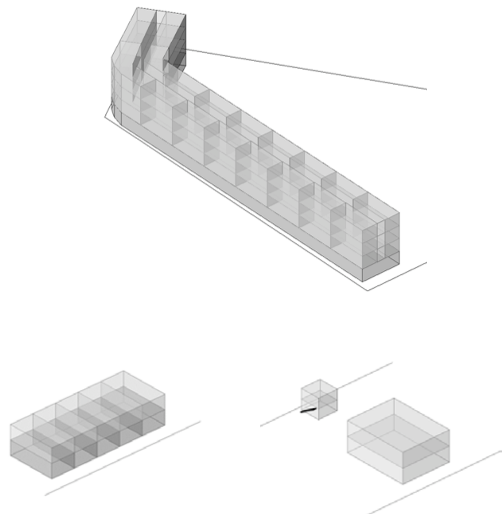

Fig 5. selected housing typologies: (above) multifamily building with three levels of small housing units over ground level commercial spaces, (below left) large live/work units, (below right) small stacked duplex units with an accessory unit on the alley configured to fit into predominantly single family streets.

2.5 Reanalysis

Following the identification of promising infill locations and the development of appropriate housing typologies an inventory of the units in the study area and the transit subarea reveals the impact of this strategy on both housing density and housing type distribution. (Table 3)

Table 3: Revised housing units, (total) number of units within the study area, (transit) number of units within the transit subarea.

housing category	total	transit
1	315	187
2	26	19
3	143	109
4	50	38
5	194	152
6	172	128
8	57	57
9	42	42
10	252	252
13	12	12
16	17	13
TOTALS	1280	1009

This cataloguing of the revised condition reveals a housing density for the entire study area of 4.4060 units / acre (10.8871 units / hectare) and a housing density for the transit subarea of 5.5743 units / acre (13.7747 units / hectare). The density in the entire study area was increased by 38.8% while the density in the transit subarea was increased by 52%. While these represent sizable increases in density, possibilities for additional development in the study area are by no means exhausted in this example. Significant additional density could still be added within a respectful approach to the existing fabric.

Additionally, the GIV model was updated in order to evaluate the simultaneous effectiveness of this development strategy with respect to housing diversity (Figure 6). Again, visual analysis allows for efficient digestion of a complex set of data. The revised images reveal a marked increase in diversity. Under the revised scenario nearly all of the study area would be awarded at least 2 points for housing diversity under the LEED-ND criteria while nearly half of the study area would receive 3 points, the highest amount awarded under this credit. The same is true for the transit subarea. The highest calculated revised SDI value for both the study area and the transit subarea was .76598. (At an SDI ≥ .8 a design team using the LEED rating system could make a claim of "exemplary performance" on this credit and seek an additional point in the "Innovation & Design Process" category.)

Notable is the complete elimination of the diversity "valley" in the northwest corner of the study area. This area was identified as having particular need during the analysis phase of the study. Accordingly, the design team devised a diverse set of housing strategies targeted to the existing local conditions in this area. This called for additional analysis of the data to understand which types of housing were predominant in the area along with particular attention to the possibilities for adaptive reuse of unused existing buildings along the commercial corridor. Both efforts were instigated and directed by a reading of the visual information.

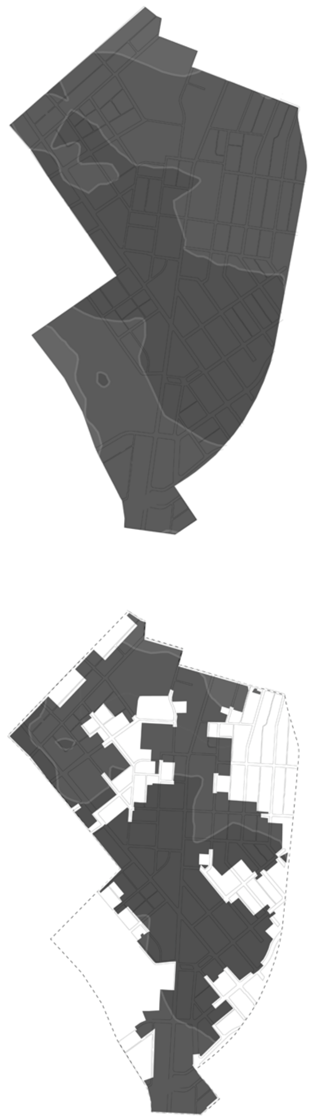

Fig 6. (above) revised SDI entire study area, (below) revised SDI transit subarea; in both images bands indicate areas of .10 SDI and the darkest areas correspond to values ≥ .70 but < .80

3. Conclusion

This study proposes a model for the use of visual analysis as a diagnostic tool to reconcile related but sometimes contradictory aspects of urban sustainability, each of which varies with location. As such, the use of visual analysis is intended to be suggestive rather than determinate – feeding a new layer of information into the design process. Ideally, this would in turn inform an iterative investigation that would allow designers and/or policy makers to explore through visual means the impacts of their decisions on the complex urban environment.

While this study dealt only with the relationship of two variables (housing density and housing diversity) overlaid with a third (walking distance to a transit stop) future investigations should focus on using visual analysis to reconcile multiple aspects of urban sustainability linked to density. Possibilities for future investigation of density related issues include – configuring neighbourhoods for beneficial solar interaction [6], locating optimal spaces for agricultural production imbedded in urban neighbourhoods [7], and increasing density while simultaneously protecting areas vital for the maintenance of hydrological health [8]. As previously stated, a critical hurdle to representing such polyvariable information in graphic form is the identification of some common unit of measure with which to ground this future investigation.

4. Acknowledgements

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