Suburban change: A time series approach to measuring form and spatial configuration

George D. Hallowell
College of Design
North Carolina State University, USA

Perver K. Baran
College of Design, College of Natural Resources
North Carolina State University, USA

Pages: 74-91
Suburban change: A time series approach to measuring form and spatial configuration

George D. Hallowell  
College of Design  
North Carolina State University, USA

Perver K. Baran  
College of Design, College of Natural Resources  
North Carolina State University, USA

With few exceptions, the field of suburban studies has largely ignored the question of what happens to a suburb after initial development, and efforts toward this end are often hampered by limited techniques for the direct measurement of built form and space over time. Historic data sources and computational advancements are prevailing against some of these limitations, but there remains a need for techniques to gather and process formal and spatial suburban data: not merely in the aggregate, but also in detailed patterns within a study area. Given the permanence of spatial and formal configurations in our cities, it is essential to develop the tools to better understand and predict future patterns of growth and change. In this study, a method for examining the relationship between long-term changes in built form and predictive characteristics such as global integration and block size is developed and explored. Conzenian morphology and space syntax approaches are integrated within a geographic information system (GIS) framework, and used to study an historic first-ring suburb in Raleigh, NC at four points in time over a 96-year span. Aerial images, historic road and insurance maps, and GIS sources are used to generate spatial configuration and building data for each study time period. These data are then processed and analysed to identify statistical and map-pattern morphological and syntactic relationships. It is concluded that the resulting database is capable of identifying and successfully investigating relationships between predictor and outcome variables such as global integration and building demolitions – both in the aggregate and in bivariate patterns. Further, this methodological approach should provide a rich set of prediction tools for urban designers and planners.

1. Introduction and purpose
The pattern of persistence and stability in older North American cities can be jarringly different between neighbourhoods, even within the same urban area. Often it is ‘first-ring’ suburbs that most reflect economic fluctuations, moving between residential, mixed-use, commercial and industrial uses, and sometimes blight and abandonment. While some of these communities have experienced a downward spiral, other similar neighbourhoods have survived as stable islands near the city core, emerging relatively unscathed through waves of urban expansion, diminution and gentrification. What are the physical factors that may have helped some neighbourhoods to survive and even thrive, and do these characteristics differ from other nearby first-ring suburbs that have experienced rapid change, decline, or even abandonment? It has been noted that although the origins, compositions, and cyclical nature of America’s suburbs have been well researched, little effort has been exerted to understand the process of change within neighbourhoods over time (McManus and Ethington, 2007, p.318). With a few notable exceptions, the field of suburban studies has largely ignored the question of what happens to a suburb after it has been created: after it ceases to be part of the leading growth-edge of a city. Understanding the mechanism of change requires a shift of focus, from suburbs at the point of their initial founding
on the periphery, to a comprehensive longitudinal study of their on-going change or inertia, long after they have matured and been absorbed into their larger metropolitan regions. Yet new developments and revitalisation efforts within older suburban communities continue to occur, with little empirical evidence about how these new or restored suburbs will perform. Indeed, without a better understanding of the long-term process and patterns of change relating to the physical and spatial characteristics of our urban design efforts, we have limited tools and prediction techniques to offer architects and planners. Given the permanence of land use, property ownership, and street configurations, our challenge as environmental design researchers is to understand the process of growth and to create new tools to predict change and persistence.

The purpose of this inquiry was to explore and refine methods that appear capable of quantifiably studying relationships between existing patterns of space and form, and change or persistence in suburban neighbourhoods. Collver and Semyonov (1979) suggest that change and persistence are complementary aspects of every active, open system of relationships. ‘Whether a system is to be described as changing or stationary depends on the conceptual and time frames within which it is viewed and the sensitivity of the instruments for detection of change’ (ibid., p.480). Critical in this inquiry then, was the notion that change is a diachronic concept. Change is only measurable with knowledge of an earlier condition or series of conditions. Clearly, understanding the process of change requires a longitudinal measure of the physical and spatial characteristics of a neighbourhood, but it is also crucial that the metric should be patterns of change in a community that occur in relation to the independent variables, not simply levels of aggregate change within the community. In other words, merely measuring whether a suburban area underwent a certain level of aggregate change over time would not confirm whether the measured transformation would have occurred even without the independent variables. Several challenges were associated with the goal of developing longitudinal techniques capable of quantifying the relationships between the dependent variable of change in an urban neighbourhood and specific formal and spatial independent variables. The first of the challenges (1) was to create a comprehensive historical database of buildings, roads, plots, land uses, and other physical and spatial measures within a geographic information system (GIS) framework. This database had to be capable of direct comparisons of georeferenced data, both within and between time periods. The second challenge (2) was to integrate disparate morphological and space syntax research techniques into a singular holistic approach in order to study building forms, spaces, legal plot boundaries, and spatial configurations within the same dataset. Finally, (3) the research techniques and dataset had to overcome the impediment of identifying complex patterns of variable relationships both in time and space, rather than merely gauging aggregate change within a suburban neighbourhood.

2. Background

Recent studies have suggested a series of physical characteristics in urban form and space that appear related to measurable patterns of change. Siksnas’s (1997, p.29) study of the effects of block size and shape on change or persistence in the gridiron of 12 different cities in the US and Australia, demonstrated that where initial block sizes were small and relatively square, the street and block patterns remained intact over time. In cities with larger block sizes, such as Adelaide, the author found that the street and block patterns had been considerably modified. The study suggested that large blocks were more easily reconfigured by the insertion of new streets, alleys, and arcades. Further, smaller
blocks were less likely to change than larger blocks ‘because they produce a finer-mesh circulation and finer-grained block and urban fabrics’ (Siksna, 1997, p. 22-25; Scheer and Ferdelman, 2001, p.15).

Within the area of a city block, Moudon (1986, p.134) observed that small lots as territories of ownership affect building form and change, and are significant mechanisms regulating urban form. More time, difficulty, and costs are involved in assembling smaller lots for larger or different land uses. ‘As a result, the smaller the typical lot in any given area, the greater the difficulty of changing the environment’ (ibid., p.141). In a study of the morphogenesis of a first-ring residential neighbourhood in Cincinnati, Scheer and Ferdelman (2001, p.20) identified four important factors that related to the survival of historic buildings in the neighbourhood: street width and continuity, lot configuration within the block, building size, and land use. They also found that several or all of these factors could be interrelated in their relationship to urban morphology. Scheer and Ferdelman (ibid.) also found that building size related to persistence, as the most likely to change buildings were the very smallest, particularly when less than 700 square feet in building footprint. The widest streets appeared to be the ideal location for larger commercial and industrial buildings, and were more vulnerable to obsolescence, disuse, abandonment, and finally destruction, whereas buildings on narrower and discontinuous north-south streets remained relatively intact. There is a significant push to repair and widen streets rather than build a new – partially because of cost implications – but also because the developed spatial patterns reinforce the existing structure. In a reference to the persistence of urban street patterns, Bosselmann (2008, p.242) maintains: ‘Streets have permanence because they give access to properties. Once defined in space, property owners will strongly resist any change to a street’s routing.’ The case for examining streets as a likely predictor of change in suburban neighbourhoods seemed fairly clear. However, in order to incorporate research methodologies with the capability of quantifying street system characteristics, beyond localised metrics such as road width and continuity, studies were reviewed that had successfully incorporated space syntax techniques. Although Sections 2.2 and 2.3 provide additional detail for the syntactic measures discussed here, studies using space syntax techniques indicated that global integration (radius = N), local integration (radius = 3), and connectivity would serve well as independent variables in our methodological approach (Haklay, et al., 2008; Jones, et al., 2008; Griffiths, 2009).

Drawing from previous studies, a likely set of predictor variables relating to change in the built environment appeared to be: block size, plot size, and building footprint size, global integration, local integration, and connectivity. The most likely measure of change as the dependent variable in suburban neighbourhoods seemed to be either frequency of demolished or new buildings or changes in parcel land use. However, a set of research techniques that had proven useful for identifying and quantifying these variables in the past was also needed.

**Methodology**

The overarching goal of this study was to develop a methodological approach and comprehensive database to investigate how the formal and spatial characteristics identified in earlier studies might help to explain the mechanism of change – change measured as buildings newly constructed or demolished, or changes in land use. This goal required a longitudinal procedure to answer the primary question of the research: How do existing patterns of buildings, plots, blocks, and streets relate to change or persistence in a first-ring suburban neighbourhood? Efficacious techniques selected for this research therefore required sufficient rigor to identify and quantify detailed changes occurring in the physical environment of the study area.
over long periods of time. But more critically, the methodologies needed the capability to show clear and detailed geographic patterns of relationships between the predictor and outcome variables.

Without the ability to directly study the socio-psychological attitudes and behaviour of neighbourhood residents over multiple decades, the approach adopted had to look at the accretion and synthesis of incalculable numbers of decisions made as individual and group actions – actions that moulded and transformed the built environment over long time periods. Urban morphologists focus on just such tangible culminations of socio-economic and cultural forces at play, rather than the decisions themselves: analysing a city’s evolution from its inception through all of its subsequent transmutations, identifying, categorising, and dissecting its manifold components (Moudon, 1997, p.3). They study the consequences of ideas and intentions as they take shape on the ground, just as a geologist would carefully sift through soil strata to identify change over long periods of time.

In a broad sense, there are three schools of thought in the field of urban morphology that involve architects, geographers, historians and planners studying city form, space and change: the British, Italian, and French Schools. Two of these points of view centre on the works of prominent early figures in the field: M.R.G. Conzen founding the British school with his detailed study of Alnwick (Conzen, 1960), and Muratori (1963) in his operational histories of Venice and Rome as a theoretical basis for his architectural design studios. This study follows the general process of Conzen and the British School, including the teachings of M.R.G. Conzen and later researchers such as J.W.R. Whitehand (1977), K. Kropf (2009), and P. Larkham (2006). At its most basic level, the Conzenian school of urban morphology looks at plots – property ownership boundaries, streets and the blocks they form; constructed space – built forms; and open space – parks, gardens, plazas, yards, etc. All of these components are examined at multiple points in time in the life of a city or suburb (Levy, 1999, p.79). The goal is to track the physical indicators of change in a diachronic process to record and code micro-level changes at first in the separate individual details. These changes are then examined in the aggregate toward identifying a discernible mosaic. The fundamental cells of Conzenian theory are the individual plot of land, buildings, open spaces, and the city block area. Over a period of time, various physical elements of the urban form are used differently by different social or economic classes, or transformed, demolished, or replaced with new built forms. The rates of change vary according to the city or region of the country, and are commonly related to concurrent cycles in the economy, or the rhythm of change in the structure of society and culture.

**Space syntax**

At any scale, Hillier (1996, p.153) notes that form and function in space are not independent. At a very basic level, Hillier observed that there is a natural geometry to what people do in space:

> ‘People move in lines, and tend to approximate lines in more complex routes. Then if an individual stops to talk to a group of people, the group will collectively define a space in which all the people the first person can see can see each other’ (ibid.).

Further, the fundamental correlate of the spatial configuration of cities and suburbs is movement. In fact, a foundational tenet of space syntax is that the configuring of space in cities provides the material preconditions for patterns of movement, encounter, and avoidance (Hillier and Hanson, 1984; Osmond, 2010, p.14). The primary theorem of movement in space syntax theory involves linear spaces such as roads in urban areas or circulation spaces in buildings, and the paths of movement along and through those spaces. The notion of an urban movement economy says that if a city is considered as a
complex that carries movement from every space to every other space inside the system, then certain linear spaces that are most directly connected to every other space will have a tendency to attract higher densities of through-movement: they will be most integrated into the system as a whole.

A hybrid of morphology and space syntax
Jones, et al. (2008, p.048:2) contend that research focused on the built environment has suffered because of a lack of collaboration between disciplines, and the use of inconsonant analytical techniques by researchers in the built environment and human and social geographers. However, recent studies by urban geographers, morphologists, and designers have demonstrated an awareness of the social-spatial complexities of Anglo-American suburban morphology (Harris and Larkham, 1999; Whitehand and Carr, 1999; McManus and Ethington, 2007; Vaughan, et al., 2009; Griffiths, et al., 2010). Recent studies have also examined the longitudinal relationship between early street systems and historic settlement patterns in suburbs (Hillier and Vaughan, 2007). At issue, however, is the relative paucity of research techniques that are capable of combing both meaningful descriptions of road networks, from the macro-scale to the day-to-day micro-scale of human activity, with a quantifiable approach to the role that historic built forms and spaces play in the historic block patterns and the formative mosaic of property ownership. Several recent studies have utilised mixed-method and case study approaches to examine urban and suburban form and change. Of note is a research effort by Griffiths et al. (2010) in a study of the persistence of suburban centres near London. This longitudinal multi-case study looked at three suburban centres and how they changed over four points in time, using a combination of space syntax and Conzenian techniques. This inquiry built on previous works of the authors (Haklay, et al., 2008; Jones, et al., 2008; Griffiths, 2009) that had also attempted to develop quantifiable theory and methodology to examine the persistence of suburban form over time. Following the Larkham (2006, p.130) suggestion that ‘a great opportunity clearly exists for exploring the potential complementarity of the different traditions of space syntax and Conzenian morphology’, the authors proposed a combination of methodologies through the shared belief that it is the historical grain of the built environment rather than administrative boundaries that address the interrelationship of society and space (Griffiths, et al., 2010, p.87). Both space syntax and Conzenian traditions have shown that it is the configurational structure of space rather than the formal geometric manifestations or arrays of objects that explain the fundamental social nature of space. The value in combining the two disciplines is that where space syntax is robust at network analysis, providing a technique for bringing the regional properties of a road network to bear on the morphological characteristics and land-use patterns of particular suburban centres, it is not as sensitive to place-specific historical complexities of development (Griffiths, et al., 2010, p.88). By adding a Conzenian approach, the researchers were able to enhance their analysis of the historic relationship between street plan, plot patterns, and land uses in the fine grain structure of socio-economic activity. Our goal in the current study was to increase the level of detail in these techniques, and to provide an approach for developing a comprehensive and interactive database for their use. In the interest of simplifying the integration of morphological and syntactic data at the scale of the individual plot, the current study also employed axial analysis rather than the segment angular analysis used in the Griffiths, et al. (2010), Haklay, et al. (2008), and Jones, et al. (2008) studies.

Three independent, or predictor measures, and the dependent measure of change were identified for use in the current study. These variables have
been successfully examined using a Conzenian morphological approach developed by M.R.G. Conzen, Muratori and others (Conzen, 1960; Moudon, 1997; Levy, 1999; Whitehand and Carr, 1999; Larkham, 2006). Counts of new building construction, frequency of building demolition, and changes in land use could be used as dependent variables; and block size, plot size, and building size were appropriate as independent variables. Examining the specific techniques utilised in previous studies, including the nature of the data, how the techniques are performed, and how the findings were likely to appear, informed the use of a morphological approach in our investigation. As with several similar studies, built forms and spaces such as buildings, plots, open spaces, and blocks were analysed and interpreted with a typical Conzenian morphological approach. However, streets and boulevards were investigated and interpreted by using space syntax techniques: specifically by examining measures of global integration \( (radius = n) \), local integration \( (radius = 3) \), and connectivity. The separation of roads is a departure from many previous morphological studies, but the necessity for focusing on accessibility and movement in an examination of the neighbourhood and regional street networks takes precedence over the inclusion of street-as-surrounding-space in the morphological approach. Using a similar approach, Griffiths, et al. (2010) have successfully completed several studies in historic suburbs in Great Britain that incorporated space syntax with a simple form of urban morphological study in the Conzen tradition. Following the example set by these studies, as well as other hybridised techniques in research by Scheer (2001a) and Osmond (2010), the current study used a modified methodological approach that incorporated sections of these earlier studies, but was more specific to a longitudinal exploration of change and persistence. We were also faced with the challenge of developing a database able to integrate morphological and syntactic characteristics down to the detail level of individual property parcels (plots) and building footprints, as well as allowing comparisons between geographic locations over the entire time span of the study.

3. Database development and site selection

As part of a much larger study (Hallowell, 2013), longitudinal case studies were developed for four first-ring suburbs within two cities in North Carolina, USA. The methodological approach and database discussed in Sections 1.0 and 2.0 of the current inquiry were utilised in the larger study, and one of the four case study areas, Oberlin Village, is briefly described here in order to exemplify and evaluate the success of the methodological approach and database design.

**Selection and brief history of Oberlin Village, North Carolina, US**

In the years following the Civil War, a large African-American community was formed outside the north-west boundary of Raleigh, named Oberlin Village. Following the conclusion of the Civil War, area landowners offered building lots to African-American freedmen at 50 dollars an acre from their personal farms and homesteads (Simmons-Henry, 1993, p.18). The new residents of Oberlin Village immediately set to work building homes, churches, civic buildings, and businesses. By 1880, the relatively prosperous community had streets lined with simple, sturdy vernacular houses on regular quarter and half-acre rectangular lots, as well as grander examples of Queen Anne and Colonial Revival style homes on larger acreage. Between the 1870s and the turn of the 20th century, the village had also constructed a public grade school, a number of churches, and an African-American Col-
lege. Originally a discrete rural village on the edge of Raleigh, the community was soon enveloped by the growing city, partially driven by the development of North Carolina State University along the southern edge of the neighbourhood (Perkins, 1994, p.80). After the Second World War, 158 acres of a former estate were developed into the Cameron Village Shopping Centre, accelerating the growth of the community (Waugh, 1992, p.183). In 1914, Oberlin Village had a total of 238 residential structures over 250 square feet in size, and by 1950, that number had grown to 747 homes and major outbuildings. Following the construction of Cameron Village, Oberlin Road and Hillsborough Road saw increased growth of commercial structures, whereas the number of individual homes grew only slightly to 786 in 1980. As of 2010, the number of residential buildings had actually diminished slightly to a total of 726 structures.

**Database development**

Figure 1 illustrates the general framework for the Oberlin Village database. Four points in time were selected due to the availability of raw data, as well as the rough equality of time spans: 1914, 1953, 1980, 2010. The 1914 dataset was considered the origin point for the study, and all change in buildings and land use were referenced to that point. Therefore, 1953, 1980, and 2010 became datasets for identifying change as an outcome variable, and the predictor variables of block size, plot size, building footprint size, global integration, local integration, and connectivity.

The process of developing the GIS master database for Oberlin Village began by creating a skeleton of existing GIS layers from readily available city and county sources using ESRI ArcMapTM 10. Sanborn Insurance maps and other historic paper maps were scanned for the 1914 and 1953 time
periods, and building, road, parcel boundary, and other formal and spatial data were ‘heads-up’ digitised, or traced directly within the software so that all new data layers were georeferenced, and would be available across different time periods. Formal and spatial data for 1980 were derived by digitally tracing aerial photographs from that time period. The 2010 time period already contained building, plot/parcel data, road surfaces outlines. From the road outlines in each time period, an axial map (Jiang and Claramunt, 2002, p. 297) was generated within ArcMap™ and exported as a DXF file to UCL Depthmap X for processing. Derived values for global integration (radius = N), local integration (radius = 3), and connectivity, were then re-imported to ArcMap™ and joined with the original axial map. Because our original challenge included the development of a comprehensive database with integrated morphological and syntactic data that were geographically and temporally researchable in detail, all independent variable data had to be directly comparable at every dependent variable location. For example, if a house were demolished in 1980, the dataset had to contain global integration values for the closest adjoining street to that house – as well as plot, block, connectivity and local integration information. Although many previous studies did not have that level of specificity, it was necessary here for defining specific relationship patterns between predictor and outcome variables. To provide this detailed comparison in GIS, an intermediate ‘driveway’ layer was created that allowed all syntactic data to be spatially joining directly onto the adjoining parcel/plot and then building layers (see light red ‘driveway’ lines in Figure 2).

4. Findings for Oberlin Village: Morphological

In order to review and assess the methodologies and database development suggested here, this section provides a brief overview of findings from the Oberlin Village case study. The first research question in the larger study (Hallowell, 2013, p.67) asked how block size, plot size, and building footprint areas within the Oberlin Village neighbourhood related to change over time – change measured as new buildings or demolitions, or as changes in land use. Initially, findings for the outcome measures of change were compared to morphological predictor variables with simple descriptive statistics. For example, new and demolished buildings occurring in the quartile of largest blocks were compared to those in the quartile of smallest blocks. It was found that in all three time periods (1953, 1980, 2010), the percentages of buildings that were demolished in the quartile of largest blocks were between 3 and 20 times more than the demolition percentages in the quartile of smallest blocks. Indeed, in 1953, 66.3 percent of demolished buildings in Oberlin Village...
occurred in the quartile of largest blocks, versus only 3.2 percent on the quartile of smallest blocks (see Figure 3). A consistent relationship was also seen between new construction and block size, with over 50 percent of new construction occurring in the quartile of largest blocks, while less than 3 percent took place on the quartile of smallest blocks in the 2010 time period (see Figures 3 and 4).

Plot size was also seen as a reliable and consistent predictor of change. All three time periods showed a substantially greater percentage of demolished buildings in the quartile of largest plots versus the quartile of smallest plots. The most significant difference between the largest and smallest plots was in 1980, with 66.3 percent of demolitions in the quartile of largest plots and only 11.6 percent in the quartile of smallest plots. This finding supported a number of previous studies (Moudon, 1986; Siksna, 1997, p.30; Scheer and Ferdelman, 2001, p.20). In fact, Moudon (1986, p.141) found that small lots affect rebuilding and thus the rate of change in neighbourhoods.

Bivariate linear regression analyses were also performed, and findings suggested significant (P≤0.05) but still fairly weak linear relationships (Holcomb, 2009, p.114) between building change and the predictor variables of block size, plot size, and building footprint in most time periods (see Table 1). It is quite possible that the relationships between predictor and outcome variables were not

Figure 3:
Charts showing existing, new, and demolished buildings by block size.

Note: Largest 25% refers to the category of the largest 25% of blocks in the study area.
Figure 4:
Oberlin Village: Block size and demolition in three time periods.

a. Oberlin Village in 1953
b. Oberlin Village in 1980
c. Oberlin Village in 2010

Oberlin Village maps of three time periods illustrating the predictor variable of block size compared with the outcome variable of building demolition - both residential and non-residential building demolition between the time period listed and the previous time period. In other words, the 1953 map shows demolitions of buildings occurring between 1914 and 1953 in Oberlin Village. Note that layers showing existing and new buildings in these maps have been hidden in order to clarify patterns of demolition.
linear – especially over time, even though findings were significant in most cases. It is also possible that residential and commercial building change need to be separately examined in order to fully understand their relationships. These results did however help to confirm findings from other data analysis techniques including Chi-square tests, which were not reported in this paper, and the findings in Figures 3 and 5.

Research questions also asked how building size in Oberlin Village might relate to change over time. Existing and demolished buildings in 1953 saw a negative relationship with building size. Indeed, 16 times as many demolitions occurred in the quartile of smallest building footprints compared to those seen in the quartile of largest buildings. These findings seemed to support Scheer and Ferdelman’s (2001, p.25) contention that buildings most likely to change in their study were the very smallest – at less than 700 square feet in area. All three time periods in Oberlin Village indicated this same pattern, with between 2.5 and 16 times more demolitions among buildings in the quartile of smallest footprints compared to the quartile of largest footprints. It would seem that building footprint size was quite a good predictor of change in demolition and new construction in Oberlin Village, but it was a negative relationship.

Findings for Oberlin Village: Space syntax
Although Oberlin Village was not primarily the result of formal clustering at historic crossroads, as Griffiths et al. (2010) found in their study of early hamlets near London, the construction of new buildings and the demolition of others in the Oberlin Village study area has nevertheless clustered along the early arterials with the core of highest global integration. Indeed, by 1953, 27 percent of new buildings were concentrated along the 10 percent core of the most globally integrated street segments, and more than 36 percent of new buildings had been constructed along the 10 percent core of the most locally integrated street segments. Also in 1953, 57.9 percent of the demolished buildings occurred along the 10 percent core of highest global integration street segments. In other words, well more than half of all building demolitions occurred along only one-tenth

<table>
<thead>
<tr>
<th>Bivariate Relationship</th>
<th>Time Period</th>
<th>N</th>
<th>Morphological Properties</th>
<th>Syntactical Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Block Area</td>
<td>Plot Area</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Radius = N</td>
<td>Radius = 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>R² 0.102**</td>
<td>R² 0.034**</td>
</tr>
<tr>
<td>Buildings - New</td>
<td>T1 – T2</td>
<td>726</td>
<td>R² 0.416**</td>
<td>R² 0.411**</td>
</tr>
<tr>
<td>(Frequency Count)</td>
<td>1953</td>
<td></td>
<td>R² 0.088</td>
<td>R² 0.071</td>
</tr>
<tr>
<td></td>
<td>T2 – T3</td>
<td>334</td>
<td>R² 0.208**</td>
<td>R² 0.020</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td></td>
<td>R² 0.217**</td>
<td>R² 0.194**</td>
</tr>
<tr>
<td></td>
<td>T3 – T4</td>
<td>144</td>
<td>R² 0.217**</td>
<td>R² 0.173**</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buildings - Demolished</td>
<td>T1 – T2</td>
<td>105</td>
<td>R² 0.116**</td>
<td>R² 0.308**</td>
</tr>
<tr>
<td>(Frequency Count)</td>
<td>1953</td>
<td></td>
<td>R² 0.219</td>
<td>R² 0.210</td>
</tr>
<tr>
<td></td>
<td>T2 – T3</td>
<td>323</td>
<td>R² 0.230**</td>
<td>R² 0.013</td>
</tr>
<tr>
<td></td>
<td>1980</td>
<td></td>
<td>R² 0.256</td>
<td>R² 0.236</td>
</tr>
<tr>
<td></td>
<td>T3 – T4</td>
<td>189</td>
<td>R² 0.025</td>
<td>R² 0.092</td>
</tr>
<tr>
<td></td>
<td>2010</td>
<td></td>
<td>R² 0.163</td>
<td>R² 0.144</td>
</tr>
</tbody>
</table>

Note: *indicates P ≤ 0.01 , Red numbers indicate non-significance. SPSS version 20.
of the street segments in Oberlin Village. This fact would seem a fairly convincing argument for global integration values predicting building change.

Descriptive statistics also showed consistent relationships between change, both as new construction and demolition, and local integration. The proportion of demolitions that occurred along the street segments with the highest 10 percent local integration values was up to 7.5 times more than the proportion of demolitions that occurred along the entire lowest half of local integration streets. In other words, in 1953, 63.2 percent of the demolitions were along the five streets with highest local integration, while only 8.4 percent of the demolitions occurred along the 27 of 54 total street segments in the neighbourhood with the lowest local integration.

Using bivariate regression analysis, a significant relationship was seen between new and demolished buildings and both global and local integration in all time periods. Analysis (see Table 1) also showed significant ($P \leq 0.001$) but weak to moderate linear relationships (Holcomb, 2009, p.114) in both 1980 and 2010 between global integration and building demolition. Table 1 also showed significant relationships ($P \leq 0.01$) between new construction as an outcome variable and global integration as a predictor variable in every time period in Oberlin Village.

The maps in Figure 6 illustrate an unambiguous clustering of demolitions along the highest global integration street segments in each time period. Although plot boundaries are not shown in Figure 6, Figure 2 illustrates the care that was used in assigning street frontages and global integration values to the individual properties and buildings. It is also interesting to note the change in concentration from 1953 to 1980. In 1953, demolitions did occur...
Oberlin Village maps of three time periods illustrating the predictor variable of global integration compared with the outcome variable of building demolition - both residential and non-residential building demolitions between the time period listed and the previous time. In other words, the 1953 map shows demolition of buildings occurring between 1914 and 1953 in Oberlin Village. Note that only layers showing demolished buildings are visible in these maps. Plot lines not indicated here – see Figure 7.
primarily along high global integration streets, but even more so after the opening of Cameron Village and development along adjoining streets. It would seem that in the period between 1953 and 1980, the Cameron Village development accelerated the associated commercial construction and the demolition and replacement of older residential and commercial buildings along Oberlin Rd. However in addition, the opening of Oberlin Road to the north and its interconnection in 1980 with the east/west Wade Avenue connector increased both global and local integration values along Oberlin Road, thus attracting even more building development and change. It is important to remember that over time, the development of denser commercial and institutional uses attracts ever more movement – and the pattern feeds on itself, with continually increasing movement along high integration segments. In this sense, the dependent variable of building change in 1953 becomes a predictor of new movement in 1980.

Discussion of findings for Oberlin Village

It was found that larger block sizes in Oberlin Village consistently related to greater change over time, all other things being equal. The change that was seen on larger blocks in Oberlin Village was most often building demolition. New construction on larger blocks was also fairly consistent. It seems logical that, in at least the early stages of growth in a neighbourhood, development is easier and less expensive within larger potential existing block acreage. That is to say, it is less expensive and less complicated to buy and combine parcels of land, demolish buildings, plan, and develop within the undifferentiated areas of larger blocks. It was also found that larger plot, or parcel, sizes in Oberlin Village related to greater change over time. *ceteris paribus.* New construction was most frequently the change that occurred within larger parcels in the neighbourhoods of this study. Again this finding seems quite logical and entirely consistent with earlier studies. As pressures mount for growth or change in a neighbourhood, the easiest targets for purchase, clearing/demolishing, and new construction needed for development are usually the largest parcels in the area. Moudon (1986) observed that more time, difficulty, and costs are involved in assembling smaller lots for larger or different land uses. ‘As a result, the smaller the typical lot in any given area, the greater the difficulty of changing the environment’ (Moudon, 1986, p.141). Building demolition also appears to have a consistent and negative relationship to building footprint area. In other words, smaller buildings are more likely to be demolished, and medium to larger buildings less likely. It seems apparent that less cost and difficulty are incurred in the purchase and demolition of small existing structures for new development. Contrary to the Scheer and Ferdelman study (2001, p.25) however, Oberlin Village found that the very largest buildings were not the second most likely category to be demolished in this study. In fact buildings in

Figure 7 indicates land use change between 1914 and 2010 in Oberlin Village compared to global integration. Due to the fact that all syntactic data had been joined to both individual plots and buildings, it was possible to track changes that had occurred both in plot and building land use over time. It was determined that land use change as a dependent measure had limited usefulness in this study for two reasons. First, it was not possible to control for legal and political mandates on land use over time, such as zoning or land use codes. Second, the number of plots changing use in each time period was statistically small, and diminished significantly toward the later time periods. Nonetheless, the maps in Figure 7 do indicate a fairly clear clustering pattern along the core 10 percent global integration axial lines, especially in 1980.
Oberlin Village maps of three time periods that illustrate the predictor variable of Global Integration compared with the outcome variable of Land Use Change in individual plots (parcels). Change is measured as either residential to non-residential between the time period listed and the previous time period, or the reverse. In other words, the 1953 map shows land use change occurring between 1914 and 1953 in Oberlin Village.
the quartile of largest footprint area were the least likely to be demolished here.

It was found that higher levels of global integration in Oberlin Village related to greater change over the entire 96-year time span of the study. The change most often associated with higher global integration in the case neighbourhood was building demolition. The relationship between global integration and change also appeared to be fairly linear in nature, with incremental increases in global integration relating to increasing frequency of building change over time (see Table 1). The space syntax Theorem of Movement may supply some understanding of why there appears to be a consistent relationship between global integration and demolition. If the street network of the City of Raleigh is considered as a complex that carries movement from every space to every other space inside the system, then certain linear spaces that are most directly connected to every other space have a tendency to attract higher movement densities (Peponis and Wineman, 2002, p.271). If this were occurring continually over the 96-year study period in Oberlin Village, then property values along high global integration street segments would increase to suit the highest and best use. Studies have also shown that highest and best use - even when remaining within the same land use, such as residential, would demand higher densities of use and higher land values (Desyllas, 1997; Kim and Sohn, 2002; Enström and Netzell, 2008). It thus follows that street segments with higher integration values would likely see more change along them, as cycles of increasing highest and best use are followed by cycles of demolition and new construction as higher density and value properties are developed. High global integration street segments thus become attractive for demolition and new construction, especially for land uses inclined toward higher volumes of vehicular and pedestrian movement.

Higher levels of local integration in Oberlin Village were relatively consistent in their relationship to greater change over the entire time span of the study. The change most often associated with higher local integration in the case study neighbourhood was building demolition, although new construction on street segments with high levels of local integration was also fairly consistent. It was found that global integration and local integration were both reliable and fairly robust predictors of change in new and demolished buildings. It should be noted however, that future studies might benefit from separating residential and non-residential buildings prior to comparisons with both the syntactic and morphological predictor variables. We would contend that commercial buildings viewed separately would see even greater change in relation to the predictor variables. The Theorem of Movement as applied to global integration is, after all, particularly focused on commercial uses and their desire for high, wide-area movement density.

5. Conclusion

Just as Larkham (2006, p.130) suggested, it was found that by integrating Conzenian morphology and space syntax research techniques, the Oberlin Village case study was able to quantifiably and consistently measure form and spatial configuration and their relationship to changes taking place in the built environment over long periods of time. The first of our challenges was the development of a GIS database capable of georeferencing formal, spatial, and boundary information across disparate locations and over long spans of time. It was found that by combining all data together in the same GIS framework, and spatially joining syntactic and morphological characteristics to specific buildings and plots, it was indeed possible to successfully generate and then flexibly utilise such a database. Finally, we found that by digitally combining recent GIS files with hand-traced historic information, we
were able to longitudinally track changes in building inventory and land use, and relate these changes to the predictor variables of block size, plot size, building size, global integration, local integration, and connectivity.

The identified relationships were also sufficiently rich and detailed enough to identify and measure discrete patterns of relationships rather than aggregate change within the case study neighbourhood. By combining and refining a hybrid of morphological and space syntax techniques, formal and spatial characteristics of a suburb can be related to change in buildings and land use, both at a single point in time and longitudinally. The research approach presented here is a step toward a broader understanding of the long-term processes and patterns of change relating to the formal and spatial configurations that we, as designers, help carve into our suburbs and cities.

References


About the authors:
George D. Hallowell (george_hallowell@ncsu.edu) is a Ph.D. candidate and adjunct instructor in the College of Design at North Carolina State University. He is a registered architect and has worked in the profession for 25 years in New York, Seattle, and Houston. He has a Master of Architecture degree and BA in Urban Geography, and his research focuses on urban and suburban morphology. His recent studies have focused on the concept of structural inertia, particularly as it relates to the formal and spatial characteristics of older urban and suburban neighborhoods.

Perver K. Baran (perver_baran@ncsu.edu) is a Research Associate Professor in College of Design and College of Natural Resources at North Carolina State University, USA. Her background is in architecture and urban planning. She teaches doctoral and master’s courses in the areas of research methods, research paradigms, and geographic information systems (GIS). Her recent research focuses on understanding how urban and neighborhood spatial structure relate to physical activity and health, and GIS, in particular, its potential for urban design and active living research.


Muratori, S. (1963), *Studi per una Operante Storia Urbana di Roma* (Consiglio nazionale delle ricche, Roma).


