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Space syntax investigation of Lubbock, a grid-like American city and some insights into isotropic layouts

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ABSTRACT

This paper describes an in-depth study of a grid-like American city using traditional and recent space syntax analytical methods. The case study is Lubbock, located in west Texas, and is characterized by its 'almost' ideal grid layout – one that is perhaps prototypical of American conditions west of the Mississippi River. After extensively describing the city, it is examined by using topological, angular and metric radii of space syntax analysis. From these, comments are made on factors influencing its layout and functional distribution, their relationships to syntactic understandings and some recent development trends. Through this process, the paper addresses the debate regarding the appropriateness of space syntax in investigating grid conditions, and responds to an emerging syntax theorem: local structure is metric and global structure is topo-geometric. In addition, the historical development of grid-like cities in the US is described, an implicit comparison of three syntax methods is provided, and a renewed case of syntax applicability to grid-like cities is made.

Introduction

The theory and methods of space syntax has become significant in the investigation of cities. It identifies unique properties of spaces, models them with robust purpose-built software, proposes theoretical insights, and tests them by observations and experimentation. Through these interrelated processes theoretical basics, computational tools and experimental methods have evolved and have led to the formation of even stronger intellectual ideas. In almost 35 years of sustained development that began with examining organic settlements (Hillier and Hanson 1984), one idea has remained solidly at the core. It is that since 'the process of aggregating buildings … create[s] the physical city' (Hillier 2012a, 26; Hillier and Hanson 1984) so the 'city spaces' and their organization are the crucial elements for urban analysis. While the methodology proposed by space syntax researchers were tested and found appropriate in many cities, Ratti (2004a, 2004b, 2005) put forward a relevant challenge. With theoretical demonstrations he suggested that space syntax application may be appropriate for organic layouts but does not seem applicable to grid conditions. Thus for US cities, especially those located west of the Mississippi River, where an isotropic grid becomes the basis of development, space syntax may be less applicable. Another aspect regarding these cities is

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that here roads (spaces) are built much earlier than buildings and so the notion of aggregating buildings to make urban spaces may not apply. The first challenge was responded to by Hillier and Penn (2004). Considering the second, both the 'vertical' process of creating a hierarchy of spaces through buildings (i.e., structure) and the 'lateral' process of making functional relationships because of the structure of the spaces thus created (Hillier 2012a, 2012b, 2012c) are called to question. So how much is space syntax applicable in pre-planned gridded cities? Are there such cities in reality? What does the use of grids in city formations look like, and how do they function? This paper deals with these questions by critically examining Lubbock, a grid-like American city located in the flat lands of west Texas. It begins with an introduction to basic syntax ideas, measurement techniques and criticisms, a description of Lubbock and its environs, and then discusses space syntax applications to this grid-like condition. Through this process the relevance of space syntax to cities based on isotropic grids is explored.

Space syntax

Space syntax is devoted to the study of layouts through their configurational properties. This includes both analytical techniques to discover the underlying configuration of any layout, and studying the effects of configuration on different functions. The associated methodology identifies and calculates values of each individual space in a pre-selected study area based on its 'connections' to immediately neighbouring spaces, other spaces 'connected' through those neighbouring spaces and so on, until all spaces in the study area have been taken into account (Hillier and Hanson 1984). Using this method, space syntax calculates complex values called 'integration' and 'choice' for each unit area. 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. From a reverse point of view, this is also a measure of 'closeness'; that is, how close a space is, on average, from all other spaces in that network. In a probabilistic sense, these spaces would be appropriate destinations and so can be expected to generate 'to-movements'. Choice values indicate the likelihood of a space being used while going from all spaces to all other spaces. This is considered a 'betweeness' score, measuring to what extent a space lies between the shortest paths between spaces. Theoretically these spaces are expected to feature in 'through-movement'. Before continuing, four aspects need clarification: definition of unit spaces, the concept of distances between them and their measures, radii of those distance measures considered in the analysis, and demarcation of the study area.

Unit spaces in space syntax methodology are carefully defined. The most common ones used for urban analysis are 'axial lines' and 'segmented lines'.[1] An axial line is the longest uninterrupted visibility line that can be drawn in a plan of the city. A collection of such lines covering the entire study area is called an axial map (Hillier and Hanson 1984) or a 'least line' map (Hillier 2012a). This method calls for identifying the least number of possible lines through the open space system, and in turn demands picking the longest possible lines. While this concept generally holds in densely built up cities such as the old towns of Europe or the Middle East, it is not so appropriate in spread out conditions of newer cities (Ratti 2004b), especially American ones. In these cases road centre-lines have been used, either those obtained directly from GIS maps (Turner 2007), or were manually drawn (Berhie and Haq 2015). Segmented lines are axial lines that are made discontinuous at each connection,

and therefore yield a much larger set of lines. Thus, two types of axial maps for any city can be generated, a least-line map or a set of segmented lines.

Regarding the concept of distances between lines, space syntax began with considering topological distances, i.e., connections between lines. Later, however, methods of including angles between lines and distances between their centre-points were accepted. At present there are three concepts of distances –topological, geometric and angular, and two variables for each unit space – Integration and Choice (Hillier and Iida 2005). Analysis using any of the three distance measures produce three types of Integration or Choice values of each line, and when these are mapped back on them create Integration or Choice maps. Typically, they are displayed from warm to cool colours, with warmer colours indicating higher values. Occasionally, a map of the lines having the highest values (usually 5% or 10%) will be produced. This shows the syntactic structure of the analysis area, and is called the 'core'.

Integration or Choice also depends on the radii that is considered, i.e., how many connections are calculated for the analysis. Based on the concept of distances this is usually measured in three ways: by the number of connections considered, pre-selected angular change or a specific metric distance after which connections to other spaces (lines in the case here) are ignored. For example, some topological analysis might ignore all connections farther than the immediate two or three, and metric and angular analysis might ignore connections after a specified length or angle has been reached.

Finally, since space is a continuous element, the selection of the boundaries of the study area in space syntax methodology has remained arbitrary. It is generally decided by the researcher based on the needs and scope of the research project.

Visual studies of 'core maps' of organic cities coupled with a general understanding of their functional distribution and comparison to ideal cities have led to an early distinction between 'order' and 'structure'[2] (Hillier 1999c). While 'order' is geometric and visible in a synchronic condition (like looking at a map or a diagram), syntax 'structure' may be considered diachronic and is revealed over time by locational aspects and cognitive developments of its peripatetic visitors (Haq 1999a, 1999b, Penn 2001). Space syntax 'core' maps are special because they illustrate diachronic experiences synchronically, and in doing so reveal the underlying 'structure' in the apparently chaotic organic cities. Hillier (1997) has previously argued that this 'structure' is geometric and takes the shape of a 'deformed' wheel where a small-scale central area is highlighted (hub of the wheel) with longer connections to peripheral areas (spokes). While such a 'structure' has been reported in many organic cities (Hillier 1999c, 2012b; Hillier and Vaughan 2007), theoretically this cannot be the case for isotropic grids where all lines attain the same syntax value (Ratti 2004b; see also Figure 1a). Thus, it would be useful to study an isotropic gridded city and gain additional insights.

Empirical work using observational studies in many cities across the world has found generally positive correlations between topological integration values of axial lines and both pedestrian and vehicular movement patterns (Hillier et al. 1987, 1993; Peponis et al. 1989; Penn and Dalton 1994; Penn et al. 1998; Read 1999). From these, it has been estimated that approximately 60–80% of movement can be predicted by the spatial configuration of the city layout itself (Stonor 2011). Such discoveries have led to the proposals of a different set of related theories such as 'natural movement' (Hillier et al. 1993; Hillier 1999b), 'movement economies' (Hillier 1996; 1999b) and 'live centrality' (Hillier 1999a).

As the theories, methods and software developed, two puzzles remained. The first is that of the layout, specifically the challenge posed by an isotropic grid in space syntax analysis.

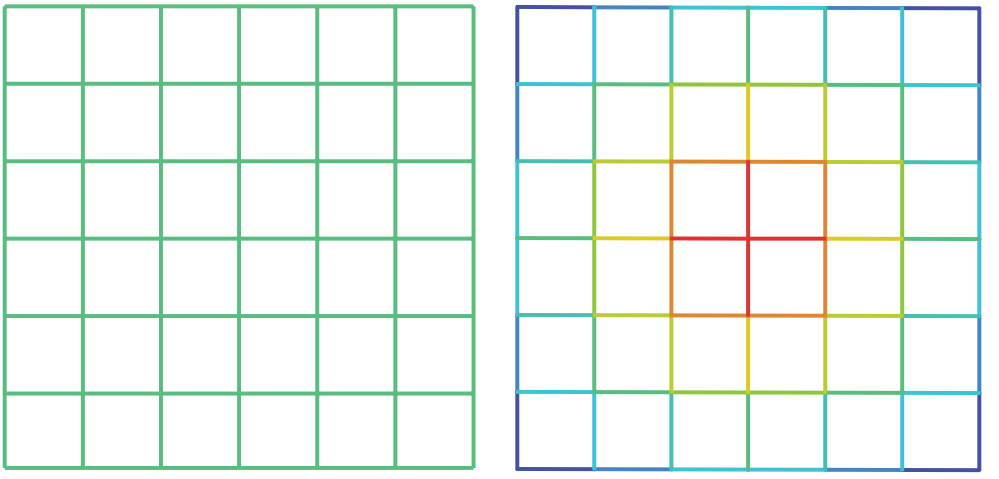

Figure 1. Integration pattern of axial and segmented lines of an isotropic grid. In the first case all values are equal, in the second case higher values are seen at the centre.

Carlo Ratti (2004b) had correctly pointed out that in an analysis of such a grid all lines will attain the same topological integration value (Figure 1a). In this case, the geometric order and the underlying structure will be similar, and if all the lines were segmented at their intersections, then the syntactic structure would favour the geometric centre (see Figure 1b). Thus geometry, or order, will prevail over any underlying structure. In both the cases, the argument for the relationship between syntactic patterns to movement and associated city functions described earlier seem unrealistic.

As introduced earlier, this challenge 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, some streets invariably connect to areas outside the city and so attain different integration values. Consequently, they create 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 the edge conditions being defined by natural boundaries also contribute to the breakup of an ideal grid creating a non-regular situation, and, in the case of some American cities, individual isotropic gridded sections were sometimes connected to one another in a non-geometrical manner. In sum, the accepted argument was that these 'deformations' of the layout was enough to produce a configurational structure different from that of its geometric one. As such, theories of 'deformed wheel' (Hillier 1999c, 2012c, Hillier and Vaughan 2007), 'natural movement' (Hillier et al. 1993; Hillier 1999b), 'movement economies' (Hillier 1996; 1999b) and 'live centrality' (Hillier 1999a) that were developed in organic cities were expected to be reproduced in isotropic gridded ones too.

On another trajectory, in an effort to produce evidence-based explanations of observed relationships between syntax Integration values and movement patterns, a subsequent wave of space syntax studies in the late 1990s and early 2000s undertook experimental work. One set of such studies explored wayfinding behaviour (Peponis, Zimring, and Choi 1990) and cognitive dimensions of axial lines (Haq 1999b, 1999c; Penn 2001). These demonstrated that

not only are highly Integrated axial lines used more often by exploring and wayfinding adults, they are also featured in their cognitive maps. From these studies both Peponis et al. (1990) and Haq and Zimring (2003) identified intersections of axial lines or nodes as places of decision making and so a natural spatial unit for space syntax consideration. Haq (2003) went further and proposed the deconstruction of axial lines to smaller units created by segmenting the longer lines at their intersections. At about the same time, another far-reaching experiment examined the path patterns of moving people and demonstrated the role of angles between street connections. Specifically, the study indicated that moving individuals generally 'followed their noses', i.e., preferred least angles while travelling (Dalton 2003).

These experimental works led to the inclusion of segmented lines, i.e., lines that were broken at their intersections, as new space syntax units, and angles between lines as another measure of distance, in addition to topology, were considered in the analysis (Dalton 2001; Turner 2001). Simultaneous with these experimental and theoretical advances, some computational software were also developed, and the paramount one today is DepthmapX (Varoudis 2011–2015). This can analyze both axial and segmented line maps, and can calculate 'integration' and 'choice' values by considering connections (topology), angles between them (geometry) and distances between their centre points (metrics).

In a chronological review of space syntax, a third development was the theoretical clarifications and finer distinctions between integration and choice, their development from topological, geometric and metric considerations, relationships to 'through-movement' and 'to-movement' and greater applications of space syntax to the understanding of city functions. Previously, all movement and locational variables were correlated to topological Integration values of axial lines, and some distinctions made between global and local integration (Haq 2003; Hillier and Iida 2005). Now, as detailed descriptions of 'closeness' and 'betweenness' were compared with 'integration' and 'choice' (Hillier 2012b) respectively, more integrated areas were expected to have more 'to-movement' and areas with higher choice values were expected to have more 'through movements' (Hillier and Iida 2005). There has been some observational research that supports this claim. In terms of what measures would be more useful in understanding cities, Hillier et al. (2007, 001–02) claimed that each worked at different scales of the city. 'In terms of understanding structure function relations, urban space seems to be globally topo geometric but locally metric'. As shown later, this prediction has a central role in the investigation of Lubbock.

Isotropic gridded cities: an existing case

A very general distinction between geometric and organic cities suggested by Hillier (2012a) was that one type had obvious geometry and the other did not. Figueiredo and Amorim (2003) classified cities into four different classes as highly regular, regular, irregular and highly irregular grids based on the degree of aggregation of continuity lines. According to this method, 'highly irregular grids will tend to present high aggregation degrees with narrow angles of continuity opposed to regular grids' (Figueiredo and Amorim 2003). In this paper the idea of different distinctions of urban grids is proposed. Conceptual city layouts can range from the isotropic right angled grid to the ideal organic, yet none of them exists in real life. Rather, some cities are closer to one end of the spectrum and some to the other, and many display mixtures of different types. Thus what was described in previous literature as 'geometric' cities can be 'grid-like', 'grid-inclusive' or have 'colliding grids'. Grid-like cities

are those that have small deformations of the isotropic grid, such as Lubbock or Salt Lake City (Berhie 2016), grid-inclusive cities are those that have some city sections with gridded characteristics, such as Barcelona (Hillier, Yang, and Turner 2012), and colliding grids are those where regular or near regular grids collide at various angles, such as Pittsburg (Berhie and Haq 2015) or Atlanta (Major 1997). Empirical space syntax studies that attempted to investigate 'geometric cities' failed to make this distinction, and perhaps this is the reason why the findings do not show a conclusive pattern. For example, Mora (2003) studied the gridded centre of Barcelona (a grid inclusive city); while he did not report the correlations of movement and integration, he noted weak correlations between land use and syntactic values. Later, he and a colleague (Mora and Dahany 2005) studied a very small semi-gridded part of Toronto (grid inclusive, but the grid was not isotropic) and reported r^2 values of 0.403 and 0.555 for correlations of global integration with pedestrians and vehicles, respectively. Previously, Peponis, Ross, and Rashid (1997) reported that in the colliding grid of downtown Atlanta, correlations between vehicular traffic and integration (r^2) was 0.58. Paul (2009, 2013) studied 'grid-like' Lubbock and found very poor correlations ($r^2 = 0.18$). Such inconsistent empirical results in so-called geometric cities perhaps point towards the variation within grid types, a factor that was never considered.

To critically investigate the role of space syntax in a grid-like functional city, there is a need to identify one that is close to the isotropic grid condition to use as a case study. The investigators believe that Lubbock is such a city. However, before the particularities of this city are explored, an introduction to it is warranted.

Lubbock: a grid-like city, prototypical of the American condition

American cities that developed west of the Mississippi River have particular characteristics that distinguish them from organic ones; they generally have gridded layouts with lower density and are usually driven by economic incentives, with transportation-based growth being preeminent. In a succinct essay identifying the characteristics of these cities, J.B. Jackson (1985, 27), said '… the street, the road, the highway has taken the place of architecture as the basic visual element, the infrastructure of the city'. He notes that in addition to being visually dominating, the streets are also the first elements to be developed and are more permanent than other urban elements. Streets are the generators of development; they regulate access to and hence control the areas they serve. Thus minor changes such as installing traffic lights, outlawing parking etc. can cause tremendous economic shifts in adjacent areas. Street-based expansion means that a web of streets appears much earlier than buildings, and development takes place in a very large scale where creating a unique characteristic of a subdivision is often more beneficial than creating individual buildings. Incidentally, to J.B. Jackson (1985), the prototype of such cities is Lubbock.

An important factor not addressed by Jackson, but central to the space syntax community and certainly relevant to the study of Lubbock, is that of 'layout'. From this point of view too, this city presents a special case. It is located in the very large, flat, semi-arid, and treeless geographical area called 'Llano Estacado' or 'staked plains'[3] (Figure 2, Aerial View). In this mostly undifferentiated landscape, counties are laid out in approximately 30 miles x 30 miles square shapes demarcated by roads, and further subdivided in a one-mile square grid. Such a concept relates well to the planning proposal set forth by Thomas Jefferson and adopted by congress in 1785 (Rayner and Schmidt 1955). It specified that townships should be subdivided into sections one mile x one mile square, or 640 acres. Such a square pattern might

Figure 2. Bird's eye view of Lubbock and its surrounding areas indicating the flatness of the land. Source: Google Map, collected 12/17/2015.

be the basis on which Lubbock has developed over the years. In this city, the one-mile grid forms the major or arterial roads (which are much wider than the rest), and a one-square mile area becomes a major subdivision. These square sections are further reduced by a finer grid of narrower roads. (Figure 3, Axial Integration map of Lubbock County). As Lubbock grew, some diagonal and circular roads were added, but largely it is this genotypic pattern of a one-mile grid that both characterizes Lubbock and regulates its growth and development (see Figure 4). From an urban analysis point of view, the street layout of Lubbock, especially the one-square mile major grid, is as close to the notion of an ideal (or isotropic) grid as a functioning city can have. On the other hand, the layout inside each square mile grid may or may not be gridded. This indicates that while a larger plan of the city is implemented, it remains open to smaller and varied layout proposals. A closer analysis also suggests a chronological variation as described later.

After being founded in 1890, Lubbock steadily grew over the years (Chaloult et al. 1990), always adhering to the genotypic idea of a mile square subdivision and generally favouring a west–southwest expansion.[4] The downtown area containing businesses and commercial functions, and a residential area just west of it, was the earliest to be developed. Downtown had (and still has) a very regular, square and dense grid (approximately 350 feet x 350 feet, road centre to road centre; see Figure 4a). In contrast, the early residential area was designed with more streets going in the east–west direction than north–south, forming rectangular areas that clearly favour north–south oriented houses (Figure 4b). While the planning logic behind this approach could not be discovered, this was undoubtedly deliberate and is quite apparent in the 1920s historical layout of Lubbock (accessed from https://www.tsl.texas.gov/arc/maps/images/map2222.jpg, on 12 May 2017). From this, one might postulate that in residential developments prior to the advent of air-conditioning north–south oriented houses was a logical choice. (It must be emphasized here that this is merely an observation.) As a result of the buildings opening towards them, the east–west residential roads are livelier, while the north–south roads, usually faced by blank side walls and fences of the homes, are not. As the city grew, newer residential areas exhibited varied layouts such as radial

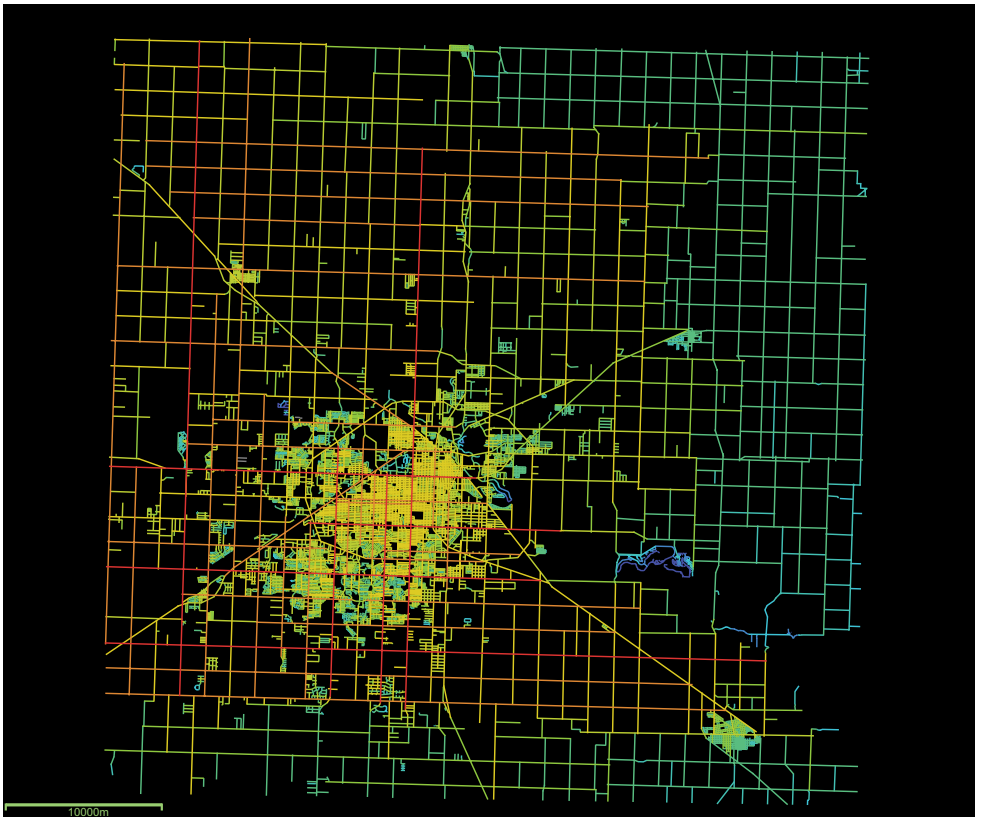

Figure 3. Axial integration map of Lubbock County. This also indicates the grid layout of its roads. Lubbock city is the large dense (and more syntactically integrated) area.

arrangements, cul-de-sacs, interrupted grids etc. inside each one-square mile grid (compare Figures 4b and 4c).

The one-mile grid of Lubbock recalls the idealized design of a neighbourhood originally proposed by Clarence Perry who had suggested that in single family areas, a half-mile radius should be the controlling dimension for convenience regarding walkability to schools, parks and local shops (Perry 1929). The 1943 plan of Lubbock actually mentions the half mile walking distances with respect to locations of parks and playgrounds (City of Lubbock Planning Department, 2006). The repetition of the one-mile grid of Lubbock and its functional distribution meet the walkability factor in a very special way. The centre of a grid becomes a suitable spot for schools and playgrounds while the peripheral roads become commercial attractions for half neighbourhoods on either side of the wider arterial roads (see Figure 5).

While the rationality of a pervasive uniform grid with wider peripheral roads may suggest that commercial areas be located along them, this has not been the case everywhere. As mentioned previously, the original business district was in one square mile downtown area with a dense urban grid layout. As the city grew west–southwest, major highways that crossed the city were designed to be the natural connectors, and commercial areas (shops and businesses) were planned along them. The 1943 plan identified such connectors, some arterial and some not, but by the plan of 1953, most of the non-arterial roads were left out (City of Lubbock Planning Department 2006). Thus some, but not all, arterial roads became

Figure 4. Hierarchy of street system of Lubbock. Arterial roads and highways are shown in thick lines. Note different patterns inside each subdivision. Subdivisions a, b and c are 'called out' for the reader's convenience.

zones for commercial activities. Curiously, this phenomenon is seen in more east–west roads than north–south ones (see zoning map, Figure 6). Because of this, more arterial roads going east–west have shops and businesses that open to them, have broader sidewalks and are livelier than those going north–south, which only face blank walls (compare Figures 7a and 7b). The 1986 development plan indicates that intersections of arterial roads were to be developed as commercial areas and occasionally parts of arterial roads, both north–south and east–west (this can be seen in Figure 6 land use map). Nevertheless, at present more east–west roads have commercial areas along them than north–south ones.

It has been demonstrated that there are at least three forces behind the development of Lubbock; a one-mile isotropic grid layout that includes not only the city but the surrounding region as well, a specific response to highways as connectors and thoroughfares, and permissive attitude that accepts varied layouts inside each square-mile block. This paper will now investigate how these forces can be understood through the lens of space syntax.

Space syntax explorations of the grid-like city of Lubbock

Now that a preliminary discussion of space syntax developments, some challenges and responses regarding gridded conditions of city layouts and a brief description of Lubbock

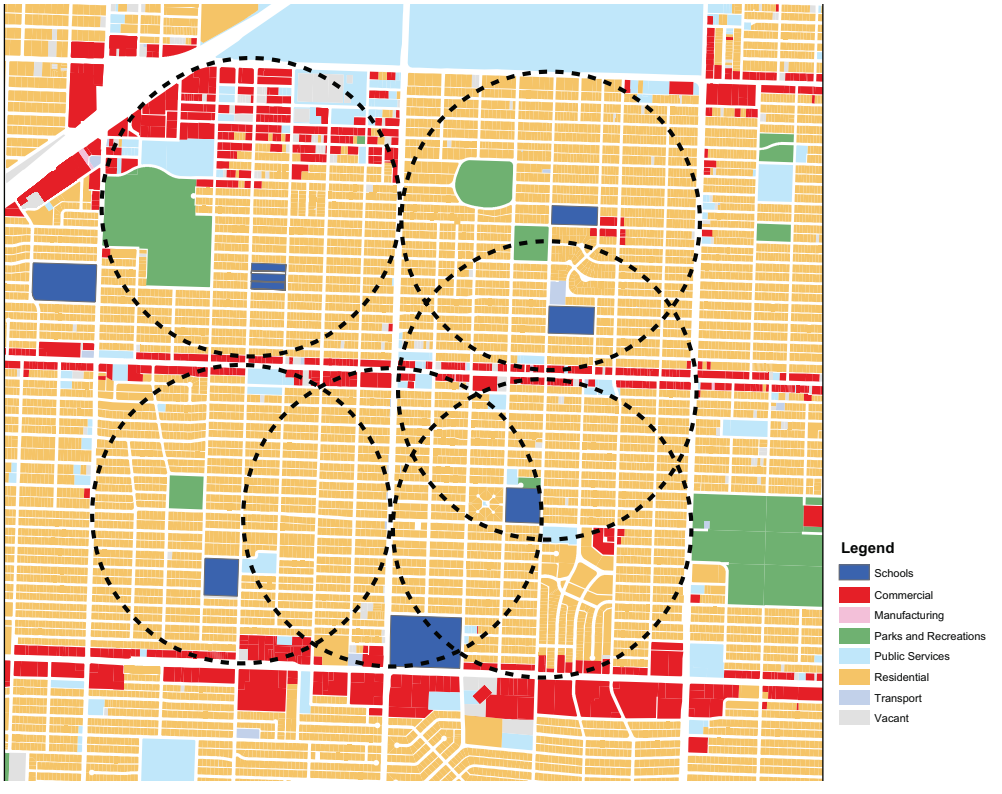

Figure 5. One square mile neighbourhood pattern with 0.5 mile radii circles to indicate scale and walking ranges; both within the neighbourhood and across them.

have been presented, the discussion will move to a case study of this city with the aim of comparing space syntax analysis from an isotropic gridded city to previously published 'enduring' findings and more stable theoretical positions from space syntax literature. At the outset, it is acknowledged that this is a qualitative effort and the comments are based on very careful visual analysis of complex maps. Some of these were created through consolidation of GIS data and two types of space syntax data.

A deformed wheel of no consequence

Former studies of 'least-line maps' have reported one consistency in both organic and geometric cities. Typically, there would be a very small number of long lines and a large number of short ones (Hillier 2001, 2012c). In addition, the longer the line, the more likely it is to end in nearly straight connections to another (5–25 degrees), creating a route-like form, and the shorter the line, the more likely it is to end or intersect at right angles, creating local clusters (Hillier 1999c, 2012c). This observation across many cities has led to a few theoretical insights. City street networks acquire a dual structure that is made up of a dominant foreground network marked by linear continuity and a background network of a localized character formed by shorter lines with less linear continuity. The foreground network is normally highlighted by two syntax representations: integration core maps of topologically measured axial lines (Hillier 1999c) and geometrically measured (angles) segmented lines[5] (Hillier 2012a, 2012c). Typically, they bring out a pattern that has been characterized as a

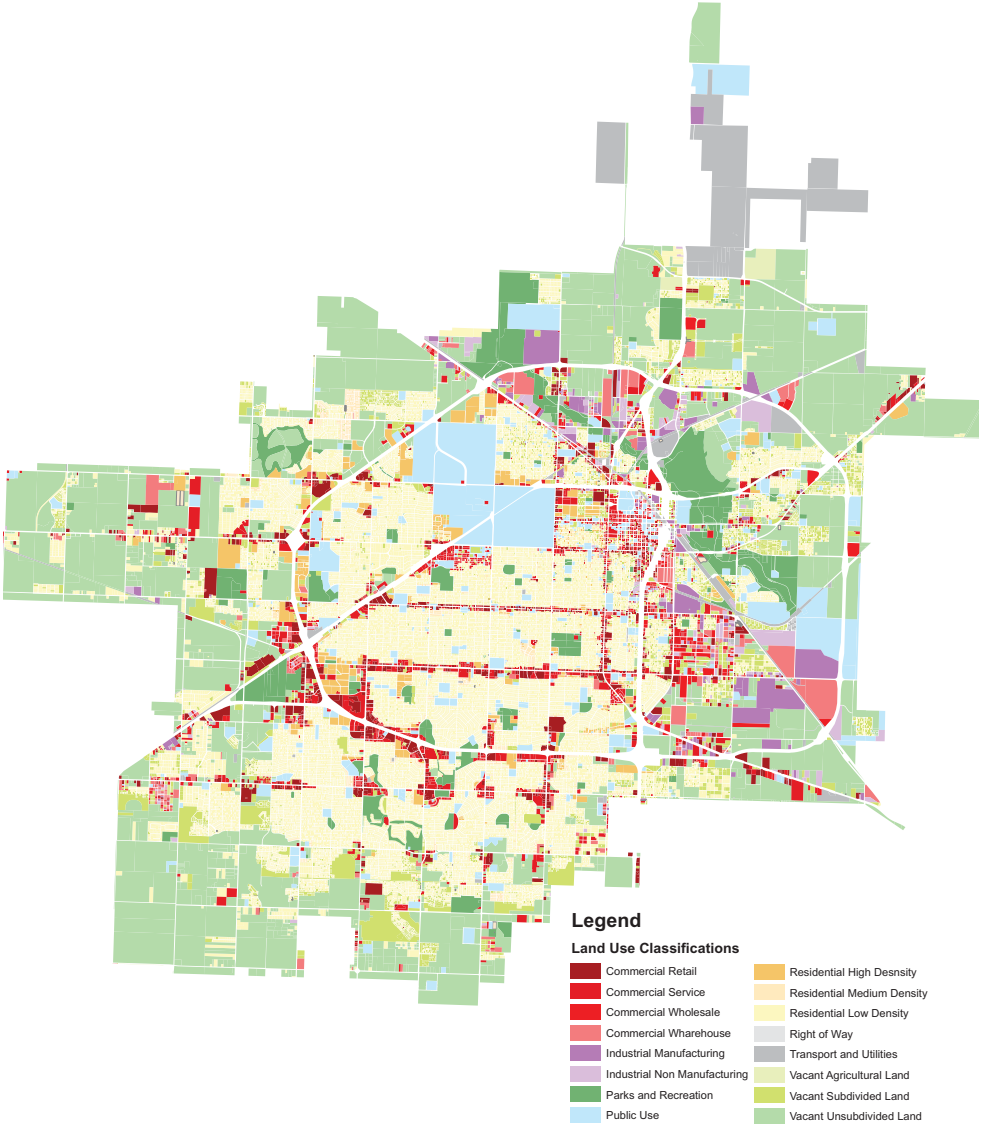

Figure 6. Land use map of Lubbock (2013). (Created from data available at https://www.mylubbock.us/departmental-websites/departments/gis-dataservices/data-downloads)

'deformed wheel' (Hillier 1999c, 2012c; Hillier and Vaughan 2007), usually understood by a hub of lines at the centre with spokes connecting them to the periphery. As Figure 8 demonstrates, the integration core of 'grid-like' Lubbock also brings out a central dense area equivalent to the 'hub'. This city having a grid layout obviously is not expected to show diagonal connections, but it is noticed that the arterial roads connect the highlighted central area to the periphery. Thus, the deformed wheel pattern can also be identified in the syntactic 'structure' of Lubbock.

Theories of centrality (i.e., structure-function relationships) and movement economy (i.e., structure-movement relationships) postulate that the integration core in the foreground will also be associated with movement and in turn with the microeconomic activity of

markets, exchange and trading. In other words, the identified foreground core will have more traffic and will be the expected locations of shops and other commercial functions. This is where Lubbock differs. First, the identified central part is a totally residential area, and second, the 'spokes' are made up of both the north–south and the east–west arterial roads. As described earlier, the zoning of this city is such that more north–south roads are stark and has limited functions, while many east–west ones are lively (see Figure 6 and compare with Figures 7a and 7b). Therefore, although the integration core identifies a clear structure, it does not correspond to expected functions. As mentioned earlier, a study of traffic by Paul (2009, 2013) found that the relationship between integration values and traffic in the streets of Lubbock was very poor ($r^2 = 0.18$).

Meaningful patches

The subdivisions of Lubbock have been described as a deliberate creation that is bound by arterial grids at one-mile intersections which seem to follow Clarence Perry's ideas of a good neighbourhood (see Figure 5). To focus on the background structure of the city, this paper invokes the emerging and therefore less vetted 'patchwork theory' (Hillier et al. 2007; Dalton 2007). In essence, this theory suggests that the background network of residential areas is configured not to allow or enhance 'through-movement', but to restrain and structure movement according to the particular culture and requirements of a locality. This identifies discontinuities of the urban grid and is conservative (Hillier 2012c). In a theoretical exploration using axial maps of several cities, and testing with different radii of analysis, Hillier et al. (2007) found that metric analysis at lower levels identifies spatially distinguishable zones (patches) that are scattered as a patchwork across the city and that these patches grow or shrink according to the metric radii selected. Looking closely at London, they surmised that 'at an intuitive level … there seems quite a strong agreement between the patchwork and functional variation …' (001–14). However, the authors also warn that the relations between the patchwork and functions are suggestive only; they identify local areas, but may not account for live centres, unless they are part of or close to the topo-geometric core that accounts for global movement (Hillier et al. 2007). This makes sense, especially as there were no empirical works beyond describing areas from a general understanding of functions. The

Figure 7. Street views of Lubbock. (a) East-West arterial road showing businesses opening to it and associated parking. (b) North-South arterial road showing blank side walls of houses.

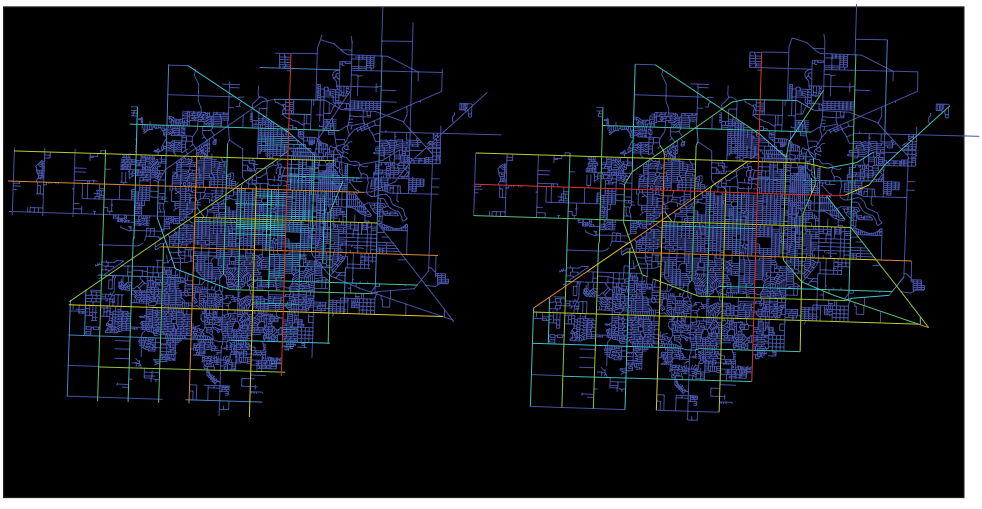

Figure 8. Integration core of Lubbock: (a) Topological integration core (5%) of axial lines; (b) Normalized angular integration core (20%) segmented lines.

question therefore becomes, what do these patches really reflect? What radii of analysis might be the appropriate one for a city? These questions have remained unanswered, but perhaps this investigation can shed some light on this puzzle by looking at a designed grid-like city such as Lubbock. Figure 9 shows the local and the global structure superimposed on a GIS map of Lubbock. The global structure is given by the higher 'choice' values calculated at the maximum radius possible (n), and the local structure is indicated with the patchwork that was created with metric analysis at the radius of one mile. From this diagram, a number of interesting things can be perceived. First, patches highlight a central area of *every* subdivision located somewhere inside the one-mile grid. Second, in all the central areas identified (patches) there is a neighbourhood amenity, either an elementary school or a park. Third, a coloured line representing the global core is connected to each centre/patch. Taken together, they indicate that the identified central patches are not only the vibrant centres of neighbourhoods (living centres), but they are also well connected to the city structure. Thus patches act as thresholds between the public and private domains of the city. It seems that the space syntax method of analysis has post-dicted a deliberate planning strategy of Lubbock. This is a remarkable discovery, and posits Lubbock as a classic example of the dual structures of cities, the specific relationship between these two structures, and the association between the global structure and local amenities.

Discussion

Space syntax identifies 'possibilities' that arise due to layout only. Planning, on the other hand, is such that decisions are made with reference to other factors. Possibilities are a question of evolution and of continuous growth and can only be understood after the layout is conceived. In top-down functional planning, climate, topology and other factors are genuine considerations before the layout is created. Lubbock is a good example to see how these two interact over time in a grid-like layout.

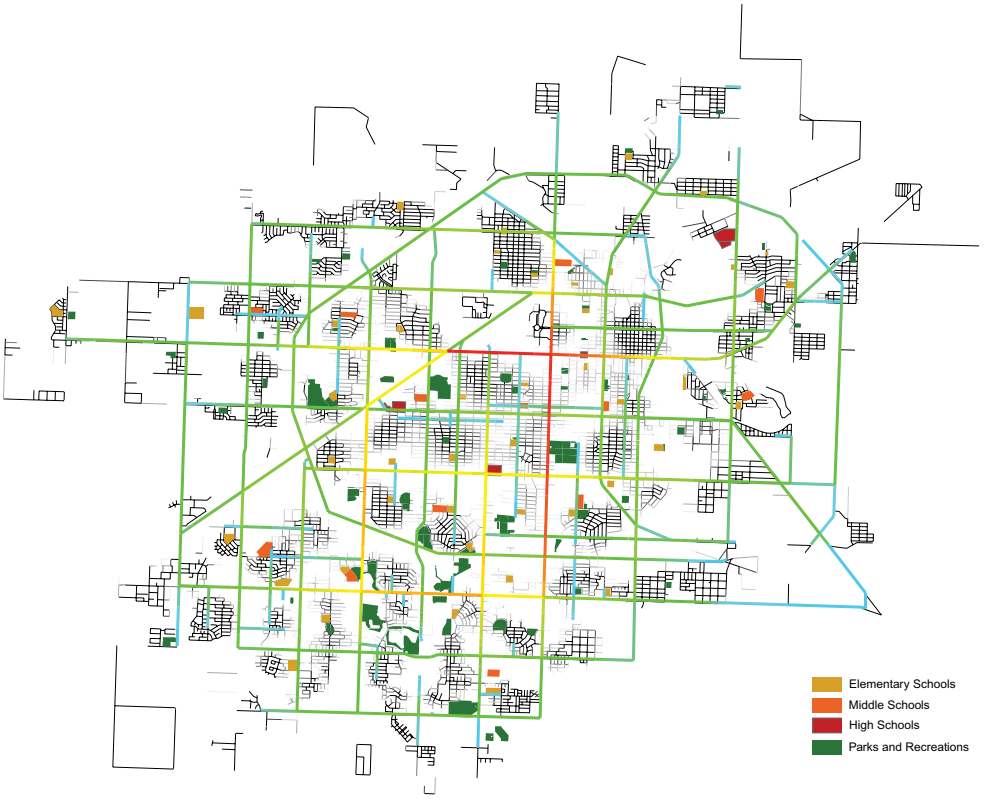

Figure 9. Superimposed foreground structure, background patches, and neighbourhood amenities of Lubbock.

Variant and invariant

Hillier (2001) had suggested that residential processes being driven by socio-cultural forces generate a distinctive pattern of local differences, but the public space production process is driven by micro-economic activities which tends to be similar everywhere and is therefore spatially universal. He suggests that 'the variants tend to be local and the invariants global' (02–9). Not only that, the shape of this global invariant looks like a 'deformed wheel', in the sense that inner areas of collective activities are connected to the peripheral areas.

For a city such as Lubbock, the local-global distribution is self-explanatory as the production process itself expresses it quite well. The invariant in this case is the large-scale grid made up by the arterial roads. They are ubiquitous, laid down to contain rapid transportation and global by design. The infills within these square areas are driven by local issues and are shaped by the idiosyncrasies of developers. The older infill patterns (near the centre of the city) are rectangular, but the newer ones (in south and southwest locations) have varied layouts (see Figure 4b and 4c). In a way, what syntax 'reveals' in organic cities are 'designed' in isotropic cities such as Lubbock. That said, syntax analysis of Lubbock is particularly interesting from both points of views. The global structure identified does bring out the notion of 'deformed wheel'. It highlights a central area and arterial streets going in both directions. Unfortunately, the 'centre' is made up of residential areas; and while some arterial roads have economic activities, others do not. What is particularly interesting is that the local metric

analysis shows a different type of invariant, one that is beginning to be understood in space syntax literature. Even though each major sub-division has a different layout, a metric analysis reveals that they are all focused on local amenities that are connected to the global structure (Figure 9). In a city with a grid-like condition, this research seems to have identified an invariant at the local level.

Organic vs. designed, aka top-down or bottom-up

It may not be unreasonable to state that space syntax was developed to find an underlying structure in cities that had no apparent geometric order, such as in organic cities mostly found in Europe and the Middle East. It began with the assumption that buildings create space (Hillier and Hanson 1984; Hillier 2012a). This can be seen in many examples that were used in early literature, and the most famous one is arguably the village of Gassin, France (Hillier and Hanson 1984). The next intellectual development was the understanding that 'as objects were placed in space, a structure of some kind emerges in that space' (Hillier et al. 2007, 001.10). This underlying structure makes the ostensible 'chaos' comprehensible. However, what about cities that are developed from a completely different perspective? Some cities are built with top-down concepts that are external to themselves and may have been imported from rational thinking, market forces, commercial or even climatic factors. These are some questions that have been addressed in this paper by looking at a case study. Lubbock's order is deliberately gridded and exists at two levels. The more important one is the mile-wide grid made by the wide arterial roads that also connect to areas outside the city (Figure 3). The second is the internal residential layouts within arterial grids (Figure 3 and 4) that are themselves gridded in the older sections and have variations in newer areas. As pointed out earlier, there are some deformations to the larger arterial grid mostly seen through inclusions of a loop road and some diagonal ones. They are beginning to deform the syntactic structure of the arterial grid but this is not significant yet. The integration core of the city (top 5% axial lines, shown in Figure 8) is very telling because it picks up both the top-down 'order' (arterial roads) as well as the bottom-up 'structure' (hierarchy within each subdivision). On the one hand, it picks up all the arterial grid streets in both directions, highlighting the arterial grid beginnings, and on the other, it also highlights a central dense area that is connected to the periphery by some, not all, of these arterial streets. In essence, a 'deformed wheel' superimposed on a rectangular grid can be discerned, a simultaneous existence of both characteristics. However, the relationship of this structure with the functional distribution is also a top-down process and perhaps not as expected by syntax researchers. Here, the function is laid down in response to external forces and is not equally distributed in the north–south streets, despite many of them having higher syntax values.

Readers may have noticed the use of the term 'topo-geometric' when discussing the global structure of cities. In this paper both topological integration (Figure 8b) and angular choice (Figure 9) were shown. In addition, it was implied that angular choice might be a better variable for Lubbock and, by extension, for grid-like cities. This is by no means authenticated. However, a previous study by Berhie and Haq (2015) had found that choice was the better predictor of transportation mode choice in grid-like cities such as Lubbock and Salt Lake City, but axial integration was the predictor in Pittsburg and Boston, which had organic characteristics. At this point it can only be suggested that topological and angular analysis might be appropriate to study grid-like cities.

Analyzing gridded cities with space syntax is like trying to find the obvious. The grid is the structure so syntax analysis is not meaningful. However, no city is an ideal isotropic grid. Lubbock, because of its development by the use of an isotropic grid of arterial roads, and its permissiveness of allowing different layouts inside each square, creates a duality seen in a comprehensive city wide strategy and a smaller block level strategy. This is a new challenge for syntax researches. However, this paper has demonstrated that while topological analysis of axial lines is less meaningful in this city, angular choice, metric analysis and their combination is meaningful. This contributes to the new understanding of the metric and angular dimension that syntax researchers are beginning to explore.

Notes

1. Other unit spaces are also used in space syntax, but since this paper deals with cities, it will only concentrate on lines.
2. This concept was explained earlier by (Hanson 1989).
3. It is approximately 37,452 square miles of flat land in Texas and New Mexico that inclines about 10 feet per mile.
4. There are many reasons for this but these are beyond the scope of this paper.
5. While core maps of topological Integration were prevalent in the early literature on space syntax, newer concepts and analytical techniques since the 2010s favour geometrical analysis, i.e., measurements using angular distances. This study shows both.

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