RICS COBRA Conference 6th – 8th September 2006

Space, society and construction refurbishment

Space, society and construction refurbishment

John Kelsey

Bartlett School of Construction and Project Management, Faculty of the Built Environment
University College London, Wates House, 22 Gordon Street, LONDON WC1H 0QB
j.kelsey@ucl.ac.uk

Abstract

Researchers in the Space Syntax group at UCL have shown distinct sets of patterns relating spatial configurations and observed movement within the built environment. They have also demonstrated how patterns of control and exclusion are implied by spatial organisation. Analytical tools have been developed to measure the extent of these patterns and so enable comparative analysis of different spaces. Axial analysis subjects grids of spaces to modelling through long lines of sight to create axial maps whose properties have been found to be associated with both pedestrian and vehicular movement, in particular, low levels of wayfinding complexity. Visibility Graph Analysis uses areas of visibility from individual points as a basis for mapping the inter-relationship of spaces and associated movement and space use by pedestrians within and between buildings. Such tools have wide application. An example is presented through the examination of the problem of phased construction refurbishment in a combined railway and retailing environment and the effect of such works in reshaping the spatial characteristics of an ongoing business which depends upon public access. Previous research findings are confirmed and demonstrate the usefulness of Space Syntax analysis in predicting the effect of spatial disruption in a commercial environment.

Key words: Space Syntax, Refurbishment, Retailing, Railways, Business disruption

Space research at the Bartlett School of Graduate Studies

In the main building of UCL there stands the figure of Jeremy Bentham to whose vision (mostly) we owe the founding of our university. One of Bentham's more controversial ideas was the Panopticon - a prison designed to allow the maximum number of prisoners to be kept under surveillance by the minimum number of (unseen) guards. Such an idea was attacked by Foucault (1975) as representative of modern institutions which use spatial layout to exercise social control.

Whatever the merits or otherwise of the Panopticon, it is appropriate that there is a group of researchers in UCL who, for over 20 years, have been looking at the interrelationship of society with the spaces created by the built environment. Much of the work of the Bartlett involves researching and teaching the planning of urban communities together with the design/construction of buildings and the management of projects. However the 'Space Syntax' group have been involved in examining how the existing built environment is both affected by and itself affects society.

In particular they have looked at the way both the spaces within and the spaces between buildings are shaped by and shape the activities carried on within or around those buildings - especially the pattern of vehicular and pedestrian flows in the urban environment. They deliberately use the term 'syntax' to point to an analogy with language. Humans learn from a very early age to put words together in a certain way to make meaningful sentences. The spaces created by the built environment have a set of interrelationships. As with the syntax of human language these show patterns which can be investigated and analysed.

At one level these spatial relationships can be seen as both expressing and helping to conserve (or disrupt) particular social relationships (Hillier and Hanson 1984). At another level, observation of how people move to and through these spaces can reveal something of the way individuals navigate through space and perceive some spaces to be preferable to others (Penn 2001, Hillier and Iida 2005). Much of the analysis which follows presents abridged and simplified versions of arguments set out in Hillier and Iida (2005) and Turner *et al*. (2001).

Method 1 - Axial analysis

Let us take an example of a small group of streets as in Figure 1. Here the blocks represent buildings which extend right up to the pavement. The intervening space represents both road and pavement space. The edges of the whole have to be 'closed' in order to form a boundary to the system.

Now the aim is to draw the fewest number of connected straight lines which can cover the whole street area. This forms the 'axial map' which is used for analysis. These are represented by the dotted lines in Figure 1. The process of doing this is rather more complicated than can be described here (Turner *et al*. 2005) but Figure 1 will serve as a good approximation.

A small street grid

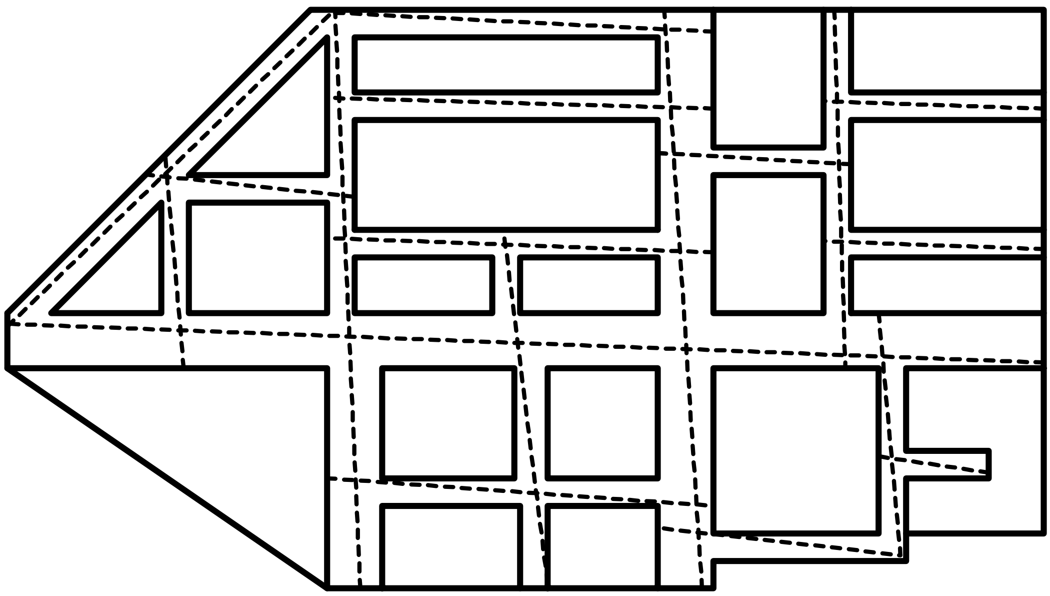

Figure 1

It is important to note that the lines are not the central lines of the road grid. They represent long(est) lines of visibility from particular points. While in practice, using the central lines of the road (parallel with the building edges) might produce a similar result, Space Syntax is used to analyse both cities and buildings with far more irregular patterns than shown in Figure 1. It is essential to have rules (based on visibility) which adequately cover all such cases.

Having obtained the basic axial amp of an urban area, it can then be represented as a network in the form of a (mathematical) graph as in Figure 2.

Graph representation of the street network

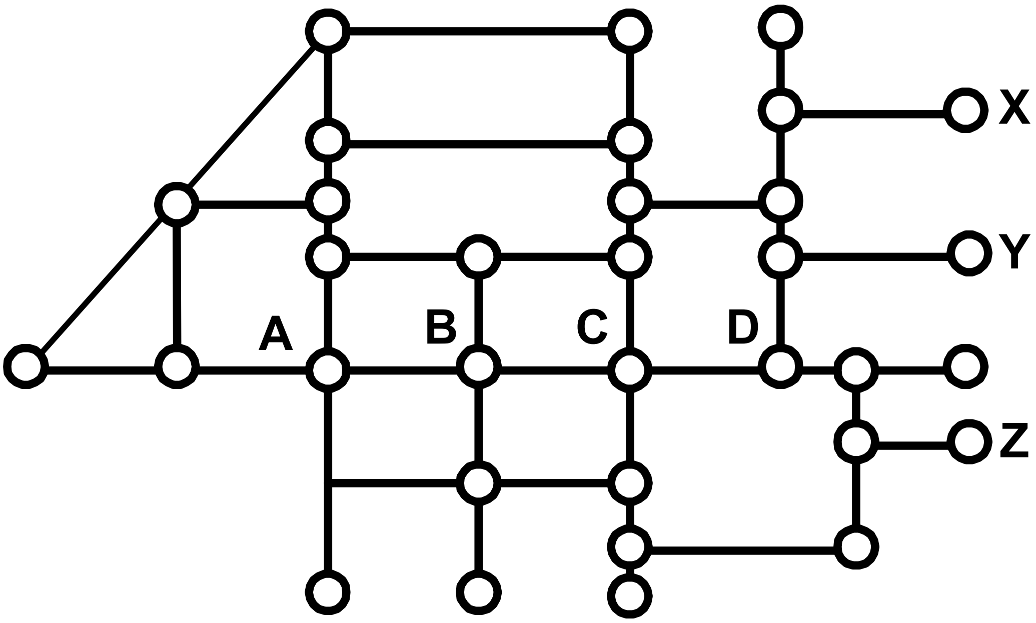

Figure 2

Looking at this graph, we can ask two questions about this road system. The first is which points are (on average) closer to all the other points in the system. Clearly points B and C are the likely candidates with points such as X or Z coming at the bottom of the list. The second is which points lie on more than any other of the available routes which connect the whole system. This is a network property called 'betweenness'. Again clearly points such as X, Y and Z will come at the bottom of the list whereas points A, B, C and D will be at the top (although only just).

This property of 'betweenness' becomes more important as an area is embedded into a large urban area. If Figure 2 merely represents the total network of an isolated country village, the 'closeness' aspect will dominate as people will tend to take mostly local journeys (or journeys to and from the network rather than through it). If, however, the network is embedded in a much larger urban area then the 'betweenness' aspect will dominate and points A and C (certainly) and maybe the line A-D will exhibit a much superior 'global betweenness' (within the whole urban area) than 'local betweenness' (within the network in Figure 2).

There is a further property however which makes A, B, C and D better candidates than other points. If we were to limit routes between points to those with the *fewest turns* (i.e. with the least wayfinding complexity) then clearly the line connecting A-D will be the most travelled line. Alternatively if we were to restrict all journeys to those with (say) only two turns, points A, B, C and D would similarly come up as winners.

Space Syntax analysts tend to look at the lines rather than the places they join. So they describe line A-D as one having 'high integration' (with the surrounding area) and those proceeding from points X,Y and Z as having 'low integration'. In standard Space Syntax presentation, lines with high integration are coloured red and those with low integration are coloured blue with appropriate spectrum colours for intermediate values. Clearly that cannot be reproduced here but it does give analysts a highly visually communicative tool with which to show patterns of urban 'integration'.

There is one obvious property of this network that has been omitted namely the physical distance of the lines between the 'nodes' of the network. Intuitively one would think that movement would be determined using the shortest physical distance between journey origin and destination.

However a study by Penn *et al*. (1998) shows otherwise. They studied four areas of London and compared observed vehicular and pedestrian flows and compared them with closeness and betweenness values and values based on a) physical distance, b) (total) angles of turns and c) fewest turns. Clearly b) is a more sophisticated version of c) but is a further, more recent refinement (Turner 2001) which we will not go into here. Both b) and c) proved superior to a) as predictors of urban movement. R^2 regression values of around 0.6 were obtained for pedestrian movement and around 0.7 for vehicular movement.

This provides evidence that urban configuration and wayfinding complexity are important determinants of urban movement patterns. Low wayfinding complexity (i.e. small numbers of turns) is associated with areas of *high* integration values and *vice versa*.

Method 2 - Visibility Graph Analysis (VGA)

Axial analysis is based on lines of visibility. What happens when we look at spaces of visibility in (say) open spaces or inside buildings? If we extend from the one dimension of axial analysis into (at least) two dimensions we can extend the idea of the axial line (the longest line(s) of visibility in a street or corridor) to the idea of an 'isovist' or the total space (area) which can be viewed from a single point. (For the purposes of this paper the analysis is restricted to two dimensions.)

Let us take a rectangular area bounded by a wall and containing a T-shaped visual obstruction as shown in Figure 3a. The isovist is the area visible from point A. A person standing at point A can see point C but not point B. If we add another isovist from point B (Figure 3b) then people standing at points A and B cannot see each other but could see someone standing at point C. C therefore provides an important visual link between A and B.

View of the areas of visibility ('isovists') from a) one point and b) two points

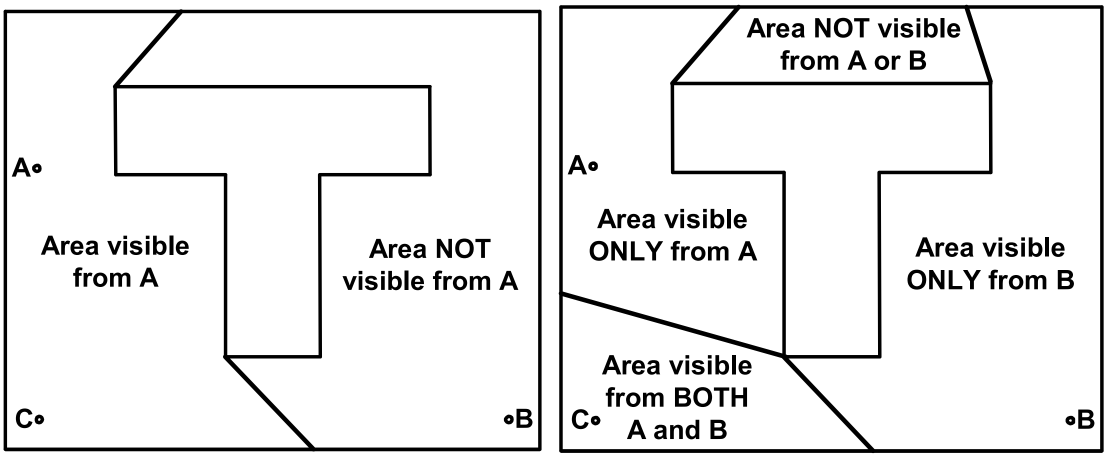

Figure 3

What is needed is a means of analysing all the points in the space and their visual connectedness to all the other points in the same space. Now clearly there is a theoretically infinite number of points so what is used is a lattice of points within the space. A graph is produced based on all the points and all the points that are visible from each point as in Figure 4. It should be noted that it is only the advent of modern computing power which makes this sort of analysis a practical proposition. In practice the lattice would be more finely grained (i.e. the dots closer together) than is shown in Figure 4a. This is a 'first-order' visibility graph which shows all the direct visual connections between all the points.

a) First-order visibility graph and b)VGA relative integration values

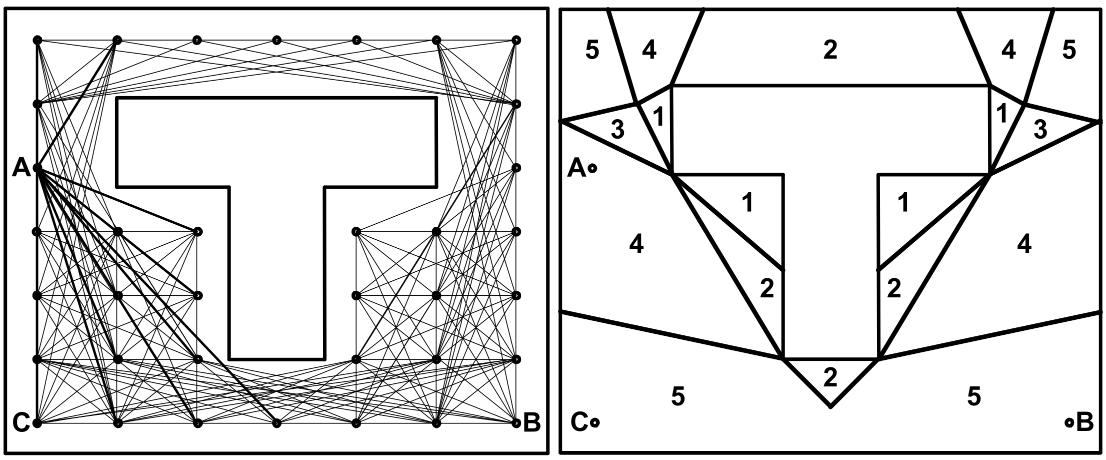

Figure 4

In measuring the connectedness of spaces, several properties can be used. The first is the idea of *neighbourhood size* which is basically the number of immediately visible points. It can be seen by inspection that this is greater for points B and C than it is for A. It can also be seen that it is particularly low for the narrow corridor 'above' the 'T'.

This value gives a sense of the direct visual connectedness of any point within the whole space relative to any other point.

The second property which interests us is what Turner *et al*. (2001) refer to as a *clustering coefficient* although isovist network density might be an alternative term.

a) Visibility network (graph) and b) Complete network of the 'A' isovist

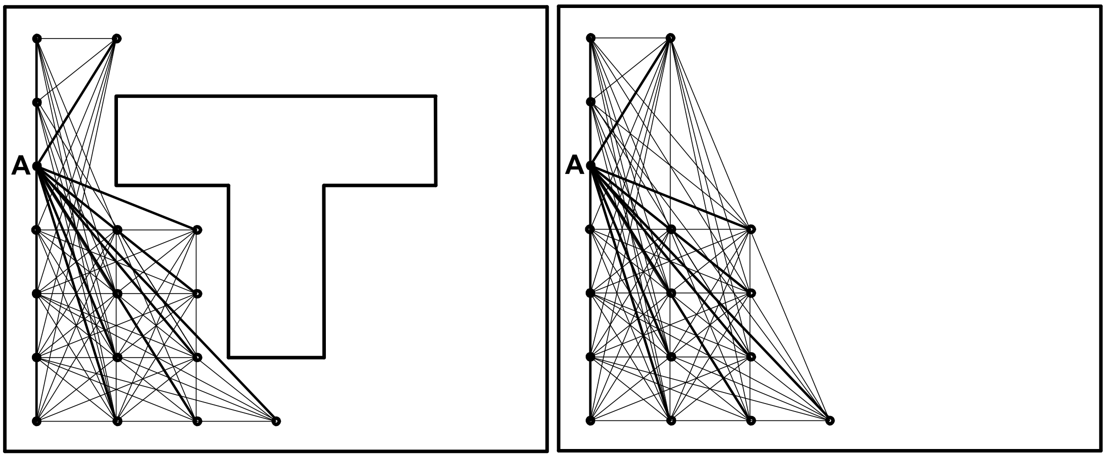

Figure 5

This is calculated as the number of connections in the visibility network (Figure 5a) divided by the total possible number of connections in the network (i.e. with the visual obstacle removed) (Figure 5b). This gives a measure of the *convexity* of the isovist which expresses its *local or internal visual connectedness*. Conversely it measures the extent to which the visual obstacle 'disrupts' the local visual connectedness of the isovist. It is a purely local property of the isovist itself rather than the whole space. It is also a measure of the extent to which the view of the space occupied by the isovist changes as an individual moves around it. A high value indicates a low degree of visual complexity and *vice versa*.

Finally and possibly the most important is the third measure of interest namely that of *mean shortest path length*. Put simply we ask how many lines of sight on average do you have to go through to get from any point in the whole space to get to any other point. This is analogous to the *fewest turns* idea encountered earlier in axial analysis. So, for instance in Figures 3/4, the path length from A to C is 1, from C to B is 1 and from A to B is 2. In a network consisting only of A, B and C the mean average path length would be 1.5 ((1 + 2)/2) for A or B and 1 ((1+1)/2) for C. In this 'mini-network' point C is the key point of integration.

In the larger network (Figure 4a) B and C are equivalent points and will display a shorter mean path length than A which is in a less well 'integrated' space. The relative degree of integration is shown in Figure 4b. As with the axial maps these are normally presented in spectrum colours with red for the high values and blue for the low values. The areas also shade into one another rather than being sharply divided by lines. Again this makes for a visually communicative presentation of spatial properties.

As with the study of external urban areas, a study of the Tate Gallery (Hillier *et al.* 1996) demonstrated that 'fewest turns' connectivity of internal building spaces was also a good predictor of movement patterns within the building and superior to origin-destination modelling based on actual physical length between locations. It also corresponded well with observed occupancy rates in various spaces within the Tate Gallery which suggests that such spaces are desirable places to be in as well as being desirable pathways to other spaces.

Application

The applications to which these findings can be put are so considerable that UCL has been able to start a commercial consultancy which now operates as an independent business under the name of Space Syntax Ltd. A full list of their work can be found at www.spacesyntax.com. The main types of uses are the analysis of the configurational effect on existing space use and the examination of and suggestions for proposals for alteration of existing spaces and the creation of new ones. One example is the Swiss Re building (popularly known as the 'gherkin') where the number and placing of ground floor entrances to were determined using Space Syntax methods.

One aspect that had not been studied is the impact of phased building refurbishment on the spatial operations of clients whose business remains open during the works. Construction clients such as BAA, Network Rail or shopping centre landlords cannot shut down their operations to do major refurbishments. They have to balance the speed and efficiency of construction against disruption to their ongoing business. One of the clearest factors in this is the spatial disruption caused by the occupation of part of the site by contractors. These are separated from the remaining open areas by the contractor's hoardings which may remain in place for weeks or even months. Refurbishment projects are also particularly troublesome in that the costs and duration of projects is harder to predict than those for new construction (Egbu 1998).

RaCMIT (Refurbishment and Customer Movement Integration Tool) was a research project carried out at UCL which used Space Syntax methods to analyse the spatial disruption caused by refurbishment works in a combined railway and retail environment. The case considered here is that of London Victoria Station (at the time under the management of Railtrack plc).

London stations not only act as railway termini but, as a result of this primary activity, are also highly profitable retail areas. A well known retail chain has its most profitable branch located in one of London's stations. (It has been found that a considerable number of visitors to London stations are there for the retail facilities and are not there to travel.) Railtrack identified a business opportunity in the redevelopment of certain retail units at Victoria which would allow a greater number of units to be created. During the refurbishment works it became apparent that the contractor was experiencing logistical problems and asked to have a larger working area which involved the closure of one of the entrances to the station.

The entrance was duly closed and Space Syntax observers were used to record movement activity before and after the change (Campos 2001). They recorded (among other things) the change in use of the station entrances (Table 1) and changes in number of people entering certain establishments (Table 2). UCL could only look at the visitor numbers to various outlets before and after the closure as actual retail revenue (and even periodic percentage changes) is very closely guarded and commercially sensitive information. It should be noted that there were 15% less visitors to the station for the observation period after the entrance closure than before it (for reasons entirely unconnected with the closure) and that therefore -15% should be regarded as the 'expected' change (rather than 0%).

London Victoria Station - changes in movement through entrances before and after temporary closure of Entrance 4

Entrance	% change in movement
1	-21.9
2	-20.6
3	-38.3
4	CLOSED
5	+109.8
6	+20.7
7	-11.7
8	-3.6
9	-70.6
10	-14.0

Table 1

An axial analysis of the station was correlated with 73% of the observed pedestrian movement into and out of the station before the entrance closure and 67% after it. This confirms the findings in the London studies referred to earlier (Penn *et al*. 1998)

London Victoria Station - changes in entry into selected outlets before and after temporary closure of Entrance 4

Outlet	% change in visitors
A	-7
B	+28
C	+6
D	no change
E	-31
F	-41
G	-9
H	-58
I	-14
J	-34
K	-4
L	+12

Table 2

Visibility Graph Analysis was used to look at the more complex relationship between areas used for movement and areas used for standing within the station area. The maps are too complex to be displayed here but we can take look at one outlet namely H (Figure 6).

Local spatial configuration before and after the entrance closure

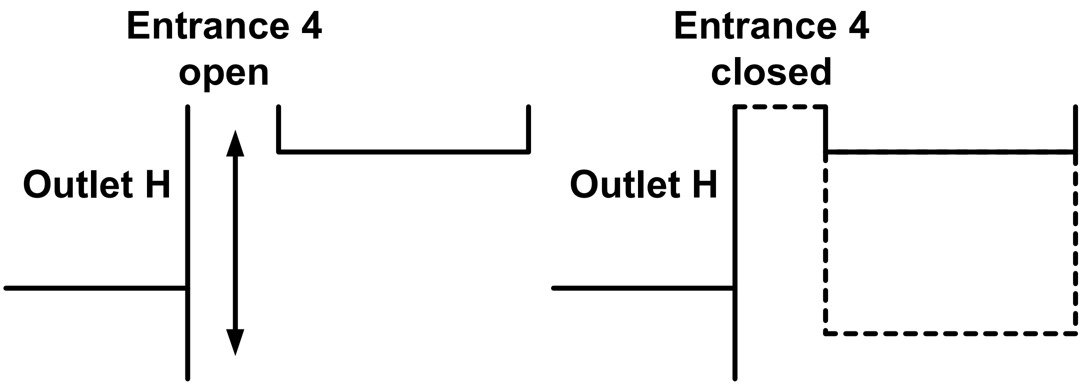

Figure 6

The closure of the station entrance and the erection of the contractor's hoarding (shown by the dotted line) not only removed passing pedestrian traffic but effectively cut off outlet H from the visual field of most of the rest of the concourse. Not surprisingly it suffered the greatest drop in visitors (Table 2). Fortunately Railtrack, being warned that this might happen, relocated a non-commercial user in outlet H and so did not suffer financially from the drop in visitors to that outlet.

So what might we learn from this and other Space Syntax studies? Additional visibility analysis in Victoria and elsewhere show that there is an important relationship between good movement and good standing areas. Fundamentally the standing areas need to be out of the main movement areas but visually well connected to them. This is also important for retail only environments.

When people shop they want space to look at the shop but have time (and space) to decide whether or not to enter the shop. They do not want to be pressured into a decision one way or the other. However people do not want to stand for any length of time in areas which are not visually well-connected to the main lines of pedestrian movement (unless they are standing there for antisocial purposes). This is where the idea of convexity is especially important.

Accordingly if we look at Figure 7a this shows the spatially ideal situation for a retail environment. If refurbishment works have to be carried out outside then arrangement 7b (with the heavy dotted line as the hoarding line) is highly undesirable because i) it increases the wayfinding complexity of the movement network and b) the movement through the standing area disrupts the function of that area to the detriment of the retailers. Likewise 7c is also undesirable because the standing area is visually detached from the movement area. A better arrangement would be 7d whereby the movement area remains separate from the standing area but is still reasonably well-connected to it visually. It might well be in 7c and 7d that there needs to be a high-level connection between the two areas (for instance if high-level services are being renewed or repaired) but one which allows the eye-level visual field (and floor-level physical movement) of the pedestrian to be minimally disrupted.

Possible layout of refurbishment outside a retail area

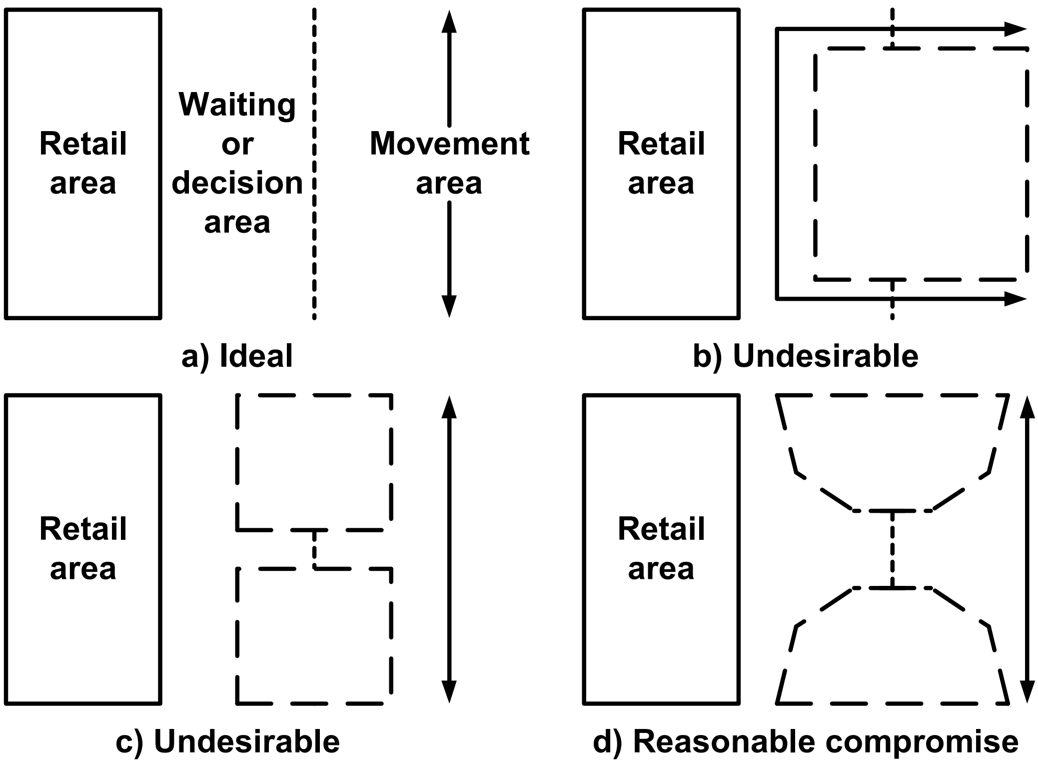

Figure 7

Conclusion

The large-scale disruption of retail or other business environments can have significant financial consequences. When planning phased refurbishment projects, tools are needed to plan not only the construction but also for minimising the spatial disruption caused by partial contractor occupation of an operating business.

The methods of analysis offered by Space Syntax provide a means to analyse the likely effects of disruption of the spatial environment upon both pedestrian movement through an area and movement to those areas within the site still open for business.

These methods also have wider application to problems of managing and changing the built environment. They have been proved successful in a range of applications not least because they have been based on over 20 years of research and observation of a wide range of built environments in many different parts of the world.

Further research is still needed to develop knowledge of the temporary alteration of the built environment caused by refurbishment in a wider range of business environments and to combine such methods with construction planning techniques to minimise the joint costs of refurbishment and business disruption.

Acknowledgements

The author acknowledges the support of the UK Engineering and Physical Sciences Research Council (GR/N 02917/01) in carrying out this research. Assistance has also been provided by Alan Penn, Alasdair Turner, Andrew Edkins, Graham Winch, Bill Hillier, Laura Vaughan and employees of Railtrack plc (now part of Network Rail Ltd), Laing Construction Ltd (now part of the O'Rourke group), British Land plc and Space Syntax Ltd. The author, however, remains solely responsible for any shortcomings in the paper.

References

Campos B. (2001) *RaCMIT: Case Study - Victoria Station: Report on the Space Syntax study* (unpublished) London, Space Syntax Ltd

Egbu, C O, Young, B A and Torrance, V B (1998) Planning and control processes and techniques for refurbishment management *Construction Management and Economics* **16** 315-325

Foucault M. (1975) *Surveiller et punir: naissance de la prison* Paris, Gallimard (Sheridan A. (tr) (1977) *Discipline and punish* New York, Pantheon)

Hillier, B. and Hanson, J. (1984) *The social logic of space* CUP, Cambridge

Hillier B. and Iida S. (2005) Network and psychological effects in urban movement in Cohn A.G. and Mark D.M. (Eds) *COSIT 2005* (Lecture Notes in Computer Science 3693) Berlin, Springer-Verlag 475-490

Hillier B., Major M.D., Desyllas J., Karimi K., Campos B. and Stonor T. (1996) *Tate Gallery, Millbank: a study of the existing layout and new masterplan proposal* (Technical Report), London, Bartlett School of Graduate Studies UCL

Penn A. (2001) Space Syntax and spatial cognition or why the axial line? *Proceedings of the Third International Symposium on Space Syntax* Georgia Institute of Technology, Atlanta GA Ch 11

Penn A., Hillier B., Banister D. and Xu J. (1998) Configurational modelling of urban movement networks *Environment and Planning B* **25** 59-84

Turner A. (2001) Angular analysis *Proceedings of the Third International Space Syntax Symposium* Georgia Institute of Technology, Atlanta GA Ch 30

Turner A., Doxa M, O'Sullivan D. and Penn A. (2001) From isovists to visibility graphs: a methodology for the analysis of architectural space *Environment and Planning B* **28** 103-121

Turner A., Penn A. and Hillier B. (2005) An algorithmic definition of the axial map *Environment and Planning B* **32** 425-444