EAAE-ARCC INTERNATIONAL CONFERENCE

2nd VALENCIA INTERNATIONAL BIENNIAL OF RESEARCH IN ARCHITECTURE

11-14 NOV 2020

THE ARCHITECT AND THE CITY

VOLUME 1

PAPER #1.10

GRID GEOMETRY AND CORE STRUCTURE: SPACE SYNTAX ANALYSIS OF SMALL AND MEDIUM 'GRID-LIKE' US CITIES

Saif Haq[a]
[a]College of Architecture, Texas Tech University, Lubbock, TX, USA

ABSTRACT

The theory and techniques of Space Syntax - originally based on topological assumptions and tested on organic layouts have been developing since the 1970's. After countless publications, and software of different kinds, this is a well-established field - respected and used by design-researchers. Unfortunately, one aspect not entirely resolved is the paradox that seems to exist between the mathematical modelling and geometric conditions of grid or grid-like layouts (Ratti 2004b, 2004a). While this challenge was quickly responded to by Hillier and Penn (2004), we now have at our disposal much more sophisticated analytical technology, namely angular and metric analysis of segmented streets that allow fine grained explorations. Haq and Berhie (2018) have used them to investigate a grid-like medium sized American city, and has demonstrated that 'Angular Choice' and 'Metric Mean Depth' is a useful tool.

This paper extends the earlier study in four grid-like towns/cities in West Texas, USA and includes 'normalized angular choice (NACH)' to compare them. Results indicate that while some of the most recent theories apply equally to grid-like and organic conditions; some special aspects apply to grid-like cases. These are (1) a background structure derived from metric analysis and a foreground structure from 'angular choice' post-dict the functions of grid-like West Texas cities at both levels, (2) such cities cannot generate center to edge connections, but create periphery to periphery links, (3) city size is a factor in the formation of a center, but the rim is highlighted in all cities regardless of size and (4) in numerical calculations of mean and maximum NACH values the grid-like city samples used here produced comparable values of much larger world cities.

KEYWORDS

Space syntax; morphology; grid cities; urban design; US Cities.

INTRODUCTION

Space Syntax theory and application methods have always been a bit unresolved when it came to grid-like cities. As its theory sharpened and methods became sophisticated, it seemed that the more contemporary ideas might be equally applicable to both organic and grid-like cities. Granted, isotropic gridded cities are not found in real instances, yet some cities are more 'grid-like' than others. Such city types have developed west of the river Mississippi, in the Unites States of America, perhaps being influenced by the planning concepts of Thomas Jefferson that was adopted by congress in 1785 (Rayner and Schmidt 1955). Driven by top-down policies, these cities were designed as a grid layout of roads for vehicle friendliness to which functions were added later. They are opposite of the idea that "the process of aggregating buildings … create[s] the physical city" (Hillier 2012)

In West Texas we find such grid-like cities/ towns of various sizes. We have selected four of them as specimens to critically examine the most recent ideas of Space Syntax. This

paper starts with an abridged history of Space Syntax and suggests three distinct periods of development, and the most recent and significant one happened during the last decade of Prof Bill Hillier. Some of the recent ideas are tested in this paper by applying them to the selected grid-like cities of different sizes.

1. SPACE SYNTAX BASICS

Space Syntax is both a theory and a method for analyzing and understanding spaces in layouts through their configurational properties. Since beginning in the nineteen seventies, its theory and method advanced in tandem, and in the process, responded to new challenges with more robust ideas. In the early days, Space Syntax methodology considered simple topological 'connections' between spaces – not simply as immediate connections to adjacent spaces (understood as connections at level one), but also connections to other spaces 'through' the immediate neighbors (connections at level two), to others that were connected to those 'neighbor of the neighbors' (connections at level three) and so on, until connections *of all spaces to all other spaces* (through a set of direct or in-between spaces) had been taken into account. In this manner of considering each space's connections to *all other* spaces, Space Syntax calculated unit values for each space. Two of these values were called 'integration' and 'choice' (Hillier and Hanson 1984). Integration value of a unit area or space is a function of the mean number of spaces in the system and the changes needed in order to reach all other spaces in that system of spaces 'Choice' calculates how likely a unit space is to be passed through in shortest routes from all spaces to all other spaces in the system (Hillier et al. 1987).

Unit spaces were carefully defined. In urban analysis 'axial lines' were mostly used. This is the longest uninterrupted visibility line that can be drawn in a plan of a city or settlement. A collection of such lines covering the entire study area is called an 'axial map' (Hillier and Hanson 1984). This method called for identifying the fewest and longest number of possible lines through the open space system. One must also realize that computers were not advanced and not easily available during the beginning days. Their use in this field probably stated in the nineteen nineties. Perhaps that is why experimental investigations only considered axial lines as units and one variable - topological 'integration'. Computers also made it easy to visually represent the analyses by overlapping on the axial map a set of colored lines to represent their numerical values of 'integration'. Typically, they are displayed from warm to cool colors, with warmer colors indicating higher values. Occasionally, a map of the lines having the highest values (usually 5% or 10%) would be produced. This illustrated the syntactic structure of the analysis area and was called the 'core'.

A good number of observational studies in many cities across the world have found generally positive correlations between topological 'integration' and both pedestrian and vehicular movement patterns (Hillier et al. 1987; Hillier, Penn, Julienne Hanson, et al. 1993; Peponis et al. 1989; Penn et al. 1998; Read 1999). From these, it has been estimated that about 60 to 80% of movement could be predicted by the spatial configuration of the city layout itself (Stonor 2011).

Such discoveries led to proposals of a set of related theories such as 'natural movement' (Hillier, Penn, Hanson, et al. 1993; Hillier 1999b), 'movement economies' (Hillier 1996, 1999b) 'live centrality' (Hillier 1999a) and 'order-structure' (Hillier 1999c). Visual studies of 'core maps' of organic cities coupled with a general understanding of their functional distribution, and comparison to ideal cities led to a distinction between 'order' and 'structure' (Hillier 1999c). While 'order' is geometric and visible in a synchronic condition (like looking at a map or a diagram), 'structure' may be considered diachronic, and is revealed over time by locational aspects and cognitive developments

of its peripatetic visitors (Haq 1999; Penn 2001; Haq 2003; Haq and Zimring 2003). Space Syntax maps are special because they illustrate *diachronic experiences synchronically,* and in doing so reveal the underlying 'structure'. Hiller (1997) had argued that this 'structure' takes the shape of a 'deformed' wheel where a small central area is highlighted (hub of the wheel) with longer connections to peripheral areas (spokes). This paper will address the contemporary development of this idea with special relevance to 'grid-like' cities.

2. A SIGNIFICANT CHALLENGE

While topological considerations in Space Syntax seemed to work quite well for organic cities, Carlo Ratti (2004b) challenged that while a 'deformed wheel structure' was reported in many organic cities, it could not be the case for isotropic grids, because all the lines attained the same integration values. Thus, geometry or 'order' will prevail over underlying 'structure'. From this, one can infer that the thesis regarding a relationship between syntactic patterns to structure or movement and associated city functions in such cities would also be unrealistic. Later research on movement patterns and Space Syntax variables reflected this point. For example, Mora (2003) noted weak correlations between land use and syntactic values in the gridded center of Barcelona (a grid inclusive city). Later, he and a colleague (Mora and Dahany 2005) reported r2 values of 0.403 and 0.555 for correlations of global integration with pedestrians and vehicles respectively in a small semi-gridded part of Toronto (grid inclusive, but not isotropic). Previously, Peponis, Ross and Rashid (1997) had reported that in the colliding grid of downtown Atlanta, correlations between vehicular traffic and integration (r2) was 0.58. Another researcher (Paul 2013) studied 'grid-like' Lubbock and found very poor correlations (r2 =0.18)

The challenge posed by Ratti (2004b) was responded to in different ways. Making the case that real cities are far different than ideal grids, Hillier and Penn (2004) highlighted two aspects of reality. First, a few streets invariably connect to areas outside the city and so attain different relationships creating unequal distribution of values across the city roads. Second, realities of geology and function inside the city cause interruptions of the intended grid (Hillier 1996). Later, Major (1997) demonstrated that in many cases natural elements also influence edge conditions and contribute to the breakup of the grid creating a non-regular situation. He also demonstrated that, in some American cities, individual isotropic gridded sections were sometimes connected to one another in a non-geometrical manner (colliding grids). In sum, it was generally accepted that these 'deformations' of the grid layout was enough to produce a configurational 'structure' different from its geometric shape (order). As such, theories developed in organic cities were expected to be reproduced in grid-like ones too. Unfortunately, this matter remained at the level of discourse.

3. THE SECOND WAVE OF DEVELOPMENT IN SPACE SYNTAX

Meanwhile to produce evidence-based explanations of observed relationships between Syntax values and movement patterns, a subsequent set of Space Syntax studies in the late 1990's and early 2000's undertook experimental work. One set of such studies explored wayfinding behavior (Peponis, Zimring, and Choi 1990) and cognitive dimensions of axial lines (Haq 2003; Penn 2001). These demonstrated that highly Integrated axial lines were used more often by exploring and wayfinding adults and were also featured in their cognitive maps. On this basis both Peponis et. al. (1990) and Haq and Zimring (2003) identified intersections

of axial lines as places of decision making and therefore a natural spatial-unit for Space Syntax analyses. Haq (2003) went further and proposed segmenting the longer lines at their intersections to create nodes. At about the same time, another significant experiment studied path patterns of moving people and highlighted the role of angles between street connections by demonstrating that moving individuals preferred least angles while travelling (Dalton 2003).

These experiments led to substantial developments of Space Syntax theory and methodologies. First, segmented lines i.e. lines broken at their intersections, were accepted as new Space Syntax units, and second, two new concepts of 'distances' between unit spaces -- angles between lines and metric distances between their center points (Turner 2001; Dalton 2003) were added. Simultaneously, computational software became sophisticated -- the paramount one being 'DepthmapX'. This remarkable software can analyze both axial and segmented line maps and can calculate 'integration' and 'choice' values at various radii by considering either connections (topology), angles between them (geometry) or distances between their center points (metrics). Furthermore, it can restrict radii of calculation in distance metrics while doing angular analyses. Of special note is an enhanced understanding of the variables 'integration' and 'choice'. At this time 'integration' was re-considered as akin to 'closeness' and so was expected to have more destinations and indicate 'to-movements' within the spatial system. 'Choice' was associated with 'betweenness' and was expected to measure 'through-movements'. Table 1 indicates the many combinations of unit spaces, variables, and analytical techniques that are available today.

4. SHARPENED THEORIES – ADVANCED METHODS

The third and most recent development wave of Space Syntax was led by Professor Bill Hillier in a series of papers published from 2000 to the time of his passing in 2019. Through this final set of publications, he was successful in transforming his beginning ideas into a complete theory of spatial analysis and formal descriptions of settlements. These papers take into account segmented axial lines as units, angular and metric distance concepts, many radii of analyses, case studies of more than 50 cities across the globe (Hillier, Yang, and Turner 2012; Hillier 2019), cognitive concepts (Hillier and Iida 2005; Hillier 2009) and existing pedestrian and vehicular movement data from four areas of London collected many years ago (Hillier and Iida 2005). Working from all these – arguably with an inductive mindset, Professor Hillier and his colleagues put forth a series of developed theories and suggested specific analytical techniques and representation standards.

With regards to the challenge reported in section 3 of this paper about difficulties of dealing with grid like cities, this set of papers implied that the distinction had been bridged with the new concepts and theories. The fifty cases in his database included both 'organic' and 'geometric' cities. Although the authors did not make categorical distinctions between them, they have discussed some of them separately when appropriate (Hillier, Yang, and Turner 2012). In this paper we plan to investigate some ideas by looking at one medium and three very small American cities/towns located in West Texas, USA. These cities/towns are Lubbock, Slaton, Idalou and Abernathy. (See table 1 for their comparisons). However, before that, let us quickly review the new ideas that were proposed.

CONCEPTS FOR ANALYSIS			TYPICAL VARIABLES OF UNIT SPACES CALCULATED BY SPACE SYNTAX			
UNIT SPACES	DISTANCE BETWEEN UNIT SPACES: • *Topological* • *Angular* • *Metric*	RADIUS OF ANALYSIS. Also • *Turns* • *Angles* • *Distance*	CONNECTIVITY	INTEGRATION (CLOSENESS)	CHOICE (BETWEENNESS)	CONTROL
Axial Lines			√	√	√	
Segmented Lines			x	√	√	
Unit of a Grid			x	√	√	

Table 1. Different unit spaces, analytical techniques, radii of analysis and calculated variables that are used today.

CITY / TOWN	DISTANCE FROM LUBBOCK (km)	POPULATION	SIZE (km^2)	NUMBER OF SEGMENTED LINES	SEGMENTED LINES ABOVE 1.4 NACH VALUES	NACH average	NACH range	STRUCTURE STRENGTH
Lubbock		255885	319	14023	1050	0.945	0 – 1.59	13.36
Lubbock inside existing ring				7617	686	1.018	0-1.61	11.10
Lubbock 4 square blocks				994	95	1.139	0-1.57	10.46
Lubbock with speculative ring road				13946	1181	.956	0 – 1.58	11.81
Slaton	27.26	6121	14.2	942	62	1.101	0 – 1.57	15.21
Idalou	19.63	2250	2.59	227	15	0.943	0 – 1.5	15.2
Abernathy	30.58	2805	3.1	461	29	1.051	0 – 1.58	15.96

Table 2. Information about the four cities/towns and speculative conditions used

4.1. The generic city and its dual structure

After almost fifty years of contemplating cities, Professor Bill Hillier never lost his conviction that "…at a deep enough level cities seem to be the same kind of thing" (Hillier 2016, pp. 200). He believed that despite differences in 'order', all cities have a common 'structure'. He called this 'generic city' (Hillier 2012, 2014), which includes the 'order-structure' idea. In this newer version he proposed it at *two coexisting levels*. The first is a 'foreground structure' that reflects micro-economic activities of the city. Since these are more or less general to all cities and benefit from maximum movement, co-presence and reach, they tend to link public center with edges and interconnects smaller centers (Hillier 2001). The shape of this structure generally follows the 'deformed wheel' idea. As such, they are expected to have a 'rim', a 'hub' and some 'spokes'. In the new 'dual structure' proposal, Hillier also added internal 'lateral' structures to link sectors of the city to

each other and away from the center (Hillier, Yang, and Turner 2012, pp.181). The second is a 'background structure'. It is conservative because it restrains movement according to the culture and requirements of a locality. It is structured by distances and it identifies discontinuities of the urban grid, usually looking like a patchwork (Hillier 2016, 2014)
So how are these structures unveiled? Hillier and Vaughan (2007, pp. 01-02) says, "In terms of understanding structure function relations, urban space seems to be globally topo geometric but locally metric. Recall that 'choice' is a measure of 'betweenness' and so indicates the potential for through movements (Hillier et al. 1987). Also, cognitive science had indicated that urban network is generally understood in geometrical and topological terms rather than metric (Hillier and Iida 2005). Armed with these two ideas they proceeded to test four sub areas in London using existing movement datasets. These indicated that "…geometric, or least angle weighting yields the strongest movement prediction, with an average of around 0.7 for vehicular movement and 0.6 for pedestrian..". (Hillier and Iida 2005, pp. 23). As such, 'choice' values derived by angular analyses of segments restricted by maximum metric radius was proposed to model the 'foreground' structure of cities (T1024 choice radius-n in Depthmap terminology). This is reproduced in figures 1 and 2 as the 'foreground' structure (in color) of the four case studies. And what about the background structure? Again, going back to Space Syntax foundations and theoretical arguments over time, the residential processes are explained as culturally biased and restrictive. It can be modelled through 'metric-integration' analysis at an appropriately low metric radius. Figure 1 and 2 show the background structure in grey tones. They were calculated at a 1600-meter radius (about one mile).

4.2. Normalization and comparison between cities

A significant aspect of Space Syntax in the beginning years was the process of 'normalization' in 'integration' calculations. This was necessary to control for physical sizes and allow comparison between them. The process compared 'integration' values of individual spaces to an ideal 'diamond shaped' graph (Hillier and Hanson 1984). It was very successful. Unfortunately, no 'normalization' was available for 'choice' values.

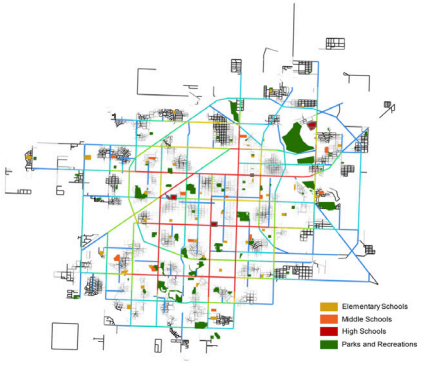

Figure 1. Dual structure of Lubbock showing the relationship to neighborhood amenities.

Figure 2. Dual structure of three towns showing the relationship to neighborhood amenities

As segmented lines became more useful and the importance of 'through-movement' were systematically understood, normalization of 'choice' became necessary for inter-layout comparisons and so the equation for 'normalized angular choice (NACH)' was developed (Hillier, Yang, and Turner 2012). Depthmap allows NACH to be calculated at any radii, with any concept of distance (see Table 1 for these). The most useful concept of distance to restrict radius in angular analysis was metric. Hillier and his colleagues systematically examined a data set of 50 cities (and some hypothetical layouts) and concluded that a range from 0.8 to 1.4 (blue to red) produced the most telling representation. Figures 3 and 4 show the NACH of our four case study towns/cities calculated at the maximum metric distance (n) and displayed in the color palette to match the .08 to 1.4 scheme.

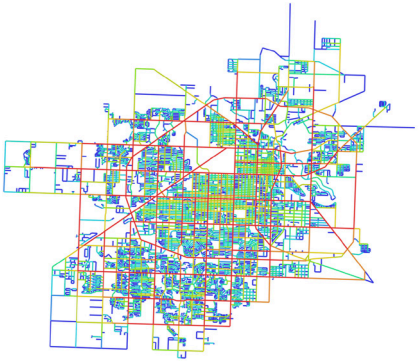

Figure 3. NACNn (0.8 - 1.4) structure of Lubbock

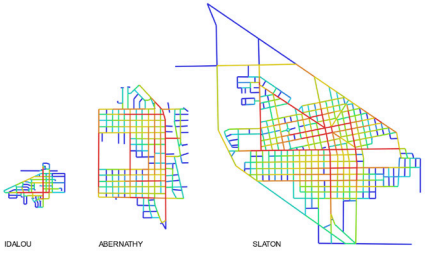

Figure 4. NACNn (0.8 - 1.4) structure of three towns

5. WHAT CAN WE LEARN FROM OUR CASE STUDIES?

It might be useful to reiterate here that metric analysis for background, and angular analysis (at a set metric distance) for foreground is a useful concept to study the functioning of individual cities, especially regarding their function at local and global levels. On the other hand, to compare cities of different sizes we should consider 'normalized angular choice values (NACH)'.

5.1. Local-global structure of grid like cities

Our four sample cities vary quite a bit in size but are similar in their general grid-like conditions. Among them Lubbock is the largest, at about 22.5 times the next town. The other three are quite small. Figure 1 shows the local and the global structures superimposed for Lubbock, and figure 2 shows the same for Idalou, Abernathy and Slaton. The global structure is given by the higher 'choice' values calculated at the maximum metric radius (n), and the local structure is indicated with the patchwork that was created with metric analysis at the radius of one mile. These diagrams unveil some interesting characteristics.

In Lubbock, the patches highlight a central area of *every* subdivision located somewhere inside its one-mile grid divisions. Second, in *all* the central areas identified (patches) there is a neighborhood amenity, either an elementary school or a park. Third, a colored line representing the global core is connected to the amenity of each center/patch. Taken together, they indicate that the identified central patches are not only the vibrant centers of neighborhoods (living centers), they are also well connected to the city's (global) structure. Thus, the patches seem to act as thresholds between the public and private domains of the city. The other three cities are too small to have clear neighborhoods defined, but the phenomenon

observed in Lubbock is also discerned. In small cities, where neighborhoods are few, the school buildings usually act as a public amenity. In all the cases shown here, the schools are located in the global structure, but also close to neighborhood patches.
This method of analysis, it seems, has post-dicted the planning of grid-like cities. This is an important finding and shows that even in grid like conditions the logic between local and global structures and the logic of placing local amenities endures.

5.2. Rims and edges

Since NACH values do not depend on the size of a system, we can use it to compare cities. A visual survey of the three small towns in our sample (figure 2 and 4) reveals that the edges or the 'rim' is highlighted as predicted by Hillier. In many of the cities that have been described through NACH in the literature, specifically those with an outer ring, the rim had become highlighted. For example, when London inside the circular M-25 is modelled, the rim becomes quite significant (Hillier, Yang, and Turner 2012) . It is the same case for Tokyo, Santiago, Barcelona, Beijing (Hillier, Yang, and Turner 2012), Apt (Hillier 2019), Nicosia (Hillier and Vaughan 2007) and other circular shaped cities. Lubbock does not have a well-defined edge (figure 1). It has a 'ring-road' but has grown out of this circular boundary. Even then, the analysis depicts this ring as significant (figure 1 and 3). Two interesting questions pop up: does the shape of the edge influence the 'rim' being highlighted, and do the city size matter? We investigated this question with three theoretical maps created by extending or reducing Lubbock. They are, Lubbock modelled inside the loop road only (figure 5a), a four-quarter section of Lubbock bound by its arterial roads (figure 5b), and Lubbock with a speculative larger loop around it with the gridded arterial roads extended to meet it (figure 5c). In all the cases we find that the exterior roads, either circular or not, *when continuous*, become highlighted. From this small experiment we can answer the two questions: (1) when exterior roads are continuous, an outer rim will be identified by NACH analysis, supporting Hillier's assertion, and (2) size of the city do not play a role in the formation of this highlighted edge (rim).

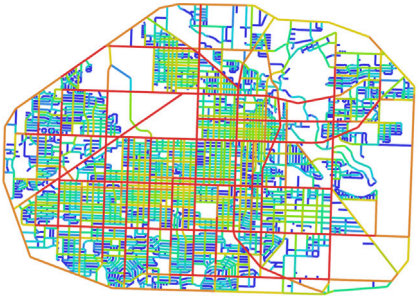

Figure 5a. NACH (0.8 - 1.4) Lubbock inside ring road

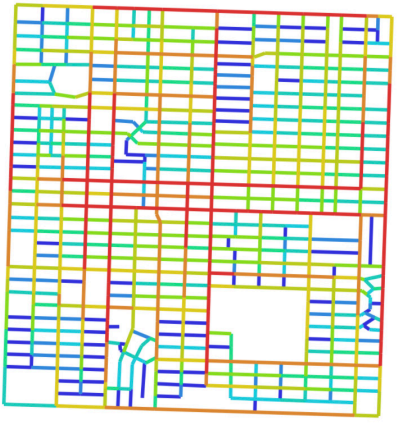

Figure 5b. NACH (0.8 - 1.4) Lubbock four arterial roads

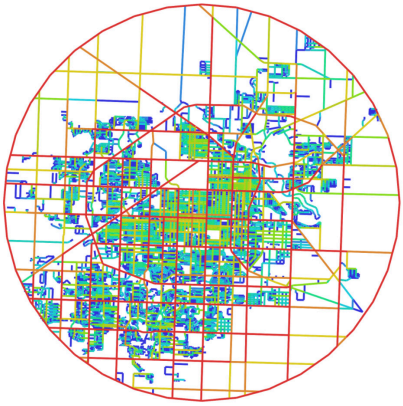

Figure 5c. NACH (0.8 - 1.4) Lubbock speculative ring road

5.3. Spokes or edge to edge connections?

In terms of creating the 'spokes' however, we do not see a clear pattern. Obviously, the grid-like layout does not provide opportunities for radial streets, but we do notice in the three small towns that some roads connecting edge to edge (of the rim) is highlighted. This is curious, because the streets seem to have connected one part of the edge to another without meeting at a significant center, since it may not exist. So, we may extend the original idea with this: in the case of a missing city center for very small grid-like towns, the foreground structure of the city will connect edge to edge, serving the global requirements of a 'bypass'. This becomes especially important for grid like conditions because, as mentioned by Ratti (2004b), the geometry also has a strong influence. Once identified, we also notice some 'edge-to-edge' roads in Lubbock,

5.4. Center formation

Theoretically, the geometry of a grid works against the creation of a center. As cities grow, settlement processes, economic factors, policy, legislation, natural terrain etc. interact and make changes to the ubiquitous grid. The smaller towns studied here has not been developed enough or are not large enough to attain a configurational center. We can discern the semblance of a center in Slaton, the largest of the three small towns (figure 3), and certainly in Lubbock where a clear central area can be identified. From these we can infer that, unlike the edge, city size has a role in the creation of a 'center'.

5.5. Numerical comparisons

Hillier, Yang, and Turner (2012) studied a data set of 50 cities, where the smallest city had less than 1000 line segments, and the largest one had more than 250,000. Among them, some are discussed as 'geometric' – perhaps the closest approximation of a grid-like city, although not clarified. They also studied hypothetical structures of three grid like layouts – (1) a 60 segment by 60 segment orthogonal grid, (2) the same grid with a single pair of crossed diagonals at the center grid, and (3) the same grid with two continuous diagonals. Their analysis revealed that mean NACHn values were higher in the grid-like conditions (1.25) than any actual city they studied. In our four towns and three theoretical layouts the mean NACHn value was not very high (0.93-1.139). From this we can say that our sample cities behave less like isotropic grids, and more like actual working cities. Second, in the Hillier et.al study above, hypothetical gridded conditions displayed lower values of maximum NACHn when compared to their sample cities (more than 1.36 as compared to 1.6+). In all our cases the maximum NACHn values were 1.5 -1.61, which is approximately the same range as the previous study. So, in this comparison also, the four grid-like cities of West Texas functions similarly to the other cities reported in the literature. Thus our studies support the statement "…Cities in effect seem to sacrifice

NACH to create the pattern of high values that we call the structure of the system." (Hillier, Yang, and Turner 2012, pp 163)

CONCLUDING REMARKS

Our sample had one medium and three quite small grid-like cities and three speculative conditions from a mid-sized city. They were investigated with the most advanced Space Syntax technology available – 'segmented angular analyses' for the foreground structure and 'segmented metric analyses' for the background structure. Additionally, 'normalized angular choice' was used to compare between them and to published values of world cities from literature.

This study demonstrated that in general, theories developed with predominant illustrations of organic layouts also work for grid like city conditions. For example, all the layouts explored here produced very comparable maximum and mean NACH values. Some specific findings are that city center formation in the foreground structure is a factor of city size, but the outer rim is a ubiquitous phenomenon. Also, in grid-like conditions instead of center to edge connections, we find edge to edge connections. Overall, this paper suggests that advanced theories and methodologies developed by Prof Bill Hillier (and his colleagues) in the last decade of his productivity is indeed applicable to both grid like and organic cities and the theory can be considered (almost) complete.

REFERENCES

Dalton, Ruth Conroy. 2003. "The Secret is to Follow Your Nose: Route Path Selection and Angularity." *Environment and Behavior* 35 (1): 107-131.

Haq, Saif. 1999. "Can Space Syntax Predict Environmental Cognition?" 2nd International Space Syntax Symposium, Brazilia.

---. 2003. "Investigating the Syntax Line: Configurational Properties and Cognitive Correlates." *Environment and Planning B: Planning and Design*, *Pion Publications, London* 30 (6): 841-863.

Haq, Saif, and Girmay Berhie. 2018. "Space syntax investigation of Lubbock, a grid-like American city and some insights into isotropic layouts." J*ournal of Urban Design* 23 (1): 5-22. https://doi.org/10.1080/13574809.2017.1369872.

Haq, Saif, and Craig Zimring. 2003. "Just down the road a piece: The development of topological knowledge of Building Layouts." *Environment and Behavior* 35 (1): 132-160.

Hillier, Bill. 1996. *Space is the Machine*. Cambridge: Cambridge University Press.

---. 1997. "The Hidden Geometry of Deformed Grids or, why space syntax works when it looks as though it shouldn't." Space Syntax First International Symposium, London.

---. 1999a. "Centrality as a Process: accounting for attraction inequalities in deformed grids." Space Syntax Second Internationa Symposium, Brasilia, Brazil.

---. 1999b. "The Common Language of Space: a way of looking at the social, economic and environmental functioning of cities on a common basis." [web page]. http://urbandesign.ir/wp-content/uploads/2017/11/Urban_space-syntax-hillier.pdf.

---. 1999c. "The hidden geometry of deformed grids: or, why space syntax works, when it looks as though it should'nt." *Environment and Planning B* 26: 169-191.

---. 2001. "A Theory of the City as Object Or, how spatial laws mediate the social construction of urban space." 3rd International Space syntax Symposium, Atlanta.

---. 2009. "Spatial Sustainability in Cities Organic Patterns and Sustainable Forms." 7th International Space Syntax Symposium, Stockholm, Sweden.

---. 2012. "The City as a Socio-technical System: A Spatial Reformulation in the Light of the Levels Problem and the Parallel Problem." In *Digital Urban Planning and Modelling* edited by Stefan Müller Arisona, Gideon Aschwanden, Jan Halatsch and Peter Wonka, In Communications in Computer and Information Science, 24-48. Berlin Heidelberg Springer-Verlag.

---. 2014. "The Generic City and its Origins." *Architectural Design* 84 (5): 100-105.

---. 2016. "What are cities for? And how does this relate to their spatial form?" *Journal of Space Syntax* 6 (2): 199-212.

---. 2019. "Structure or: Does Space Syntax Need to Radically Extend Its Theory of Spatial Configuration?" 12th International Space Syntax Symposium, Beijing JiaoTong University: Beijing, China.

Hillier, Bill, Richard Burdett, John Peponis, and Alan Penn. 1987. "Creating life: Or, Does Architecture Determine Anything?" *Architecture and Behavior/Architecture et Comportment* 3, No 3: 233-250.

Hillier, Bill, and Julienne Hanson. 1984. *The Social Logic of Space*. Paperback Edition 1988 ed. Cambridge, UK: Cambridge University Press.

Hillier, Bill, and Shinichi Iida. 2005. "Network and Psychological effects: A Theory of Urban Movement." 5th International Space Syntax Symposium, Delft, The Netherlands.

Hillier, Bill, and Alan Penn. 2004. "Rejoinder to Carlo Ratti." *Environment and Planning B* 31: 501-511.

Hillier, Bill, Alan Penn, Julienne Hanson, T Grajewski, and J Xu. 1993. "Natural movement: or, configuration and attraction in urban pedestrian movement." *Environment and planning B* 20 (1): 29-66.

Hillier, Bill, Alan Penn, Julienne Hanson, T. Grajewski, and J. Xu. 1993. "Natural movement: or configuration and attraction in urban pedestrian movement." *Environment and Planning* 20 (B): 29-66.

Hillier, Bill, and Laura Vaughan. 2007. "The City as One thing." *Progress in Planning* 67 (3): 205-230.

Hillier, Bill, Tao Yang, and Alasdair Turner. 2012. "Normalising least angle choice in Depthmap and how it opens up new perspectives on the global and local analysis of city space." *The Journal of Space Syntax* 3 (2): 155-193.

Major, Mark. 1997. "Are American cities Different? If so how do they differ." Space Syntax First International Symposium, London.

Mora, Rodrigo. 2003. "Land uses in the context of a perfect grid: the case of Barcelona." 4th International Space Syntax Symposium.

Mora, Rodrigo, and John Dahany. 2005. "Mechanisms of differentiation in a regular grid: the case of Toronto." Fifth International Space Syntax Symposium, Delft.

Paul, Abhijit. 2013. "Reviewing the axial-line approach to capturing vehicular trip-makers' route-choice decisions with ground reality." *Transportation* 40 (3): 697-711.

Penn, Alan. 2001. "Space Syntax and Spatial Cognition Or, why the axial line." Space Syntax 3rd International Symposium, GeorgiaTech, Atlanta.

Penn, Alan, Bill Hillier, D Banister, and J Xu. 1998. "Configurational Modelling of Urban Movement Networks." *Environment and Planning* B 25: 59-84.

Peponis, John, E. Hadjinikolaou, C. Livieratos, and D.A. Fatouros. 1989. "The Spatial Core of Urban Culture." *Ekistics* 334, 335 Jan-Feb, Mar-Apr: 43-55.

Peponis, John, Catherine Ross, and Mahbub Rashid. 1997. "The Structure of Urban Space, Movement and Co-Presence: The Case of Atlanta." *Geoforum* 28 (3-4): 341-358.

Peponis, John, Craig Zimring, and Yoon Kyung Choi. 1990. "Finding the Building in Wayfinding." *Environment and Behavior* 22 (5): 555-590.

Ratti, Carlo. 2004a. "Rejoinder to Hillier and Penn." *Environment and Planning* B 31: 513-516.

---. 2004b. Space Syntax: Some Inconsistencies. In *Environment and Planning* B.31; 487-499

Rayner, Willam Horace, and Milton O Schmidt. 1955. *Elementary Surveying*. Philadelphia: D. Van Nostrand Co. .

Read, Stephan. 1999. "Space syntax and the Dutch city." *Environment and Planning B: Planning and Design* 26: 251-264.

Stonor, Tim. 2011. "Spatial Layout Efficiency" presentation made to National Capital Planning Commission, Washington DC, 15 June 2011. Washington DC.

Turner, Alasdair. 2001. "Angular analysis." Space Syntax 3rd International symposium, Altanta, GA, USA.

European Association for Architectural Education
Association Européenne pour l'Enseignement de l'Architecture

GENERALITAT VALENCIANA
Conselleria d'Innovació, Universitats, Ciència i Societat Digital

GENERALITAT VALENCIANA
Vicepresidència Segona i Conselleria d'Habitatge i Arquitectura Bioclimàtica

Livingceramics

CÀTEDRA LIVING ARCHITECTURE

CÁTEDRA BLANCA
VALENCIA

UNIVERSITAT POLITÈCNICA DE VALÈNCIA

ESCOLA TÈCNICA SUPERIOR D'ARQUITECTURA

Editorial
Universitat Politècnica de València