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(SUB)URBAN EVOLUTION: A CROSS-TEMPORAL ANALYSIS OF SPATIAL CONFIGURATION IN AN AMERICAN TOWN (1989 – 2002)

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1. Introduction

Research on the configurational properties of space has shown that spatial configuration is potentially a predictor of both pedestrian and vehicular traffic flow in urban environments. While the earlier examples of this research tends to focus on the observed patterns of pedestrian movement and their relationships with local and global configurational properties (i.e. Hillier and Hanson, 1984; Peponis et al., 1989; Hillier et al., 1993; Hillier, 1996, Read, 1999), recent research has included analysis of vehicular traffic flow. A major finding of this research is the significant positive correlations between the global integration values of streets and the amount of vehicular flow (i.e. Penn et al., 1998). However, space syntax researchers acknowledge that these relationships go hand in hand with social, psychological, and economical factors in cities (i.e. Hillier, 1996). The attempts to understand how configurational properties of cities relate to vehicular traffic flow are significant, predominantly because they constitute an alternative to traditional transportation planning, by focusing on entire configurational systems rather than analyses of routes between individual origins and destinations.

While the findings of current research in this area seem to be significant, the evidence is still limited and it does not allow for broader generalization mainly due to two reasons. First, research in this area so far has focused mostly on European urban environments whose cultural as well as built environments are not generalizable to other contexts. Second, most of this research is based on cross-sectional vehicular flow data. In order to safely predict that spatial configuration affects vehicular traffic flow in urban environments, one needs to present evidence based on multiple observations in time, since if the effect does exist, it would be expected to be observable at multiple points in time as the city evolves.

This paper will present the preliminary findings of an ongoing study, which aims at exploring the role of spatial configuration in an American suburban context by examining the relationship between spatial configuration, vehicular traffic flow, and land use patterns using cross-temporal data from a rapidly growing, predominantly suburbanized American town, Cary. In doing so, this paper will only discuss the changes observed in the spatial configuration of Cary over a thirteen-year period, 1989-2002.

2. Town of Cary, NC: Brief Background

The town of Cary is significant for the purposes of this study due to the type and pace of development it has faced over the last five decades. Originally founded as a small settlement named Bradford's Ordinary in 1750, Cary was incorporated in 1871, shortly after two railroads formed a junction in the town. It remained a small town up until 1950's, during which it was home to a few thousands (Town of Cary, n.d.). With the start of the Research Triangle Park (RTP) in 1959, one of the two largest research parks in the US (Link and Link, 2003), Cary started to exhibit fast and significant changes. Its growth as a bedroom community for RTP and the nearby city of Raleigh started in 1960s, with the population tripling to approximately 22000 in the 1970s. The growth rate of Cary was so fast that, its population doubled two times, both in the 1980s and 1990s. In 2000 the town had an approximate population of 94000. Cary's growth is still continuing today, along with the expansion of RTP (Town of Cary, n.d.).

Cary's growth as a bedroom community has resulted in its rapid suburbanization. Today, the town is predominantly a low-density settlement, with more than 90% of all its buildings, from single-family houses to retail facilities, being one or two-story. Consequently, Cary is significant for the current study for three reasons. First, the fast pace of suburban growth has caused significant changes in its spatial configuration. Second, since the majority of the buildings are one or two-story, the main access to these buildings is through driveways, further affecting the configuration and vehicular traffic flow. Third, cul-de-sacs and low densities are important components of Cary's spatial pattern. Overall, Cary can be considered as prototypical of suburban American towns. An additional advantage for us was the existence of temporal GIS data, which allows robust spatial analysis.

3. Configurational Properties of Cary over Time

Axial maps of Cary, North Carolina were constructed for 1989, 1994, and 2002 using the official town plans and GIS data. Using the *Ovation* software, configurational analysis of the town was conducted separately for these three years. Since, unlike European high-density urban environments, driveways constitute the main point of access to the majority of the buildings in Cary, we assumed that the number of buildings on a street, more specifically, the number of driveways connecting to an axial line, would affect its vehicular traffic flow significantly. In order to account for this contextual situation, we formed two sets of axial maps for Cary; one that includes all the driveways that connect properties to streets, and one that includes all the streets only. Thus the former set of axial maps, to a certain degree, accounts for densities. Using these two sets of maps for the three years, we analyzed the configurational changes in time.

Our initial observation was that there was a steep increase in the total number of axial lines in the axial maps of Cary, which reflected its rapid suburbanization. When only streets were considered, the number of axis had increased from 3796 in 1989 to 4950 in 1994, and to 6316 in 2002 (the overall increase between 1989 and 2002 was 66.4%). The increase was even steeper when driveways, hence the number of additional buildings was considered in the axial maps: the number increased from 20074 in 1989 to 28614 in 1994, to 40045 in 2002 (the number of axis almost doubled between 1989 and 2002, with an increase of 99.5%). To see how suburbanization affected the configuration of the town, we looked at the descriptive statistics for global integration, local integration, and intelligibility parameters (Hillier and Hanson, 1984).

The distribution of global (radius=n) integration values across the three years, with and without driveways, indicated that there was a steady decrease in the global integration of streets in Cary. While the maximum observed global integration decreased steadily from 0.85 to 0.70 with driveways and from 0.62 to 0.56 without driveways, these data sets indicated that the means of global integration and standard deviation values also decreased steadily from 1989 to 2002 (Table 1). These findings indicate that more and more streets were getting global integration values closer to the mean, which decreased steadily: not only streets were being more and more segregated, but also their hierarchy was flattening – i.e. configurationally, their global integration values were getting closer and closer from 1989 to 2002. It is thus possible to argue that Cary has developed in such a pattern that reinforces local movement and control by the residents, which in turn weakens the movement and control by the visitors and outsiders.

			1989	**1994**	**2002**
WITH DRIVEWAYS	**Total number of axial lines**		20074	28614	40045
	Global Integration (Rad=n)	**Mean**	0.5464	0.5049	0.4545
		Standard Deviation	0.1216	0.1058	0.0919
		Maximum	0.8540	0.7885	0.7040
	Local Integration (Rad=3)	**Mean**	1.9803	1.9825	1.9987
		Standard Deviation	1.3014	1.2438	1.2025
		Maximum	0.2109	0.2109	0.2109
WITHOUT DRIVEWAYS	**Total number of axial lines**		3796	4950	6316
	Global Integration (Rad=n)	**Mean**	0.4065	0.4007	0.3708
		Standard Deviation	0.0971	0.0878	0.0789
		Maximum	0.6245	0.6124	0.5643
	Local Integration (Rad=3)	**Mean**	1.4963	1.4878	1.4877
		Standard Deviation	0.6998	0.7022	0.6966
		Maximum	0.2109	0.2109	0.2109

Table 1. Selected descriptive statistics from the distribution of global integration values of axial lines in Cary: 1989, 1994 and 2002.

The local (Rad=3) integration parameter seemed to support this. While the mean and maximum local integration values almost remained the same over the years with or without driveways, a minimal variance was observed in the standard deviations in both cases (Table 1).

Thus, as opposed to the increasing levels of segregation globally, local configurational accessibility remained relatively stable, reinforcing local movement and control. The formation of many cul-de-sacs in the suburbanization process, which is a typical pattern for many American suburbs, is considered to account for this trend, both perceptually and configurationally.

Color-coded axial maps further supported these observations: throughout the thirteen years, not only the streets had become more segregated globally, but also Cary's integration core had been penetrated by lower-global-integration streets (Figure 1). An analysis of the top-10% global integration core confirmed this. Our analysis indicated that while the number of axis in the integration core had been increasing steadily, their mean and maximum global integration values had been decreasing. Further, a constant decrease was observed in the standard deviation levels. Thus, Cary's global integration core, while expanding in the number of streets, was being segregated from the rest of the system due to an overall decrease in global integration values (Table 2).

		1989	**1994**	**2002**
WITH DRIVEWAYS	**Total number of Axis**	391	404	651
	Mean Global Integration (Rad=n)	0.7827	0.7255	0.6470
	Standard Deviation	0.0159	0.0133	0.0119
	Maximum	0.8540	0.7885	0.7040
WITHOUT DRIVEWAYS	**Total number of Axis**	137	163	211
	Mean Global Integration (Rad=n)	0.5810	0.5692	0.5233
	Standard Deviation	0.0148	0.0140	0.0122
	Maximum	0.6245	0.6124	0.5643

Table 2. The top-10% global integration core of Cary, NC.

To see whether this was observable at the level of the entire system, we analyzed the intelligibility of Cary for 1989, 1994 and 2002 based on the bivariate relationship between connectivity and global (rad=n) integration of each axial line (Peponis et al., 1989). The findings of this analysis supported the comparisons based on global integration. The intelligibility of Cary had declined systematically over thirteen years, both with and without driveways (Table 3). This observation further supported our initial observation that in Cary more and more locally highly connected streets had become more segregated, reinforcing the movement in and control of space by local residents.

	r (connectivity and global integration)		
	1989	**1994**	**2002**
WITHOUT DRIVEWAYS	0.2884	0.2805	0.2485
WITH DRIVEWAYS	0.0846	0.0817	0.0728

Table 3. Intelligibility of Cary, NC: 1989, 1994 and 2002 (r values based on Pearson's r test for the relationship between the connectivity and global integration of axial lines).

4. Conclusion

This descriptive account of the configurational properties of Cary between 1989 and 2002 reflects the drastic changes the town has gone through. Our analyses have indicated that the rapid suburbanization of Cary has led to (i) globally, the overall segregation of streets from the rest of the system with decreasing values of global integration, (ii) an overall decline in the intelligibility of the system, and (iii) the formation of areas that support the control and movement by residents rather than visitors, with relatively stabilized values of local integration and declining global integration over time. The focus on one suburban town limits our ability to generalize from the current study. Nonetheless, since Cary's development pattern can be considered as prototypical of similar American towns, this study provides important insights for our understanding of the relationship between configurational properties and suburban development in an American context.

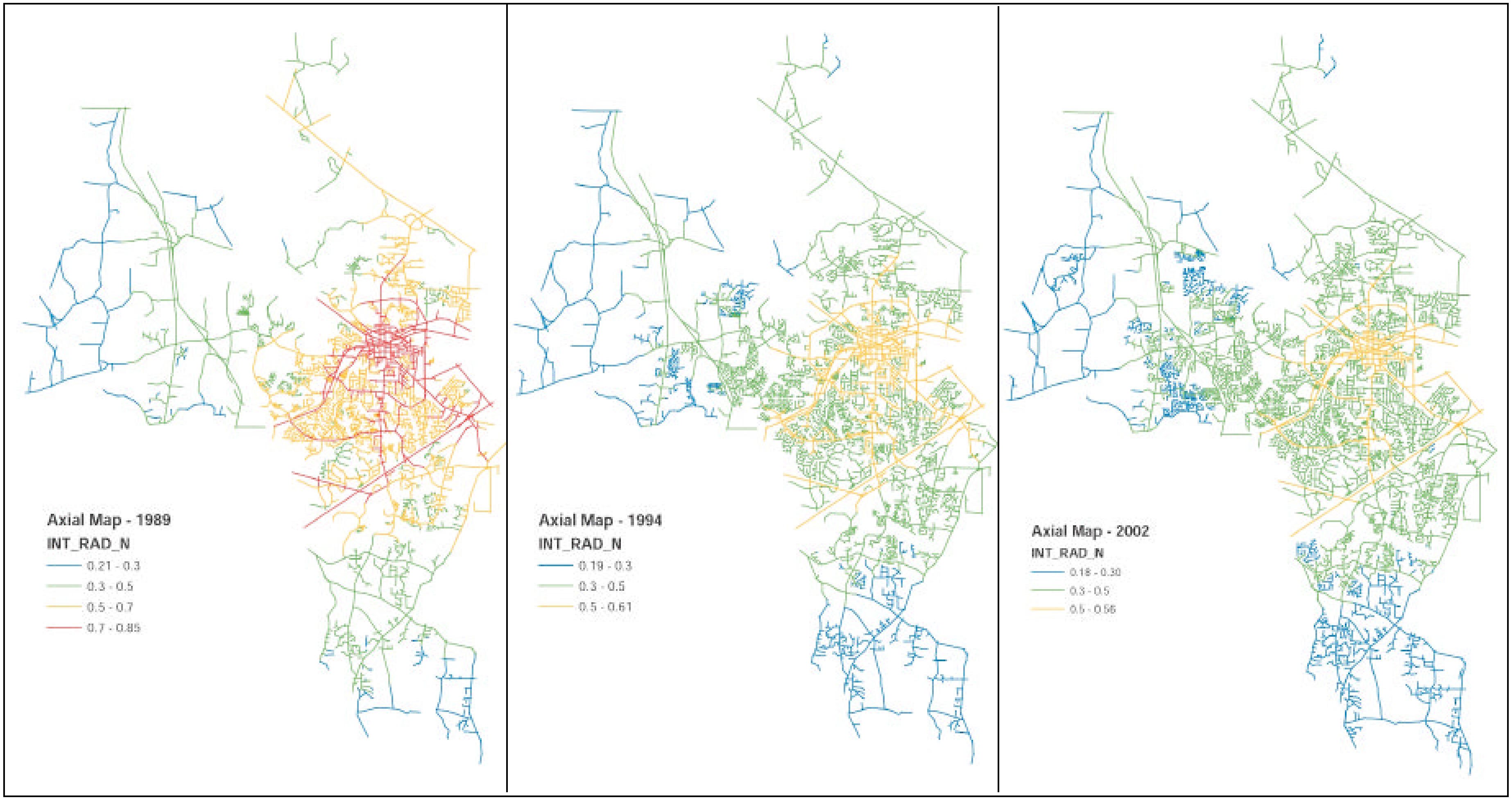

Figure 1. Axial maps of Cary, NC, showing the change in global integration (without driveways): 1989, 1994 and 2002.

5. References

- Hillier, B. and Hanson, J. 1984, *The Social Logic of Space,* Cambridge: Cambridge University Press.
- Hillier, B., Penn, A., Hanson, J., Grajewski, T., and Xu, J., 1993, “Natural movement: or, configuration and attraction in urban pedestrian movement”, *Environment and Planning B: Planning and Design,* 20, p. 29 – 66.
- Hillier, B.,1996, “Cities as Movement Economies”, *Urban Design International,* 1 (1), p. 41-60.
- Link, A.N., Link, R.L., 2003, “On the Growth of U.S. Science Parks”, *Journal of Technology Transfer,* 28, p. 81-85.
- Penn, A., Hillier, B., Banister, D. and Xu, J., 1998, “Configurational Modeling of Urban Movement Networks”, *Environment and Planning B: Planning and Design,* 25, p. 59 – 84.
- Peponis, J., Hadjinikolaou, E., Livieratos, C., and Fatouros D. A., 1989, “The Spatial Core of Urban Culture”, *Ekistics,* 56 (334/335), p. 43 – 55.
- Read, S., 1999, “Space Syntax and the Dutch City”, *Environment and Planning B: Planning and Design,* 26, p. 251-264.
- Town of Cary, n.d., Retrieved January 2005 from the Town of Cary Web site: http://www.townofcary.org.