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The common language of space: a way of looking at the social, economic and environmental functioning of cities on a common basis

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Abstract—This paper proposes that in addition to urban research which seeks to provide answers to policy questions, there is also a need for research which directly addresses the physical and spatial complexity of the built environment itself, and explores any effects it may in itself have on the functioning of the urban system. This type of research reflects the questions architects and urban designers typically ask, rather than those that preoccupy planners. For such research to be effective, the physical complexity variable must be controlled at the level at which real design decisions are made. "Space syntax" research attempts to do this by treating built environments as systems of space, analysing them "configurationally", and trying to bring to light their underlying patterns and structures. Results from space syntax research into many aspects of urban space and how it works show a consistency which suggests that analysing spacial structure can be a general means of investigating the structure and function of cities. It may, in effect, be the common language of the city.

Keywords: space syntax, urban system, London.

1 Some questions and answers about complexity

The first sentence in any discussion about the science of cities usually contains the word "complexity". One of the most obvious forms this takes is the sheer physical and spatial complexity of the city as an object. There is, however, in most urban research, a strange silence on this aspect. The reason is simple: no one knows how to control the physical complexity variable. There is no formal language is which differences between one form of complexity and another can be described with the required rigour and consistency. Without controlling the variable we cannot measure its effects, and what we cannot measure we prefer not to discuss.

Space syntax research about cities seeks to redress this balance. It addresses first a problem of description: how can the physical complexity of the city be described with sufficient rigour and consistency to permit it to be controlled as a variable in research? It proposes an answer that some find initially surprising: that it is best captured by representing it not as physical stuff, but as the system of space created by the physical stuff. This is not as odd as it sounds. Buildings are physical things, but their purpose is to create the spaces and interconnections that we use. The effect of every physical intervention is to create or modify these space patterns. Cities may be aggregates of physical stuff, but space is the universal medium which holds the physical stuff together and gives it its overall form.

On the basis of spatial representations (it turns out that more than one are needed) of the city, space syntax then asks one question: does the form the spatial complexity of the city takes make a difference, and if so, what does it make a difference to? It seeks answers by strategy: it analyses a spatial representations of the physical city to try to understands their structure, and then investigates in what ways this structure is related to observable function. To the extent that results are consistent, theoretical explorations become possible. Movement, land use patterns, social and economic performance, crime patterns, and many other aspects of function have all been

investigated using this method, with results that suggest that its may be possible to think of it as a general means for investigating the relation between the structure and function of cities. Space may indeed be the common language of the city.

2 The focus on emergence

In dealing with detailed spatial structure, then, space syntax offers a new approach to modelling the city, one which reflects the origins of space syntax in architecture, with its need to answer questions about the precise impact different design choices about physical and spatial structure are likely to have in the real world, rather than in planning. The question addressed by space syntax research is always: what, if any, is the effect of the built environment in itself on what happens in cities. The approach can be contrasted with policy-oriented urban research which seeks to understand what variable, including built environment variables, are involved in seeking overall social goals (such as energy conservation), the answers to which are more likely to be found in regulation or behavioural change rather than through change to the built environment, with the protracted time scales that entails.

But although the space syntax research programme originates at the architectural scale, the questions is a addresses are increasingly relevant to cities as global objects in the way in which we now see them: that is, not as once-for-all planned objects in a stable end-state, but as complex global structures which emerge from innumerable local decisions over a long time scale. In seeking to describe and analyse space, space syntax seeks to understand the emergent structure of the physical city, and to account for both its constructive functional logic and its functional impacts. Although the main applications of space syntax today (120 projects in the past 10 years through UCL's Space Syntax Laboratory) are in predicting the likely effects of architectural and urban design choices, all this is predicted on its prior ability to analyse urban spatial structure in a way which is informative about function. Without theoretical knowledge at this level, applications would be guesswork.

3 Analysing emergent complexity

Research which seeks to investigate the impacts of built environments in themselves requires the built environment variables to be controlled with much greater precision than would be normal in policy-oriented research. The level of precision is easy to specify. It is the level at which design decisions are made in real world projects.

Taking a spatial approach allows to do this. Space syntax models work by taking some pattern real space—in cities usually the full street network—and analysing it using simple mathematical tools that typically relate all elements to all others up to some limit. We call this approach "configurational", defining this as the study of relations which take into account other relations in a complex (Hillier, 1996a; Chapters 1 and 3). This simple strategy turns out to be quite unexpectedly powerful in detecting patterns in what might otherwise appear as inchoate complexity. For example, Fig.1 is a representation of part of the street network of London as the "fewest and longest" (i.e. street names are irrelevant) lines that cover the system. As so often with spatial structures in grown cities, there appears to be no obvious geometric order, or indeed any other kind, until we take into account the shading from dark to light, which indexes mathematical values derived from taking each line in turn and calculating the "complexity distance" (that is the minimum number of intervening lines that must be used, in whole or in part, to go from that line to others) up to three lines away. We call the measure "local integration": the darker the line the more integrated, and vice versa.

To any one who knows London, the degree to which this simple spatial calculation identifies functionally significant patterns in the urban grid is startling. For example, not only does it identify the most "integrated" line as Oxford Street, London's main shopping street, but it also picks up many of the main local shopping centers that lie on the key edge to center lines in and out of London. It also picks up, to an uncanny degree, a second level of routes, the sinuous, nearly straight routes which Londoners typically use to go grow one part of London to another, rather than from edge to center. London, it seems has a spatial logic which is intimately connected to how it functions and how it is used by people.

These are interesting structures, then, but so far they are only pictures. Do they actually make any functional sense a more rigorous level? It turns out that they do, and in many different ways. To understand this, we must explain any result of space syntax research, one that seems to be implicated in many other results: that the pattern of spatial integration is in the urban grid is a prime determinant movement patterns if the system. This sound simprobable, so the type of study that leads to the conclusion needs to be explained.

4 A key result

The technique is simple. An axial map of an urban area and its context(which must be large enough to account for the pattern of movement into and out of the area) is constructed and analysed. The analysis assigns a range of numerical values, including integration at different radii, to each line element. Observations are then made at different times of day of movement flows along each line segment by counting people passing through imaginary "gates", and expressing these as flows per hour through that gate(see left inset in Fig. 1). The values for the lines derived from the spatial analysis then compared to the movement flows by simple and multiple regression. The right inset in Fig. 1 then shows the degree of agreement between local integration and average pedestrian movement rates in part of the City of London, with an R-squared of 0.71. This is a fairly typical result. In most studies of pedestrian movement, the best performing spatial variable is " local integration", with R-squared values usually between 0.65 and 0.8, depending on the smoothness of the built forms surface, that is the degree to which the built forms and infrastructure which attract and generate the movement are uniformly distributed throughout the grid. Where they are not——for example there is a main shopping street——then normally this extra attraction will have occurred on a key movement line, and the multiplier effect that the extra attraction has on movement is captured by logging the movement variable. The degree of transformation required to linearise the movement variable in relation to the spatial variables indicates the degree to which extra attractors are present in the system. Similar results also exist for vehicular movement(Penn, 1998; Hillier, 1999).

These results are now supported by dozens of similar studies, mainly of pedestrian movement, in different parts of the world, showing that under normal circumstances(see below) the spatial configuration of the urban grid is in itself a powerful factor in determining movement flows. Some key studies are reported (Hillier, 1987; 1993; Peponis, 1990; Read, 1997). The robustness of this relation is tested at least once a month in the work of the Space Syntax Laboratory, since most design applications involve a movement study. For example the recent World Squares for all masterplan of the Whitehall area of London with Sir Norman Foster, including the re-engineering of Trafalgar Square, was done on the basis of a syntactic study of the spatial structure and pedestrian movement patterns in the area.

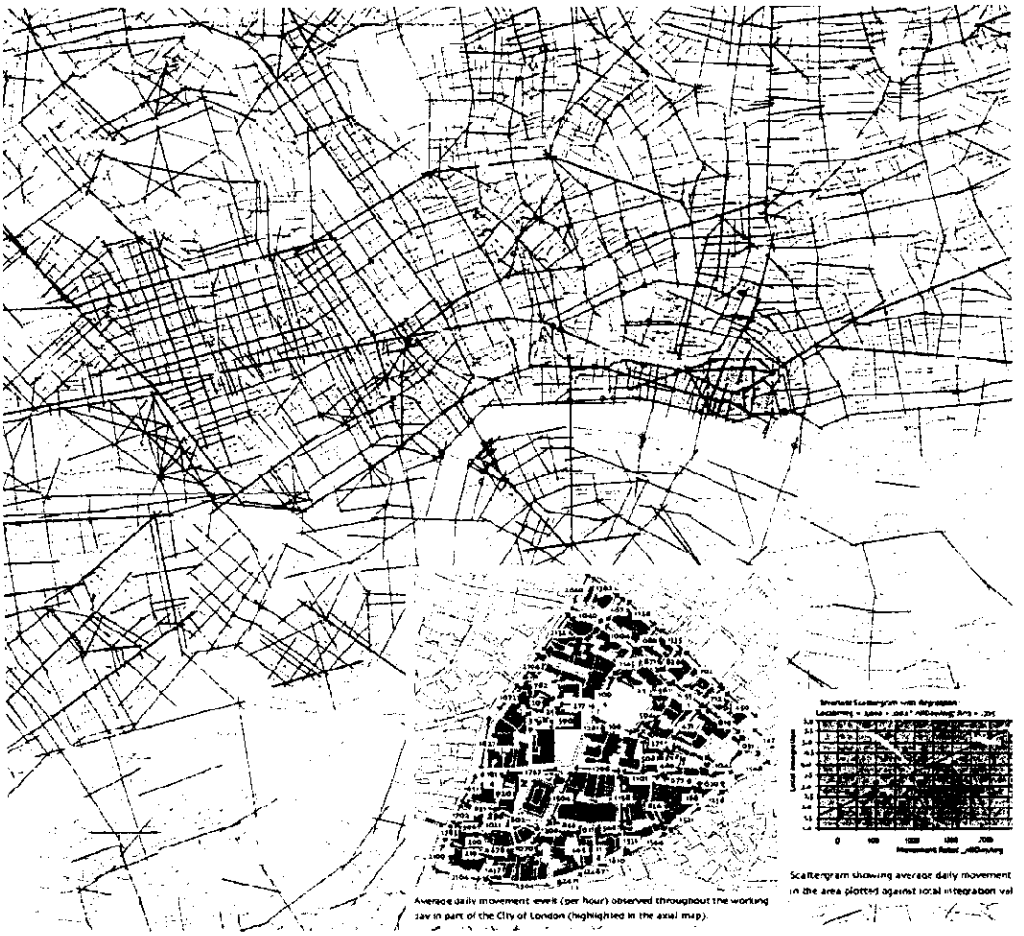

Fig.1 Part of the least line axial map of London analysed for its pattern of local integration. The lines are coloured from black and dark grey for the most integrated to light grey for the most segregated

5 Theoretical developments

The purpose of this research, however, has never been to build a model for accurately predicting pedestrian or vehicular flows, but to estimate the degree to which the urban grid configuration in itself influences movement. It is the independent effect of the built environment, and more specifically of its spatial structure, that we seek to clarify. From the results we have, two theoretical propositions have been developed concerning the nature and functioning of urban grids, both of which have proved of great usefulness for design. The first is the theory of natural movement, which proposes that to the degree that the distribution of the built forms which generate and attract movement in an area is homogeneous, then, other things being equal, movement in the spatial system linking the buildings will be determined by the grid configuration itself (Hillier, 1993). The "natural movement" in a system is thus the proportion of observable movement along lines that is produced by the structure of the grid itself rather than special attractors. There is a problem of course. Surely movement will itself attract attractors? This leads to the second theoretical proposition: the theory of the "movement economy"(Hillier, 1996a).

This proposes that there is a "central dynamic" to the spatial growth of cities, which links the evolving grid structure and its natural movement to the distribution of land uses and built form densities, and even gives rise(though in different ways in different "spatial cultures") to the local area structures that are found in historically grown cities. The mechanism is that as the accumulation of new built forms creates new spaces in the expanding settlement, the emerging structure of the spatial pattern gives rise to a natural movement pattern. Land uses which seek movement, such as markets and retail, then naturally gravitate towards higher movement locations, while others equally naturally prefer low movement locations. The added attractors in the high movement spaces then creates a multiplier effect on movement, which then attracts more, and more diverse, movement-seeking uses, and vice versa. In this way, the settlement pattern naturally evolves towards a seamless network of busy and quiet areas, with the busiest in the spatially most integrated areas, the whole process being initiated in the first place by the spatial configuration of the grid. While the theory of natural movement notes a regularity, the theory of the "movement economy" tries to account for the process by which the apparent affinity between grid structure, movement, land uses and even building densities appears(as Fig.1 suggested) to arise in naturally evolved urban grid like London. Seen in this way, the plan of a town or city ceases to be an insert physical thing, and becomes a structural record of a dynamic historical process.

6 Recent results

Important keys to the current functioning of the city are to be found in these structures which historical processes have deposited. Using the space syntax method to identify and quantify them, a whole range of new urban investigations become possible, most of which (as with the movement studies reported above) essentially involve correlating numbers describing spatial structure with other numbers representing some or other aspect of urban function. In this way we can convert the investigation of the relation between structure and function in cities into an effective research programme.

Using this paradigm for urban study, a number of critical results have been achieved in the last two years:

In a study of 17 informal settlements in Santiago, Chile, it was shown that the significant differences that had been noted between the degrees of development and consolidation of the settlements and their communities since their common foundation was highly influenced by locational and spatial factors. In particular, it as shown that the way in which the settlement was embedded in the local movement network was critical in developing externally orientated informal economic activity, and this then become the driver for economic development with the settlement, and better community and housing consolidation. This study is seen as a clear example of the urban "movement economy" in action(Hillier, 1999).

In a study of urban areas in three UK towns, it was shown that patterns of burglary and car crime were intimately related to the patterning of public space, with more crime occurring in more segregated locations which lacked visual connection and natural movement. In other words, locations which conventional "defensible space" theories expect to be safest turn out to be the most vulnerable, and vice versa(Hillier, 1999).

A comparative study of a late modern low rise social housing estate in north London and a nearby traditional street-based area showed substantial design related differences in the way in people became aware of each other through everyday activity in public area. In the social housing

estate, encounter rates were on a average only one tenth of those in the street area, and spaces became specialised in this use by different types of people——old and young, men and women, adults and children——whereas in the street area most space were used most of the time by all categories of people. Most critically, the design of the social housing area led to the rupturing of that natural surveillance between adults and children that was found in the street-based area, and this was shown to be associated with great vandalism, greater fear, and a poor evaluation of the estate. All these factors were shown to be implicated in the precipitate decline of the social housing estate from prize winning design to problem estate. Key aspects of these results were subsequently duplicated in other studies(Hillier, 1996).

Space syntax was used in studies of the micro-distribution of pollution in an urban area, with particular reference to the exposure of pedestrians to vehicle pollution. An early finding was that within tens of meters of very high pollution streets, rates on local streets were no more than background. The effects of wind were also examined, and again this showed great variation according to wind direction and side of street. Taking all these factors into account, pollution levels were related to traffic flows, and good predictions were obtained from the syntax model, which was experimentally modified to take account of the prevailing wind(Croxford, 1996).

Most recently, studies of the pattern of major and minor centers in towns and cities in the UK have show that detailed spatial structure played a vital role in the development of effective and vibrant centers. In general, it was shown that the pattern of centrality in a settlement is a function of the spatially driven movement economy process(Hillier, 1999).

7 A common language of the city?

The consistency of these result across a wide range of urban phenomena suggest that space may indeed offer something like a common language of their city. Many if not most of the relations between the form of the city and the way it functions seem to pass through space in some sense, and many also involve the space-movement relation. The fact that the most important of our results are about the urban structure itself are also suggestive. Whatever functional phenomenon we pursue, the use of syntactic techniques seem to make some kind of sense out of apparently disorderly urban patterns, and shows they have functionally sensitive structures. It is, it seems, these spatial structures that most characteristics cities, and it is these that relate the form of the city to its function.

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