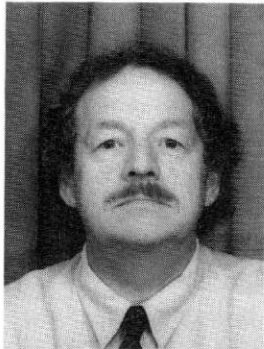


Specifically Architectural Knowledge

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Specifically Architectural Knowledge is a partial account of the ascent from building as cultural transmission to architecture as theoretical concretion. The article is based on a lecture, given at Harvard, 6th October 1990. It has first been published in the *Harvard Architectural Review* Vol. 9 (publishers: Rizzoli, New York).

THEORIES ARE FORMS OF KNOWING that summarise experience into abstract principles, and thus transform the meanings we assign to experience and the way we act on the world. Architects use theories in design, knowingly or unknowingly, not only because the creation of forms must reflect how the designer understands the world, but also because architecture, unlike everyday building, seeks as yet unknown forms, whose nature cannot, by definition, be predicted from experience.

But what are architectural theories like? Are they intellectual styles, like semiotics or deconstruction, brought into architecture from outside and interpreted within architecture? Or is there also some harder edged sense in which architectural theories are specific to architecture, aiming to explain architectural phenomena as

well as to guide design? Are architectural theories, in short, theories *applied* to architecture or are there also theories *of* architecture.

In this article, I argue that theories *of* architecture exist, and they are to be found not in the changing intellectual context of architecture as a bookish appendage to practice, but within the practice itself, guiding the answers to kinds of questions that arise at the point of design. Architecture, I will argue, is an intrinsically theoretical act. The key to architectural theory lies, I will suggest, not in the invocation of external abstractions, but in a proper understanding of the processes and products of architecture.

I will argue my case for specifically architectural theory using the problem of space as a specific instance. Architects and builders already use theory-like constructs in creating built space,

and I will try to show that it is possible to develop a much fuller theory of space, with some pretence to objectivity, and capable of augmenting our intuitions in explaining and predicting forms, and also capable of refutation. I will argue that although such theories challenge architects with much more powerful and precise tools of analysis than they have had before, they do not lead to constraint but to liberation. Better theories of space mean more freedom because they bring the 'deep structures' of architectural and urban space into the realm of rational debate and creative intuition.

In this article I will first try to distinguish architecture from building in such a way as to show how theory is central to its practice. Then I will look at the issue of space, first as a philosophical problem, then as an aspect of buildings, then as an architectural phenomenon. I will then turn to the theory of space itself and suggest that space has its own internal laws, and that it is only when these are properly understood that space can be fully a part of architecture. Finally I will draw some inferences on how this view of theory affects our view of architecture as science and as art.

Systematic intent of the architectural kind

First, how is architecture theoretical? Let us begin with some elementary semantics. If we try to unpack the ways we use the word 'architecture', it seems to refer both to an activity and a thing, that is, to the activity we call 'design' and to buildings where we note evidence of this activity. Does this imply, as it seems to, that 'architecture' is not really an 'objective' property of buildings, but only a record of a certain kind of activity?

This is a difficult question, of a kind familiar to philosophers and aestheticians, who often ask whether words like 'beautiful' refer to intrinsic properties of things, or are more akin to words like 'appropriate' which clearly do not refer to intrinsic properties of things, but judgements that we make by comparing things to other

things. (1) (2) Putting the question their way we might ask whether 'architecture' is actually a property of architectural objects, or a judgement that we make about objects, aware that they are the result of architectural activity.

Let us try to throw light on this by looking at cases where deciding what is and is not 'architecture' is particularly difficult – say, in looking at the origins of architecture, or at where to draw the line between architecture and the vernacular. A colleague of mine (3), in reviewing the archaeological record for the origins of architecture, suggested that we see architecture in the evolution of buildings when we see evidence of 'systematic intent'. By this she meant deliberate abstract thought applied either to construction or to space arrangement or to visual organisation, either at the level of the building or the settlement.

This is an interesting and persuasive definition. But if we try to generalise it we encounter problems. Suppose, for example, that we try to use it to distinguish architecture from 'the vernacular'. It doesn't work, because clearly the vernacular is full of systematic intent. To make the matter even more difficult, the demarcation between architecture and the vernacular shifts with time, in that aspects of the 'architecture' of one generation may re-appear as the vernacular of another, and vice versa. These difficulties really do begin to make it look as though architecture is not at all an intrinsic property of things but a judgement that we make about things in the light of other knowledge.

However, if we look a little more closely at the vernacular we find new possibilities. The outstanding work of Henry Glassie on vernacular housing adapts from Noam Chomsky a concept he calls 'architectural competence', which, he argues, underlies the architectural consistencies and variations by which we recognise a vernacular tradition. For Glassie, 'architectural competence' is a set of technological, geometrical and manipulative skills relating form to use, which constitute 'an account not of how a house is made, but of how a house is thought... set out like

a programme ... a scheme analogous to a grammar, that will consist of an outline of rule sets interrupted by prosy exegesis'. (4) Glassie's analogy with language is apposite. It suggests that the rule sets the vernacular designer uses are often tacit and taken for granted in the same way as the rule sets that govern the use of language. They are ideas we think with rather than ideas we think of. The proposal that the evidence of 'systematic intent' that we note in the vernacular might have its origins in some such 'rule sets' seems a compelling one.

The implication of Glassie's idea is that 'architectural competence' provides a set of normative rules about how building should be done, so that a vernacular building reproduces a known and socially accepted pattern. The house built by a builder sharing the culture of a community comes out right because it draws on the normative rules that define the architectural competence of the community. Buildings become part of what Margaret Mead calls 'the transmission of culture by artefacts'. (5) Through distinctive ways of building, aspects of the social knowledge distinctive of a community are reproduced.

Now whatever architecture is, it is clearly not simply the transmission and reproduction of social knowledge through building, though it may include that. But this does suggest where the difference between architecture and building might lie. What we mean by architecture surely is building not by reference to culturally bound competences. What we mean rather, is building by reference to a would-be universalistic competence based on general comparative knowledge of architectural forms and functions, and aimed, through understanding of principle derived from comparative knowledge, at innovation rather than cultural reduplication. The judgement we make that a building is architecture arises when the evidence of systematic intent is evidence of intellectual choice and decision exercised in a field of possibility that goes beyond cultural idiosyncrasy and into the realm of principled understanding. It is when we see in buildings evidence of this concern for the abstract

comparability of forms that building is transcended and architecture is named.

We may then generalise and say that building is transcended and architecture is named where we note as a property of buildings evidence not only of systematic intent, but of theoretical intent, at least in embryonic form. In this sense architecture transcends building in the same sense that science transcends the practical arts of making and doing. It introduces into the making of buildings a more abstract concern for the realm of architectural possibility created through theoretical concern. In this sense, architecture is theory applied to building.

The demarcation between the vernacular and architecture is then no longer problematic. The reproduction of existing forms, vernacular or otherwise, is not architecture because that requires no exercise of abstract comparative thought. But by the same criterion the exploitation of vernacular forms in the creation of new forms can be architecture, because it does involve such thought. Architecture is thus both a thing and a judgement. In the form of the thing we detect evidence of systematic intent of the architectural kind. From the built evidence we can judge both that a building is intended to be architecture and, if we are so inclined, that it is architecture.

Space as a philosophical problem

Now space, I will argue, is one of the primary means by which the ascent from building as cultural transmission to architecture as theoretical intent is made, and is therefore one of the prime targets for architectural theory. This is to say that one aspect of the abstract comparability of forms in architecture centres on spatial form, and this implies that space is, in some important sense, an objective property of buildings.

This is not obvious. Most of our common notions of space do not deal with space as an objective entity in itself but tie it in some way to human agency. For example, laymen I talk to about my interest in space will tend to transcribe 'space' as the 'use of space', or the 'perception of space', or 'concepts of space'. Space as a thing

in itself is harder to communicate. Common spatial concepts in architectural discourse are also similarly tied: personal space, human territoriality, spatial scale, and so on.

Even in architectural concepts of space where space is unlinked from direct human agency, we still find that space is not independently described. The concept of 'spatial enclosure' for example describes space by reference to the physical forms that define it. Without them, the space vanishes. This tendency finds its extreme expression in writers like Roger Scruton who think that the concept of space is a rather silly mistake made by rather pretentious architects, who have failed to understand that space is not an entity at all, but merely the obverse side of the physical object, the vacancy left over by the physical building. For Scruton, it is self-evident that space in a field and in a cathedral are the same thing except insofar as the interior built surfaces of the cathedral create the impression that the interior space has distinctive properties (6). All talk about space is in error, because it can be reduced to talk about physical objects.

In fact, this is a quite bizarre view, since at a practical level, space is manifestly the saleable commodity in buildings. We build walls, but we sell and rent space. Are developers who advertise space at so much per square foot making a category mistake? Should they be offering to rent walls and roofs? Why then is Scruton embarrassed by the concept of space? Let me suggest that Scruton is making an educated error, one that he would not make if he had not been so deeply imbued with the western philosophical tradition (7).

The dominant view of space in western culture has been one we might loosely call the 'Galilean-Cartesian'. By this I mean that the primary properties of objects are seen as their extension – length, breadth, width and so on – which are also their measurable properties. Extensions are the indubitably objective properties of things, independent of observers, unlike 'secondary' properties like 'green' or 'nice' which seem to depend in some way on interaction with ob-

servers. Now if extension is the primary property of objects, then it is natural to infer that it is also the primary property of the space within which objects sit. We can see this by the fact that when we take the object away from its space its extension is still present as an attribute of space. Space is therefore generalised extension, and as such the framework within which the primary properties of objects are defined (8).

Once we see space as a general abstract framework or background of extension, then we are doomed not to understand how it plays a role in human affairs, including architecture. Space is never simply the inert background of our material existence. It is a key aspect of how our social and cultural worlds are constituted in the real world, and structured for us as 'objective' realities. Space is not the neutral framework for social and cultural forms. It is built into those very forms (9). It is because this is so that buildings can carry within their spatial forms the kinds of social knowing that Glassie notes.

Space as a pattern problem

But because space is built so pervasively into social and cultural life, we tend to take it for granted to the point where its forms become invisible to us, so much so that we have no rational language for the discussion of these forms. The only language is that of the forms themselves. If we wish to build a theory of space, then, we must first learn this language – although in a sense we know it already – and learn to talk about space in a way that allows its form to become clear.

Let us begin by defining the problem clearly: as a *pattern* problem. Consider the two notional 'courtyard' buildings of **Figures 1a & b**, showing in black the pattern of physical elements. **Figures 2a & b** then show in black the corresponding pattern of spatial elements.

The basic physical structures and cell divisions of the two 'buildings' are the same, and each has the same pattern of adjacencies between cells and the same number of internal and external openings. But the locations of cell entrances

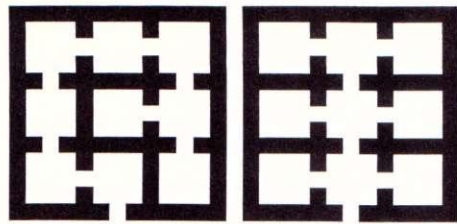


Figure 1a Figure 2a
Arrangements of physical elements into structures

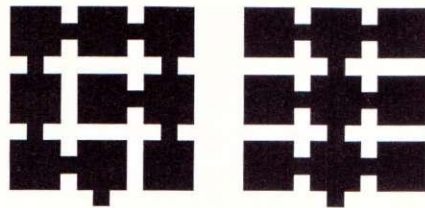


Figure 1b Figure 2b
Arrangements of spatial elements into structures

means that the spatial patterns are about as different as they could be from the point of view of the permeability of the layout. One is a near perfect single sequence, with a minimal branch at the end. The other is branched everywhere about the strong central spaces.

Now the pattern of entrances would make relatively little difference to the building structurally or climatically, especially if we assumed a similar pattern of external fenestration, and inserted windows wherever the other had entrances onto the courtyard. But it would make a dramatic difference to how the layout would work as, say, a domestic interior. For example, it is very difficult for more than one person to use a single sequence of spaces. It offers little in the way of community or privacy, but much in the way of potential intrusion. The branched pattern, on the other hand, offers a more flexible set of potential relations between community and privacy, and many more resources against intrusion. These differences are inherent in the space patterns themselves in terms of the range of limitations and potentialities offered. They suggest the possibility that architectural space might be subject to limiting laws, not of a deterministic kind, but such as to set morphological bounds

within which the relations between form and function in buildings are worked out.

We can capture the difference between the two spatial patterns by a useful device we call a justified graph. **Figure 3a & b.** In this we imagine that we are in a space which we call the root or base of the graph, and represent as a circle with a cross. Then, representing spaces as circles, and relations of access as lines connecting them, we align immediately above the root all spaces which are directly connected to the root. Then above the first row we align the spaces that connect directly to first row spaces, and so on. The result is a picture of the 'depth' of all spaces in a pattern from a particular point in it.

We can see that one is a deep tree form, and the other a shallow tree form. By 'tree' we mean that the patterns lack any rings of circulation. All trees, even two as different as in the two in Figure 3, share the characteristic that there is only one route from each space to each other space – a property that is highly relevant to how building layouts function.

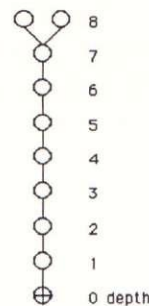


Figure 3a

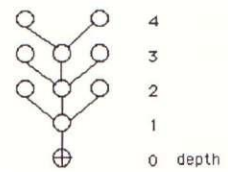


Figure 3b

However, where 'rings' are found, the justified graph makes them as clear as the 'depth' properties, as in **Figure 4a, b & c.**

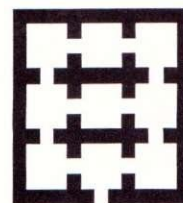


Figure 4a

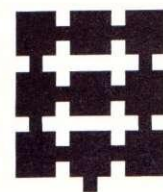


Figure 4b

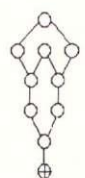


Figure 4c

Using justified graphs, then, we can begin to make visible two of the most fundamental properties of spatial configurations: how much depth they have from each space, that is how many other spaces must be passed through to get to others; and how each space relates to the pattern of circulation rings in the pattern, that is, how it relates to the choices of route available.

More significantly, we can now take the crucial step in understanding spatial configuration as a product of culture. The key to spatial configuration in buildings and cities is that within the same building or urban system, space has different configurational properties when looked at from different points of view. This can be shown by drawing justified graphs, because the differences have mainly to do with the way in which depth and rings are distributed in the spatial configuration when seen from different points of view. **Figures 5a and b**, for example, are the same spatial configuration justified from different points.

The depth and ring properties could hardly appear more different if they were different configurations. It is through the creation and distribution of such differences by the arrangement of physical constructions that space becomes such a powerful raw material for the transmission of culture through buildings and settlement forms, and also such a potent means of architectural discovery and creation.

Society in the form of the object

Let me now show how buildings can transmit cultural ideas through spatial patterning. **Figures 6a, b & c** show ground floor plans of three French houses, and their justified graphs drawn initially from the outside, treating it as a single space, then from three different internal spaces. Looking at the first graph (drawn from the outside), we can see that in spite of the geometrical differences in the houses there are strong similarities in the configurations. We can see this most easily by concentrating on the space marked *sc*, or *salle commune*. In each case, we can see that the *salle commune* lies on all non-trivial rings (a trivial ring is one which links the same

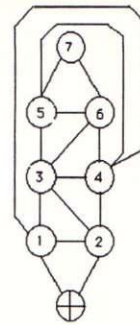


Figure 5a

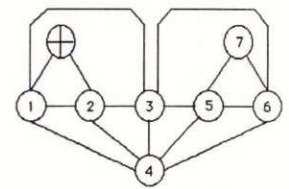


Figure 5b

pair of spaces twice), links directly to an exterior space, and acts as a link between the living spaces and the spaces associated in that culture with the domestic work of women.

The *salle commune* also has a more fundamental property, one which arises from its relation to the spatial configuration of the house as a whole. If we count the number of spaces we must pass through to go from the *salle commune* to all other spaces, we find that it comes to a total which is less than for any other space – that is, it has less depth than any other space in the complex. The general form of this measure (Hillier & Hanson 1984 for mathematical details) is called *integration*, and can be applied to any space in any configuration: the less depth from the complex as a whole, the more integrating the space. This means that every space in the three complexes can be assigned an ‘integration value’. Other measures express how strong these differences are (10).

Now once we have done this we can ask questions about the distribution of functions in the house. In the three French houses, for example, we find that there is a certain order of integration among the spaces where different functions are carried out, always with the *salle commune* as the most integrated. In other words, we can say with quantitative rigour that there is a common pattern to the way in which different functions are spatialised in the house. We call such common patterns ‘genotypes’, because they refer not to the surface appearances of forms but to deep structures underlying spatial configurations and their relation to living patterns.

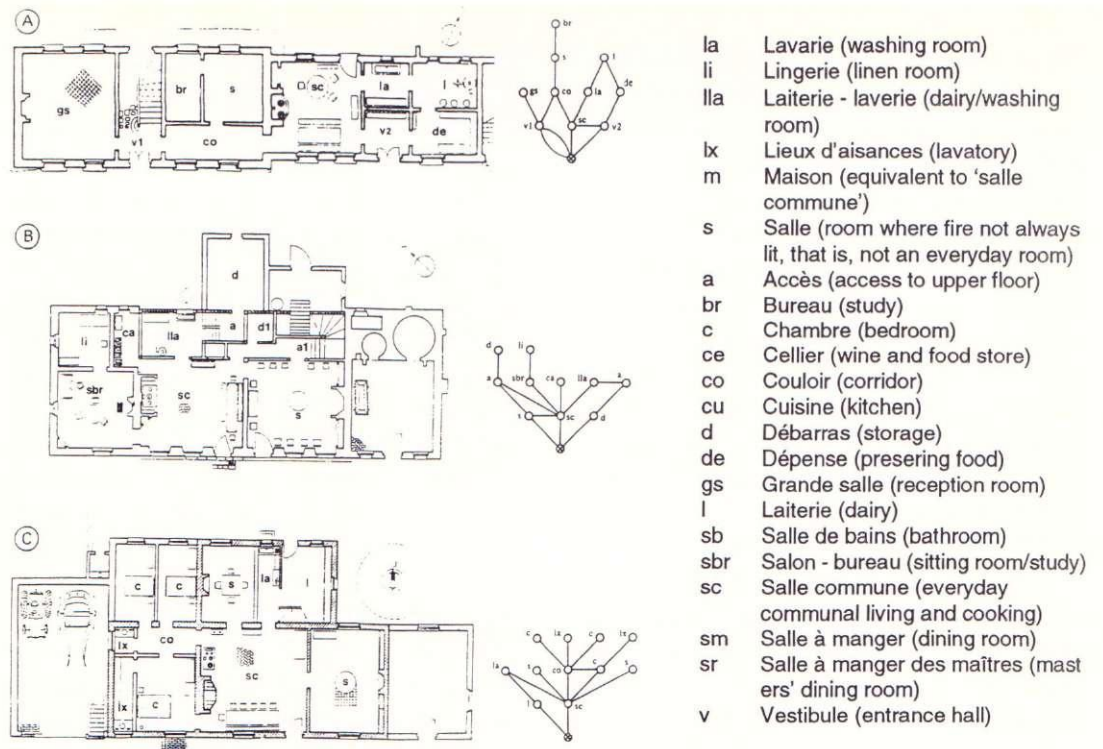


Figure 6 a, b & c.

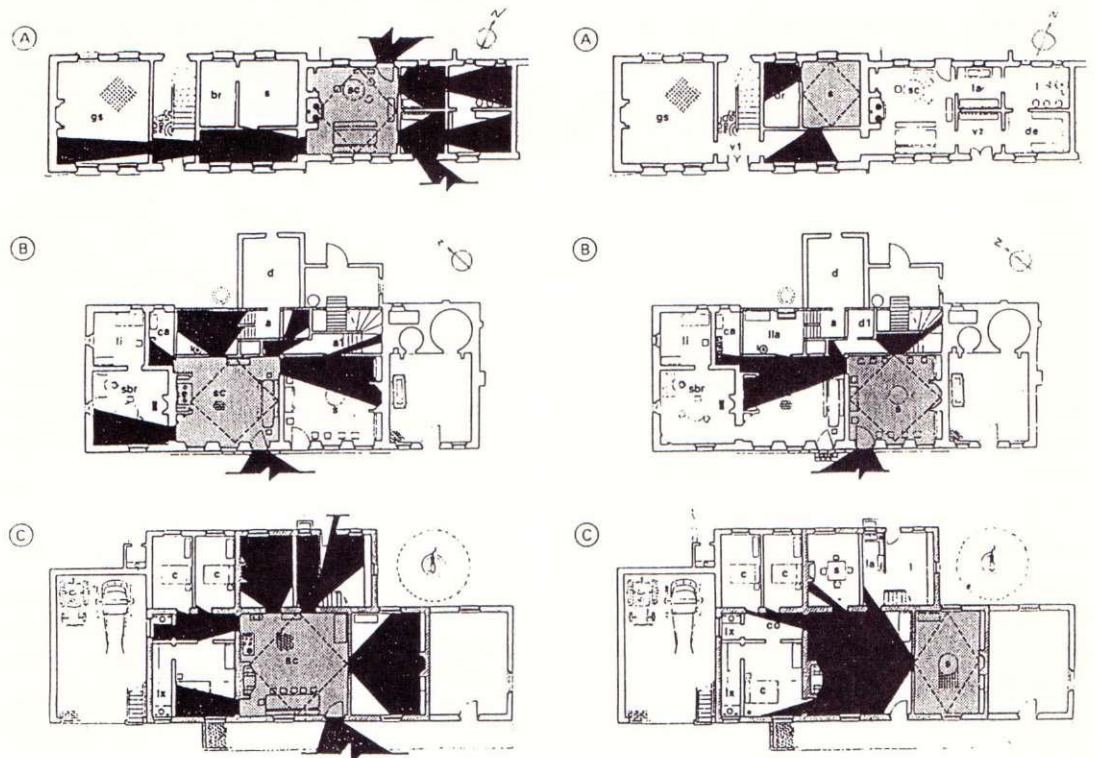


Figure 7 a

Figure 7 b

These results flow from an analysis of space-to-space permeability. But what about the relation of visibility, which passes through spaces? **Figures 7 a & b** show what we call the convex isovists (that is, all that can be seen from a space in which all points are mutually visible, in this case drawn to omit the corners of rooms in a consistent way) from the *salle* commune and another space labelled *salle*. In each case the *salle* commune has a far more powerful visual field than the *salle*. These differences again can provide a basis for quantitative and statistical analysis and subsequent exploration of genotypical cultural patterns that lie embedded in the material and spatial 'objectivity' of buildings.

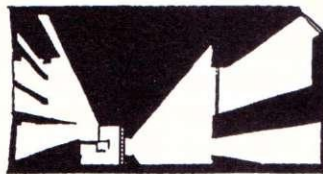
This type of method allows us to retrieve what we might call 'Glassie' properties from house plans, and to formalise the notion of cultural types. We have thus shown both how buildings can transmit social knowledge through their spatial form and how this can be retrieved by analysis. This is clearly useful knowledge for an architect to have. But it is not yet architecture, according to my definition, and certainly not a theory of architecture, even a partial one.

So how does this relate to the definition of architecture proposed earlier? Let me begin by referring you to a study of selected houses by Adolf Loos and Le Corbusier by Dickon Irwin¹ (11). I cannot do justice to the subtlety and complexity of Irwin's argument in this brief text, but I would like to review some of his conclusions. Irwin's analysis of five houses by each of the two architects showed that although in each house there was configurational differentiation of functions, there was no consistent pattern within either architect's work. It was as though each recognised the principle that functions should be spatially differentiated, but that this was regarded as a matter of experiment and innovation, rather than the reproduction of a culturally approved genotype.

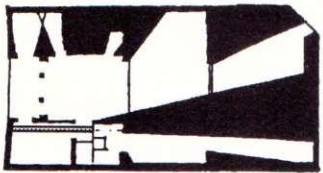
However, what Irwin was able to show was that each architect had a distinctive spatial style, in that whatever each was doing with the functional pattern, distinctive spatial means were

used to achieve the ends. For example, in the Loos houses, adding visibility relations to permeability relations added to the 'intelligibility' (for a definition see below) of the space pattern, whereas in the Corb houses it did not. Similarly, in the Loos houses, the geometry of the plan reinforced aspects of the spatial structure of the plan, in that major lines of spatial integration coincided with focuses of geometric order, whereas again in the Le Corbusier houses it did not. Some of these differences were captured by Irwin in diagrams he called 'line isovists', where he took the most integrated lines in the axial map (see below) of the house and drew all the space that could be seen from them. **Figures 8a** (Loos: Tristan Tzara house) & **b** (Le Corbusier: Villa Stein) show in order the isovists from the two most integrated lines from the point of view of the permeability pattern in each house, followed by the visibility isovists of the two most visibly integrating lines. If we imagine each isovist as an episode in the spatial experience of moving through the houses, we can see that in Loos the isovists are very rich, but relatively uniform, whereas in Corb the isovists are more selective in the spatial relations they show from the line, but each episode is dramatically different from the others.

In this respect, Irwin argues, the two architects are adumbrating more fundamental – almost philosophical – differences through architecture: Loos to create a house which is a novel expression of cultural habitability, Corb to create a less habitable, more idealised domain of rigorous abstraction. Neither Corb nor Loos is denying the social and cultural nature of the domestic interior. But each, by satisfying the need to give space cultural meaning through functional differentiation first one way then another, but with a consistent spatial style, is giving priority not to the functional ends of building but to the architectural means of expressing those functional ends. The genotype of these houses lies, we might suggest, not in the functional ends, as in the vernacular cases, but in the way the architectural means are used to express the ends. But



Loos: fourth floor: permeability isovist



Loos: fourth floor: permeability isovist



Loos: fourth floor: visibility isovist

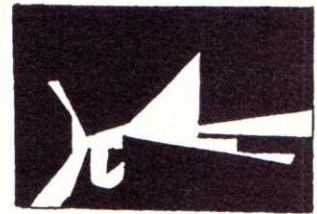


Loos: fourth floor: visibility isovist

Figure 8a

the means modify the ends by re-expressing them as part of a richer cultural realm.

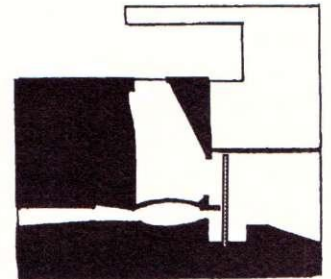
This distinction between ends and means is, I believe, fundamental to the definition of architecture offered earlier. It suggests that we can make a useful distinction, in architecture as elsewhere, between the realm of social meaning and the realm of the aesthetic – in this case the spatial aesthetic. The cultural and functional differentiation of space is the social meaning, the spatial means is the spatial aesthetic. The former conveys a clear social intention, the latter an architectural experience which re-contextualises the social intention. Meaning is the realm of constraint, the spatial aesthetic the realm of freedom. The spatial meaning of form expresses



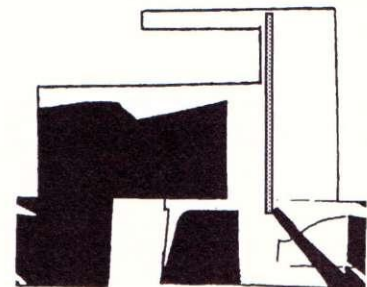
Corb: second floor: permeability isovist



Corb: first floor: permeability isovist



Corb: second floor: visibility isovist



Corb: first floor: visibility isovist

Figure 8b

what architecture must be to fulfil its purpose as a social object, the spatial aesthetic expresses what it can be to fulfil its purpose as architecture.

But although space moves outside the realm of specific codes of social knowledge, it does not lose its social dimension. The relation between spatial and social forms is not contingent, but

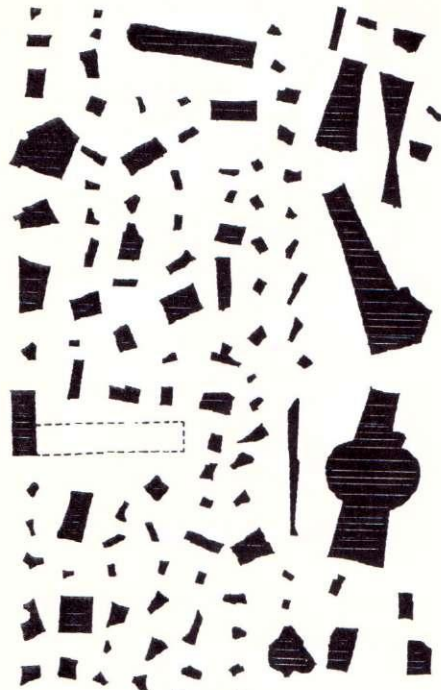


Figure 9a

follows patterns which are so consistent that we can hardly doubt that they have the nature of laws² (12, 13) The spatial aesthetic carries social potentials through these laws. The autonomy of architectural means thus finds itself in a realm governed by general principle, with its freedom restricted not by the specific spatial demands of a culture but by the laws of space themselves.

These laws find one of their strongest expressions in urban space, where the social pro-

gramming of space is much less than in building interiors. However, in looking for the operations and effects of these laws we will find that certain attributes of urban space which many have believed aesthetic in origin in fact arise from functional laws. (14) What these functional laws of space might be like is the theme of the next part of my argument.

The urban grid as an object of architectural thought

There are two factors that make the analysis of urban space especially difficult for configurational analysis. First, urban space is continuous. There is no obvious division into elements. Second, with obvious exceptions, urban space usually has a good deal of irregularity. Most towns and cities have 'deformed grids', with no obvious geometry. Both factors are aspects of the problem of representation: how do we define an element of urban space so that we can subject it to configurational analysis?

It will be useful to begin by looking at a familiar case and considering how we might think of urban grids as spatial patterns. **Figure 9a** shows in black the plan forms of all the open spaces and public squares in Rome, respecting orientation but not location. **Figure 9b** shows their location. **Figure 9c** shows the shapes, orientations, and locations, and adds a further element the full spatial shape visible from each square,

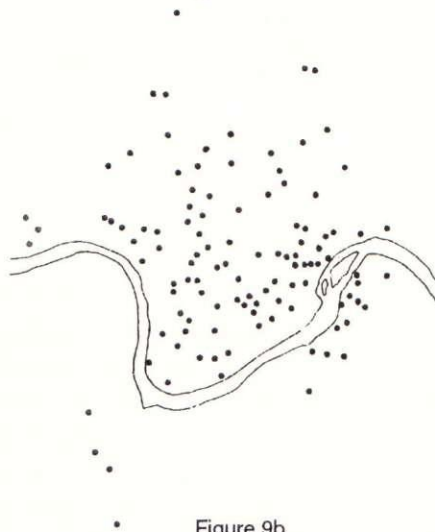


Figure 9b

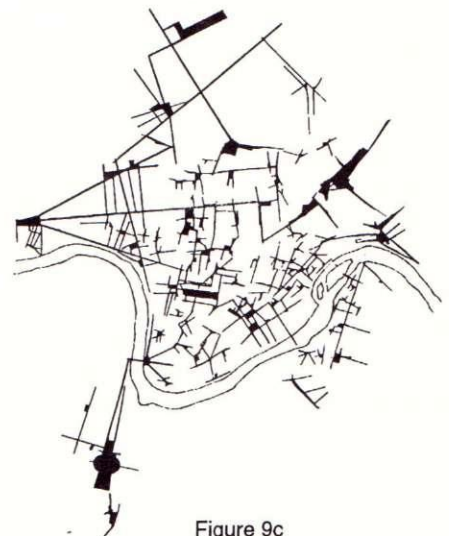


Figure 9c

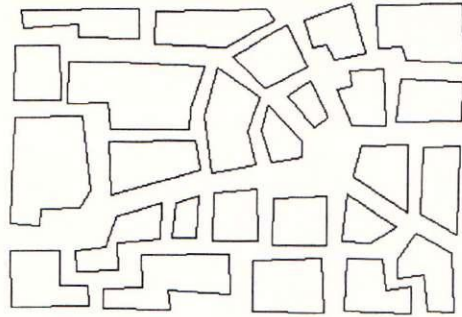


Figure 10a

that is its 'isovist'.³ From this we see that some subsets of the isovists of the spaces form interconnected clumps with more or less continuous visibility and permeability. Others do not. These are pattern properties, arising from the interrelationships of many distinct entities.

How shall we analyse these Roman properties? The complexity of the situation is such that we must recruit the computer, and begin with some simple experiments. **Figure 10a** is a hypothetical arrangement of built urban blocks, creating by their disposition an arbitrary 'deformed grid' with a major square-like space. Although 'deformed', it has a degree of continuity of space which gives it an approximately urban look, unlike **Figure 10b** where the same blocks have been re-arranged to create a pattern that is manifestly not urban. The difference is instructive. It tells us that the 'deformed grids' we recognise as urban may have a good deal of internal order to them.

Like other deformed grids, however, neither hypothetical figure has obvious spatial 'parts' or 'elements'. What then does it have that can be modelled? The answer is that as we move about a deformed grid, it exhibits everywhere local properties which continually change. Just as the shapes of space that were experienced locally in the Corb or Loos houses changed as we moved through the house, so the shape of space we see as we move from point to point in an urban grid also changes.

The question is, how does it change? And can these changes be captured in a representation? The Roman case established several concepts

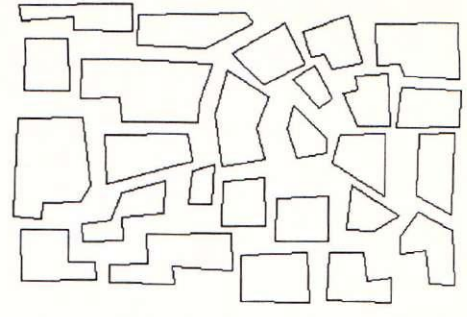


Figure 10b

that may be of use. For example, wherever we are in a deformed grid we are in some maximal convex element of space defined by the surfaces of building blocks. The property of convexity means that any two points that can be seen from a point can also see each other. **Figure 11** is a computer analysis⁴ of **Figure 10a** in which all such convex elements have been identified, allowing them to overlap as much as necessary, and then analysed and coded in terms of how 'deep' each is from all the others: the darker, the less depth, the light the more depth.

In other words, **Figure 11** shows the distribution of 'integration' (as defined before) in the convex representation of the deformed grid of **Figure 10a**, with the darkest elements making up what we call the 'integration core'.

Now let us carry out the same analysis on **Figure 10b**. We find that the pattern of integration has changed completely, as shown in **Figure 13**, with the core moving to the edge and much weaker integration in the central areas. The integration core, one feels, has a much less powerful effect in creating an intelligible pattern to the space structure.

This property of intelligibility can in fact be demonstrated quite formally. If we go back to imagining that we are moving around in the spaces of these two configurations, then we can easily see that the field that we see from points in **Figure 13** will on the whole be a good deal less rich than those in **Figure 12**. Now one way of saying this is that it will be a great deal harder to learn about the space structure as a whole because we get much poorer information from the

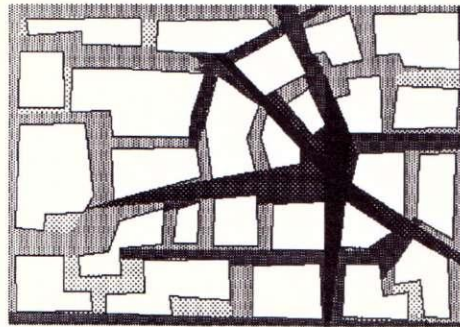


Figure 11

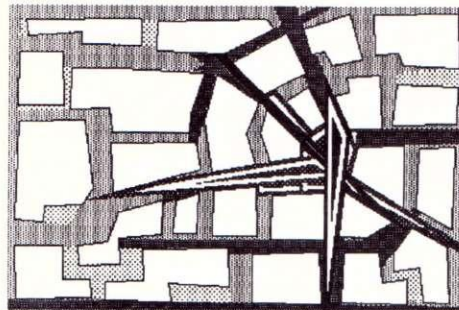


Figure 12

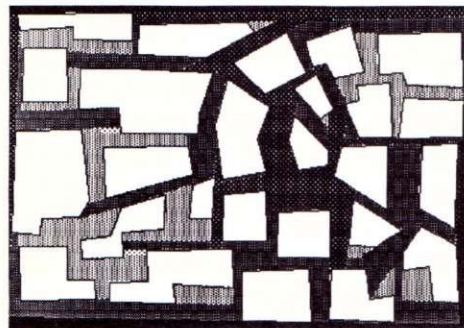


Figure 13

localised parts. Few points in the pattern give much clue to the overall structure of the pattern, and even less to its distribution of integration. In **Figure 12**, in contrast, we get a good deal of global information from local parts, and what we can see from points gives a good indication of how each space fits into the overall system.

This in fact reflects one of the most important pattern characteristics of 'deformed grid' urban space. The information you get locally from the visual field you experience as you move around gives plenty of clues about how the overall spatial system is structured. In intelligible urban

space, one might say, you get global information at the same time as you get local information about spaces, as we saw with the Roman squares.

This vital property of urban space can actually be represented formally and quantified by a simple statistical trick. **Figure 14** is a 'scattergram' in which each point represents one of the overlapping convex elements of **Figure 11** with the number of other convex elements it overlaps with indicated by its position on the vertical axis, and its degree of 'integration' in the overall pattern on the horizontal axis.

The more the points form a straight line from bottom left to top right, then the more the number of connections an element has, (which can be seen from each line), is a reliable guide to its integration in the system as a whole, (which cannot be seen from a line).

This is the formal property we call 'intelligibility'. The tight scatter in **Figure 14** shows that the first configuration has a high degree of intelligibility, and this can be expressed as a number by taking the 'correlation coefficient' of the scatter. A value of 1 would indicate a perfect straight line of points, and 0 a random scatter. If we now look at the scatter for the second configuration, shown in **Figure 15**, we can see that the scatter is much less tight, meaning that it has a lower value and therefore a lower degree of 'intelligibility'. This expresses formally what intuition suggests: that the visual fields you see locally as you move around the second configuration are a poorer guide to the the system as a whole. The space structure is too 'labyrinthine'.

This analysis of the convex organisation of urban space is more than a formal game. It relates to important functional aspects of how space is used. For example, studies have shown that the choices that people make in selecting urban spaces for informal activities, such as eating, drinking, talking and sitting, reflect proximity or adjacency to areas with strong visual fields that are well 'integrated' into the system as a whole. Such spaces are ideally suited to what seems to be the favourite occupation of

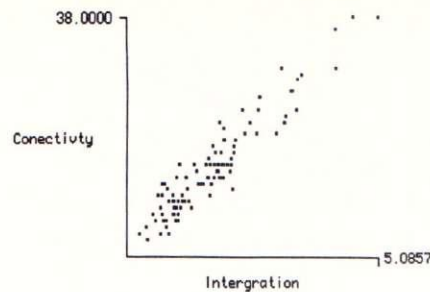


Figure 14

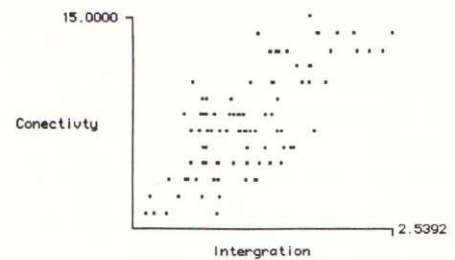


Figure 15

those using urban space informally: watching other people.

However, the most important and consistent functional effect of urban space follows from the configurational analysis of a different representation of its structure: one based on its one-dimensional, or axial, structure. We can again use the computer to explore the basics. The tangled skein of lines in **Figure 16** represents the maximal linear visibility available within the open space structure of **Figure 10a**, namely the set of all straight lines that are tangent to pairs of vertices of building blocks—that is, each line just passes by at least two such vertices, thus drawing a limit of a line of sight.

Once the computer has found this set of lines, it can then subject them to integration analysis and code the results as before as in **Figure 17**, with the darkest lines as the most integrating and showing the integration core of the pattern, and with the lightest the most segregating.

Figures 11 and 17 thus represent different con-figurational views of the block arrangement in **Figure 10a**. Each says: seen in terms of this type of local element, and analysed by that pattern parameter, the global structure of space looks like this. This is the essence of 'space syntax' modelling. It is not a single technique but a set of techniques which allow two questions to be posed: how the spatial system of interest is to be represented as (relatively localised) elements, and how the inter-relationships are to be analysed to identify global patterns, in order to allow us to understand its underlying structure.

Once we have this understanding of structure, we can begin to ask questions about function in

a new way. Because syntactic analysis assigns to each spatial element in a system (however the elements are defined) numbers which index its pattern relations, we can investigate the relation between these patterns and function simply by seeing how far the syntactic numbers assigned to spaces 'correlate' with numbers describing aspects of function in those spaces: movement rates, informal use, rents, land uses, plot ratios, and so on. We can thus pose questions about space and function in a new way. In the case of urban space we can ask: what does function mean when space is universally 'public' and

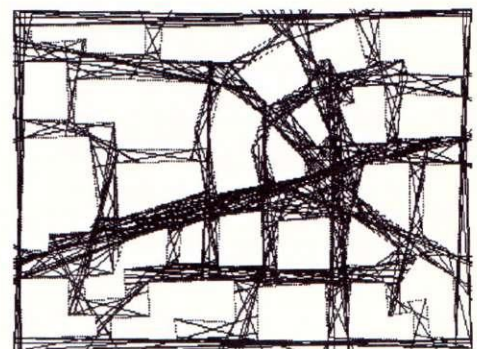


Figure 16

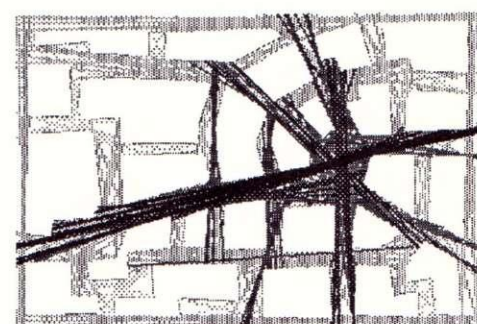


Figure 17

more or less unrestricted? We will receive a re-sounding answer: urban space is about movement. Urban space creates a field of movement and thus co-presence and potential encounter among people.

We can show this by using again the scattergram technique. **Figures 18-20** analyse the pedestrian and vehicular movement for an area of north London. The high degree of correlation in **figure 19** (the correlation coefficient is 0.85 on a scale of 0 to 1) shows that the numbers of people passing along each line are largely a function of the spatial pattern itself. The same is true of vehicular movement, whose scattergram shows a correlation of 0.81 in spite of the existence of a number of one-way systems (**figure 20**). The fundamental result is that the pattern of movement in an urban system is determined in the main by the spatial configuration itself, and in particular by the distribution of spatial integration in the axial map of the system.

These results are quite fundamental to our understanding of urban space, since they show that it is the *architecture* of the urban grid itself that is chiefly responsible for the pattern of movement, not the positioning of 'attractors' and 'magnets' as has commonly been believed. These results have been repeated so often that we have little doubt that they are something like a law. However, the law does not simply say that movement in a grid is a function of the distribution of spatial integration in the grid. The relationship, it turns out, is subject to the degree to which the grid has the property of intelligibility, as defined earlier. If you make urban space unintelligible, then you are also likely to make it unpredictable. We call this the theory of *natural movement*. Natural movement is the proportion of movement determined by the architecture of the grid itself. Where there is no natural movement, then most space will be empty for most of the time, leading almost inevitably to one aspect or another of urban malfunction. This is the reason why we must once again learn to make the urban grid an object of architectural thought.

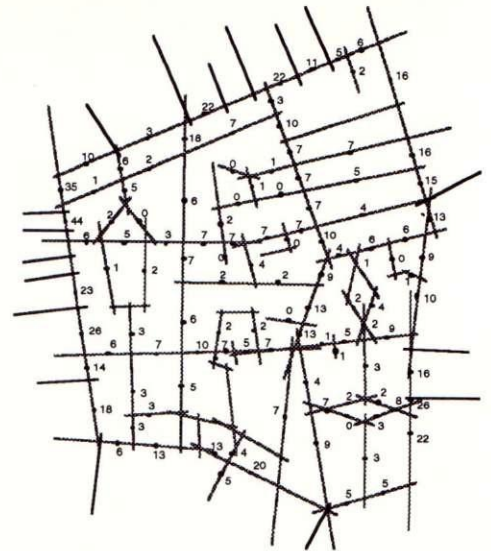


Figure 18

Because natural movement is fundamental, it is also reasonable to suppose that it accounts to a great extent for the way in which urban grids evolve. It is likely that over time a dynamic relation develops between the evolving urban grid, its natural movement patterns and the developing pattern of land uses. Certain types of use, for example retailing, survive best in locations which are both accessible and have through movement – that is, in locations that have both the spatial properties and functional effects of integration. The result is that over time, urban grids evolve not only to optimise patterns of mutual accessibility but also to optimise the usefulness of the by-product of movement from place to place – that is, the spaces that must be passed through on journeys from all origins to all destinations. Through this mechanism, spaces which are accessible for to-movement also become those with strong through-movement, and these spaces then become the busy focuses of urban life. We call this the theory of the *movement economy*. If it is right, it means that the architecture of the urban grid is of far greater significance in urban evolution than has been allowed in planning theory, and provides further reason for bringing back the urban grid as an object of architectural analysis and creativity.⁵

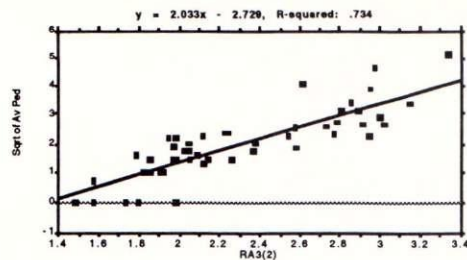


Figure 19

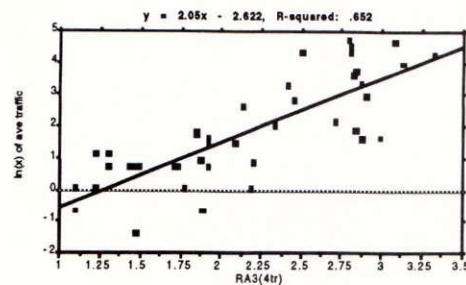


Figure 20

Designing with space syntax: the Kings Cross masterplan

What does all this imply for design? Let us proceed through a real case study: the design by Norman Foster Associates of the masterplan for the Kings Cross development in inner London for the London Regeneration Consortium. Kings Cross is currently the biggest urban development project in Europe. Our published research using space syntax to predict pedestrian movement patterns, and the involvement of space syntax in public inquiries on major urban redevelopment schemes, had alerted first the community groups, then the masterplanners and developers to the potential of using space syntax to help solve the fundamental problem of the Kings Cross site: how to design the development in such a way that it continued and related the urban structures of Islington to the east of the site and Camden to the west. Natural pedestrian movement to and through the site was seen as essential to this aim. Foster Associates, backed by the developers asked us to make a study, and work with the design team in trying to build these relationships into the masterplan.

The first step was to study the spatial structure and space use and movement patterns in the existing contextual area. This study is documented in **Figures 21–27**. From a design point of view, the key product of the study is a spatial model of the contextual areas of the site, verified by its power to ‘post-dict’ the existing pattern of movement around the site. This allows us to add design proposals to the model, and re-analyse to see how each proposal is likely to work within, and affect, the urban context.

We can therefore begin to explore intuitions as to what kind of masterplan will most successfully adapt the existing structure of the area and create the levels of natural pedestrian movement requested by the designers. This will depend on two spatial objectives being achieved: bringing adequate levels of integration into the site in a way that reflects and adapts the existing natural movement patterns in the area; and maintaining or if possible improving the level of intelligibility in the grid.

There is, however, a technical problem with the formal definition of intelligibility. Because intelligibility measures the degree of agreement between the local and global properties of space, a small system is, other things being equal, more likely to be intelligible than a larger one. We can overcome this by bringing in a database of established London areas of different sizes to compare with Kings Cross as it is now and as it will be when it is developed. **Figure 28** shows that not only is the Kings Cross area less intelligible than London areas in general, but also the small area is relatively less intelligible than the large. This is probably because the ‘urban hole’ created by the Kings Cross site has a stronger impact on the area immediately around it than it does on the larger surrounding area.

We can now use the area axial map as a basis for design simulation and experimentation. In fact, what we will be doing in this text is conducting a number of experiments which explore the limits of possibility for the site.⁶

Let us first suppose that we impose a regular grid on the site, so that it has a local appearance

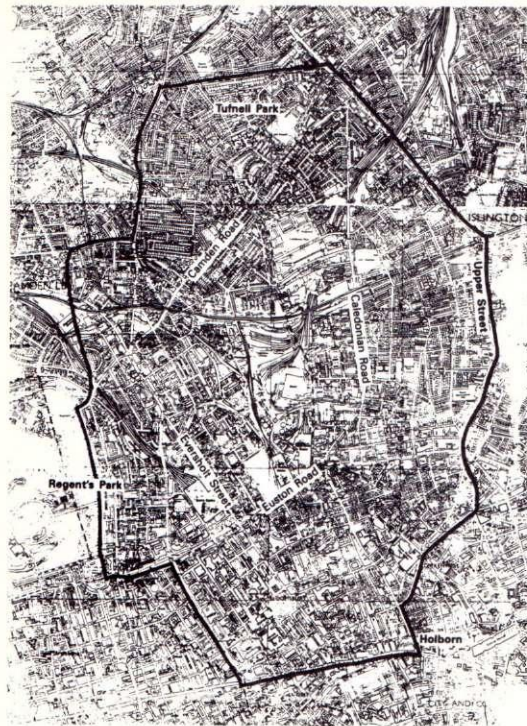
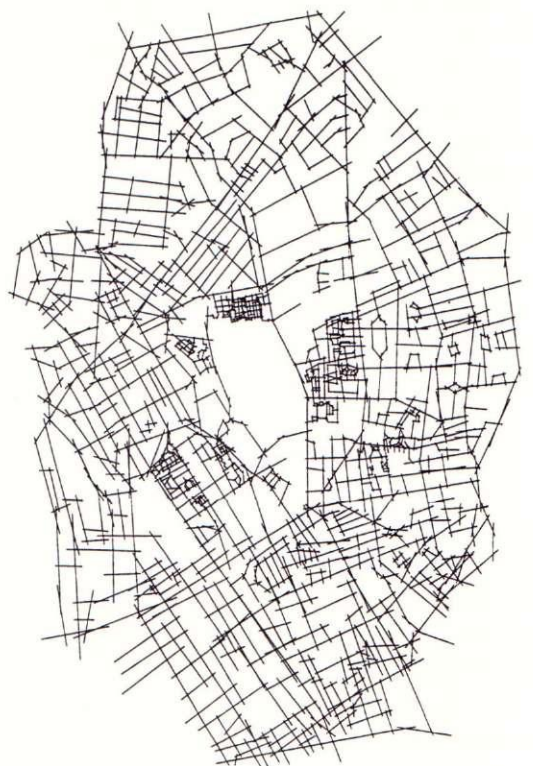


Figure 21. Ordnance survey map of part of the 15 km sq of north London surrounding the Kings Cross site studied for the Kings Cross project. Because natural movement is most strongly affected by the large scale spatial pattern of an area, the contextual study area for a new development must be large enough to cover the likely pedestrian catchment area of the development, but it must also cover the catchment area of the catchment area, in order to ensure accuracy in the investigation of the catchment area. These two levels are modelled separately as the 'small area' – usually about 5–6 km sq – and the 'large area' – up to 20 km sq – both to check that the two levels are giving the same story (large cities have no natural internal boundaries) and also to ensure that any 'edge effect' – that is distortion in the analysis resulting from the fact that some parts are close to the edge of the area modelled – is kept to the edge of the large area, and does not affect the immediate contextual area of the site.



Figure 22. A 'black-on-white' representation of figure 21, showing all the space of public access in black. The small-scale complexes around the site are public housing estates.

Figure 23. An 'axial map' of figure 22, showing the least set of longest straight lines of sight and direct access that pass through all the public space shown in the previous figure. The 'axial map' is the model of the area analysed by the computer to establish its underlying patterns. Of these the most important is 'integration', that is the mean 'depth' of each line from all others in the system. The 'integration value' of a line (or an intersection) is measured according to the number of other lines that must be used to go from that line to every other in the system.



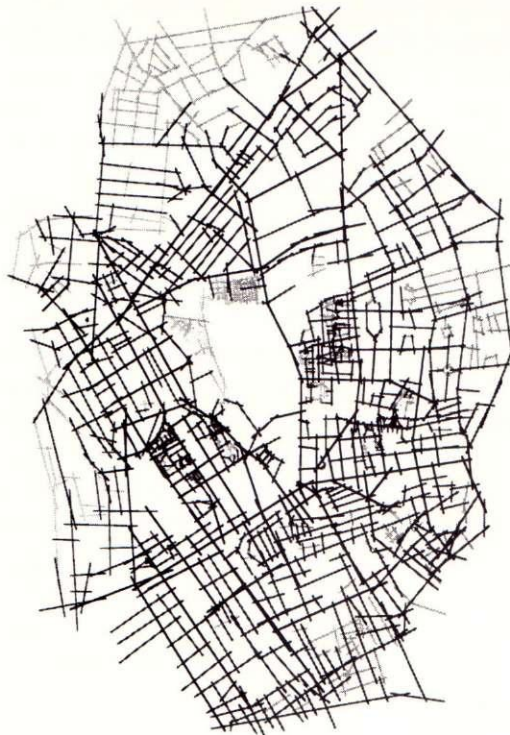


Figure 24. The axial map analysed in terms of its distribution of 'integration', with the most integrating lines shown darkest graded towards the least integrated lines shown lightest. Since 'integration' predicts natural movement, one can think of the blackness of the line as giving a prediction of the amount of movement down that line.

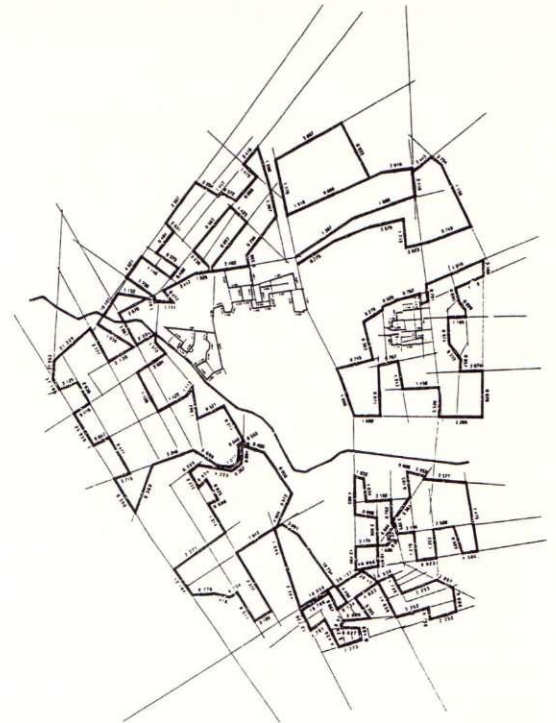


Figure 26. A map showing 239 line segments in 10 areas around the site where pedestrian space use and movement was observed using a simple moving observer technique, and distinguishing only between moving and static pedestrians, and between men, women and children.

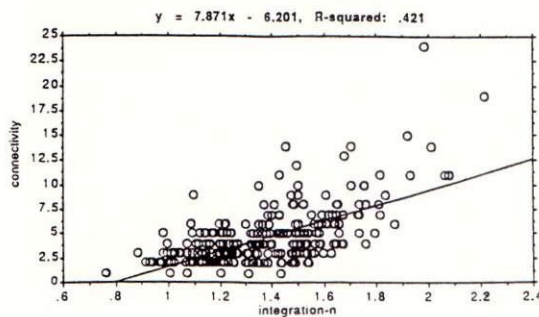


Figure 25. An 'intelligibility scattergram' of the area as it stands, in which each line in figure 24 is represented as a dot and located on the horizontal axis according to its degree of 'integration' (a global property which cannot be seen from the line) and on the vertical axis according to its degree of 'connectivity' (a local property which can be seen from the line). The 'index of intelligibility' is the square root of the number at top right. The scattergram shows a rather poor level of intelligibility, partly due to the hole in the system caused by the current Kings Cross site.

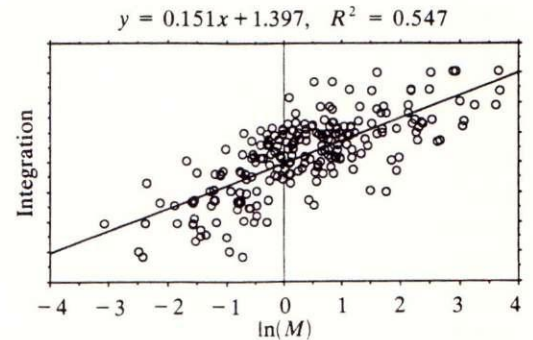


Figure 27. A scattergram showing each observed line in figure 23 as a dot located on the vertical axis according to its degree of integration and on the horizontal axis according to the observed rate of pedestrian movement along the line. The 'correlation coefficient' is 0.74, showing how strongly the pattern of urban grid itself influences the pattern of movement.

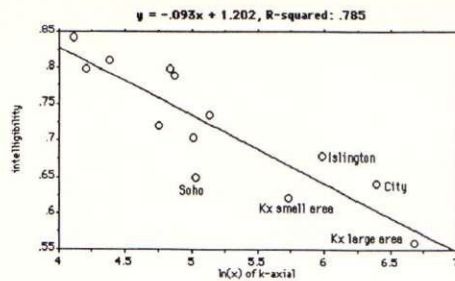


Figure 28

of being ordered but makes no attempt to take advantage of the existing, rather disorderly pattern of integration in the area (Figure 29).

In spite of its high degree of *internal* connection, the scheme acts as a substantial lump of relatively segregated spaces, rather like one of the local housing estates shown in Figure 22, which freeze out virtually all natural movement and create a quite unnerving sense of emptiness.

In other words, the 'grid' scheme completely fails to integrate itself into the area or to contribute to the overall integration of the area. The effect on intelligibility is no better. We can see this by plotting the intelligibility scattergram and using the space syntax software to locate the spaces of the scheme on the scatter. Figure 30 shows that the scheme's spaces form a lump (within the box) well off the line of intelligibility, and occupying the segregated and rather poorly connected part of the scatter. We conclude not only that the scheme is far too segregated to achieve good levels of natural movement, but also that its spaces are insufficiently integrated for their degree of connection and therefore that they worsen the intelligibility of the area as a whole.

Still in the spirit of experimentation, let us now try the opposite and simply extend integrating lines in the area into the site, and then complete the grid with minor lines more or less at will. This means that instead of imposing a new conceptual order onto the site regardless of the area, we are now using the area to determine the structure of space on the site.

In spite of its unrealism, the experiment is instructive. Figure 31 shows the integration structure that would result from such a scheme. In

effect it shows that certain lines extended across the site would become the most integrating lines in the whole area, stronger even than Euston Road (the major east-west trunk road passing south of the site – which would be the major integrator with respect to an area expanded to the south and west). We also find a substantially greater range of integration values in the development, in contrast to the much greater uniformity of the grid scheme.

This is a 'good' urban property. Mixing adjacent integration values means a mix of busy and quiet spaces in close association with each other, with the kind of rapid transition in urban character, that are typical of London. Figure 32 shows a much improved intelligibility scattergram, with the lines of the scheme picked out in bold, showing that they not only improve the intelligibility of the area, but make a good linear – and therefore intelligible – scatter themselves.

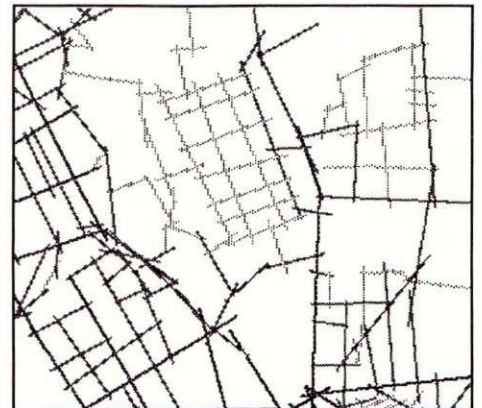


Figure 29

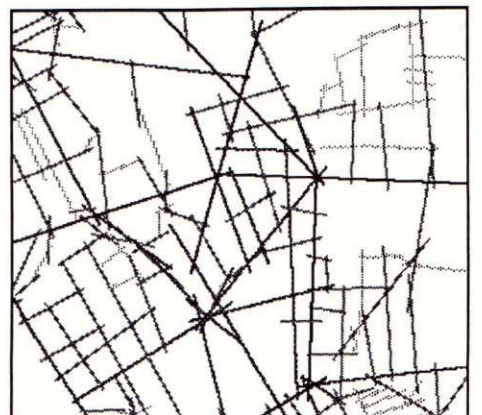


Figure 31

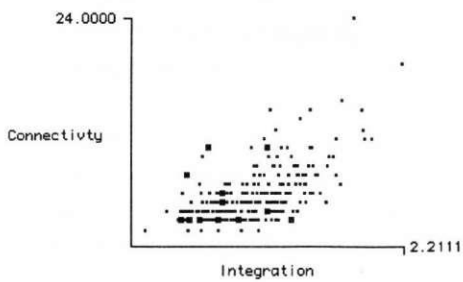


Figure 30

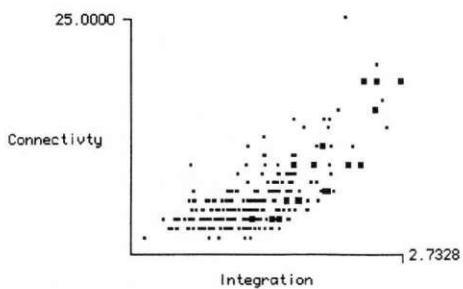


Figure 32

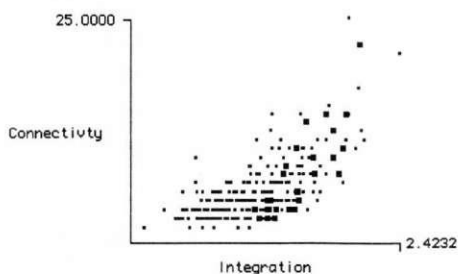


Figure 37

Now if we plot these two hypothetical solutions on the London database of intelligibility (Figure 33), we find that whereas the grid leaves the area as poor in intelligibility as it was, still lying in more or less the same position below the regression line, the 'superintegrated' scheme moves well above the regression line, and would even be above the line formed by Islington and the City. We might even conclude that we had overdone things, and created too strong a focus on the site for the mixture of commercial and residential development envisaged.

The final Fosters masterplan, working as it did within the concept of a central park to bring democratic uses into the heart of the site, is a much more subtle and complex design than

either of these crude illustrative experiments. In developing the design, a protracted process of design conjecture and constructive evaluation through space syntax modelling took place, much of it round the drawing board. The final masterplan (Figure 34-37) draws integration in and through the different parts of the site to a degree that matches the intended land use mix, which goes from urban office city and shopping areas where levels of natural movement need to be high, to quieter residential streets where they will be lower.

The intelligibility scattergram shown in Figure 37, again with the masterplan lines picked out on bold, shows that the scheme again improves the intelligibility of the area, and also has high internal intelligibility, seen in the linear scatter of the masterplan lines. But the scheme also has more continuous variation from integrated to segregated than the 'superintegrated' scheme, with its markedly more lumpy scatter. This indicates that the local variation in the syntactic quality of spaces, arising from mixing integrated and segregated lines in close proximity, is also better achieved.

This is confirmed by the overall intelligibility index. Figure 38 shows that the scheme falls

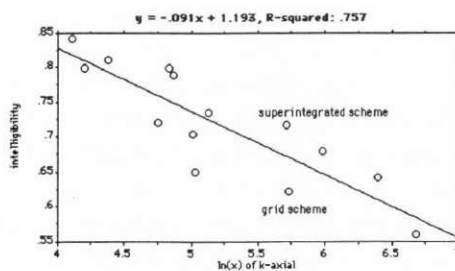


Figure 33

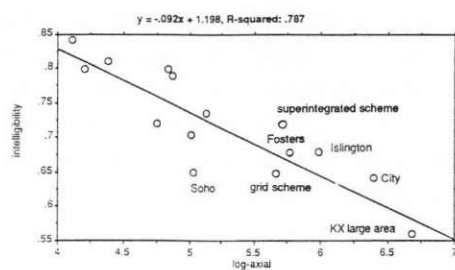


Figure 38



Figure 34

very slightly above the 'regression line', meaning that it continues the established level of intelligibility in the London grid.

Thus the design team can not only use space syntax to experiment with design in a functionally intelligent way, but they may also use the system to bring to bear on the design task both detailed contextual knowledge and a relevant database of precedent. We think of this as a prototype 'graphical knowledge interface' for designers – meaning a graphically manipulable representation that also accesses contextual knowledge and precedent databases relevant to both the spatial structure and functional outcomes of designs. The experience of using space syntax on Kings Cross and other urban masterplans has convinced us that what designers need from research is theoretical knowledge, coupled to technique, not 'information' or 'data', or 'constraint', and that with theory and technique much more of the living complexity of urban patterns can be brought within the scope of architectural intuition and intent, without subjecting them to the geometrical and hierarchical simplifications that have become the common-places of urban design.

Space syntax

as a partial theory of architecture

If these are the implications for design, what then are the implications for specifically architectural knowledge and specifically architectural theory? There are two issues here. One concerns the forms that architectural theories and architectural knowledge take, the second how we conceptualise the relation of knowledge to design.

On the first, it seems to me vital that space syntax theories are expressed in architectural form. By this I mean that theoretical knowledge is brought to bear on the design through a form of representation which is directly architectural, not only in the sense that it actually copies, and allows manipulation of, aspects of architectural forms, but also in the sense that it carries within itself, through theory, knowledge of functional consequences. Syntactic representations are *theoretical descriptions* (17), in that like buildings themselves, they are spatial forms with functional implications. Syntactic theories are architectural not only in the sense that they are about architecture, but also in the sense that they are in the language of architecture.



Figure 35

On the second, the relation of knowledge to design, let us review the 'ascent' from the vernacular to architecture. What we have seen is a series of levels at which we find theory-like entities in architecture. There is the level of the abstract social knowledge built into the 'architectural competences' that underlie the vernacular. Then there is the level of the abstract typological comparison of forms. Then there is the level of general theoretical propositions, such as the theory of natural movement.

Now what is clear from the design application is that the most useful form of abstraction for design is the third level, that of general theoretical propositions, because it is only at this level that strategic design thinking on, say, how a socially desirable functional outcome of design such as the integration of a new neighbourhood, might be achieved. It is also clear that theories generated by space syntax do not enter a theoretical void, but challenge theoretical ideas which already hold the field. Thus, in different ways, space syntax theory challenges 'territoriality', 'defensible space', 'spatial enclosure', 'legibility through landmarks', geometrical theories, and a whole panoply of urban ideas which currently play the role of theory in urban design. Space syntax even challenges how design questions are defined. For example, a current debate in Europe is the degree to which future development should be based on the past. In historic centres for example, there is a widespread fear of doing anything except 'keeping the old street system' in spite of the obvious criticism that the street system to be conserved was created by a dynamic process of growth and change as each generation modified what it inherited to meet its needs and passed it on to the next generation. Conservation leads to the paradox that to freeze this process at one point in time to conserve a specific form would be anti-historical, since it would conserve a product but violate the process that gave rise to the product.

Space syntax redefines this question by making the issue one of genotype rather than phenotype. We can ask not whether we should pre-

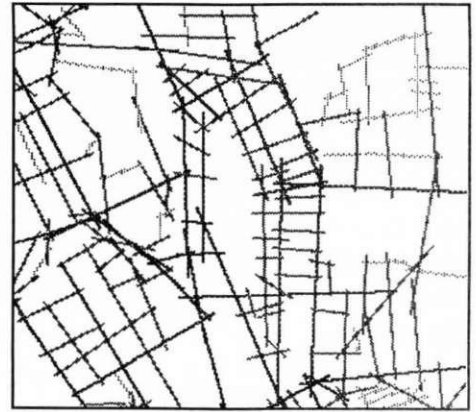


Figure 36

serve specific forms, but whether we should preserve the underlying principles of specific forms in the light of present needs, or adapt in the direction of a new genotype. History is replete with examples of both, in that, as cities evolve they can change their genotypes as well as their phenotypes (18). What history does not offer is a precedent for the current fashion of phenotype conservation.

By showing how we can understand urban space genotypes, space syntax does allow the genuine continuation of a historical tradition without necessarily copying its surface forms. It does so by suggesting what is essential and what is inessential in the structures of the past. The Kings Cross masterplan is a genotypical continuation of the logic of London. Yet it resembles no known part of London. It extends the deep structure of the existing grid, not its surface structure.

The tighter forms of reasoning permitted by space syntax thus have a liberating effect, precisely because they allow us to oppose the superstitious following of an established vernacular with abstract reason about forms and their functional consequences within an evolving structure. The intervention of theory in effect permits us to set the argument about history at the level of the evolutionary process that generate the architecture of the city, rather than at the level of its specific products. The 'theoretical ascent' from the vernacular as social reproduc-

tion to architecture as the knowledgeable exploration of form through theory – even partial theory – is thus also an ascent from social constraint to liberation. Design can seek its goals not within the stultifying constraints of particular forms of social knowledge (which nevertheless can be and must be understood) but within the limits posed by the laws of architectural and urban space, and their realisation within a particular context.

Architecture as science

This redefinition of theory in terms of liberation is not obvious. At first sight, theories seem to be abstract schemes of thought that constrain rather than liberate. They appear to fix the mind in a certain way of looking rather than opening up new possibilities. However, this is to misunderstand the nature of theories, and their potential in architecture.

For a scientist, a theory means an abstract model through which the phenomena available to experience can be related to each other in such a way that their nature and behaviour as phenomena seem to have been accounted for. But scientific theories only count if they have two kinds of clarity: the internal structure of the theory must be clear; and the reference to phenomena must be clear. These two conditions create the possibility of refutation, and refutability is the morality of science. If a theory does not predict what can be seen to be the case, or fails to predict what is the case, then we must eventually give up the theory and try another. We must also give up a theory if a simpler one explains the same phenomena. There is an aesthetics as well as a morality in science.

At first sight, architectural theories appear to be rather different. An architectural theory is usually presented as a set of precepts which, if followed, would lead to architectural success. The prime aim of an architectural theory thus seems not to be to explain architectural phenomena, but to guide design. We might therefore be tempted to conclude that architectural theories are 'normative' rather than 'analytic' – that is, they

tell us how the world should be rather than how the world is – and are therefore not subject to the strict rules that govern scientific theories.

Although architectural theories do come in a normative mode, this by no means implies that they are not also analytic. On the contrary, it implies that they are. The only possible justification for a normative architectural theory is that the theory will work because this is the nature of architectural phenomena. Theories from Alberti to Le Corbusier in fact make profound and far reaching assumptions about human nature, about perception, about behaviour, as well as about the nature of architectural order. It cannot be otherwise. All normative architectural theories are also, perhaps covertly, analytic theories.

The difference between scientific theories and architectural theories is not then, I suggest, a difference in type but a difference in clarity. It has never been possible to have architectural theories which have the two kinds of clarity – of internal structure and of reference to phenomena – that are the precondition for refutability. This is why architectural theories can be refuted by life, but not by analysis. One useful effect of space syntax is that it takes certain aspects of architectural theory a little way in the direction of the two kinds of clarity. The structure of reasoning is clear, and the reference to phenomena is clear. The propositions of space syntax can therefore be shown to be wrong – and theoretically wrong – by reference to evidence. Life is right, of course, and only life can eventually decide. But it is possible that with theories that have the two kinds of clarity more of life can be brought to bear on our theorising at the design stage.

Architecture as art

– that is, as theoretical concretion

Does this mean then that the line between architecture as science and architecture as art needs to be redrawn closer to science? I do not believe so. We can call on the beautiful ideas of Ernst Cassirer on the relation between art and science.

'Language and science', he writes, 'are the two main processes by which we ascertain and determine our concepts of the external world. We must classify our sense perceptions and bring them under general notions and general rules in order to give them an objective meaning. Such classification is the result of a persistent effort towards simplification. The work of art in like manner implies such an act of condensation and concentration ... But in the two cases there is a difference of stress. Language and science are abbreviations of reality; art is an intensification of reality. Language and science depend on one and the same process of abstraction; art may be described as a continuous process of concretion ... art does not admit of ... conceptual simplification and deductive generalisation. It does not inquire into the qualities or causes of things; it gives the intuition of the form of things ... The artist is just as much the discoverer of the forms of nature as the scientist is the discoverer of facts or natural laws.' (19)

Those of us who believe, as I do, that science is on the whole a good thing, accept that science is in one sense an impoverishment – though in others an enhancement – of our experience of the world in that it cannot cope with the density of situational experience. It has to be so. It is not in the nature of science to seek to explain the richness of particular realities, since these are, as wholes, invariably so diverse as to be beyond the useful grasp of theoretical simplifications.

What science is about is the dimensions of structure and order that underly complexity. Here the abstract simplifications of science can be the most powerful source of greater insight. Every moment of our experience is dense and, as such, unanalysable as a complete experience. But this does not mean to say that some of its constituent dimensions are not analysable, and that deeper insight may not be gained from such analysis.

This distinction is crucial to our understanding of architecture. Architectural realities are dense, and as wholes unanalysable, but that does not mean to say that the role of spatial configuration (for example) in architectural reali-

ties cannot be analysed and even generalised. The idea that science is to be rejected because it does not give an account of the richness of experience is a persistent but elementary error. Science gives us quite a different kind of experience of reality, one that is partial and analytic rather than whole and intuitive. As such it is in itself that it is valuable. It needs to be accepted or rejected on its own terms, not in terms of its failure to be like life or like art.

It is in any case clear that the dependence of architecture on theories, covert or explicit, does not diminish its participation in Cassirer's definition of art. (20) This is true both in the sense that architecture is, like art, a continuous process of concretion, and also in the sense that, like art, 'its aspects are innumerable'. But there are also differences. The thing 'whose aspects are innumerable' is not a representation but a reality, and a very special kind of reality, one through which our forms of social being are transformed and put at risk. The pervasive involvement of theory in architecture, and the fact that architecture's 'continuous concretion' involves our social existence, define the peculiar status and nature of 'systematic intent of the architectural kind': architecture is theoretical concretion. Architects are enjoined both to create the new, since that is the nature of their task, but also to render the theories that tie their creation to our social existence better and clearer. It is this that makes architecture distinct and unique. It is as impossible to reduce architecture to theory as it is to eliminate theory from it.

Architecture is thus both art and science not in that it has both technical and aesthetic aspects but in that it requires both the processes of abstraction by which we know science and the processes of concretion by which we know art. The difficulty and the glory of architecture lie in the realisation of both: in the creation of a theoretical realm through building, and in the creation of an experienced reality 'whose aspects are innumerable'. This is the difficulty of architecture. And this is why we acclaim it.

Notes

1. A student on the MSc in Advanced Architectural Studies at the Bartlett in 1989.
2. In the two cited papers, it is suggested that there are three types of spatial law: type 1 are limiting laws which govern the constructibility of usable spatial patterns, and give rise to the fundamental analytic properties like depth and rings; type 2 are laws through which social forms express themselves in space, for example through the integration of certain types of function and the segregation of others, as seen in the French houses; and type 3 are laws through which spatial forms produce specific social effects, for example, the effect of axial patterns on movement and thus on patterns of the natural co-presence of people in space, as set out in the next section.
3. This set of figures is taken from a study of Roman space by Marios Pelekanos, a student on the MSc in Advanced Architectural Studies in the Bartlett, University College London in 1989.
4. All the computer programmes used here form part of the 'Space syntax' software developed by N. Dalton of the Unit for Architectural Studies at the Bartlett, University College London, with funding from the Science and Engineering Research Council and our industrial partner, t² solutions Ltd.
5. These issues are dealt with at greater length in a series of recent papers on natural movement (reference 15), the movement economy (reference 16) and the urban design implications of both (reference 17).
6. In the real situation, the experimentation took a rather different form, and was more oriented to real design ideas and constraints. The experiments here are therefore illustrative, not historical.

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 14. For example, Camillo Sitte, Gordon Cullen. Even the Krier brothers are strongly influenced by this tradition.
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