Kelsey, J. M. (2003) Drawing the hoarding line: balancing the spatial requirements of customer and contractor in occupied refurbishment of railway stations *Proceedings of the 19th ARCOM Conference* 3-5th September, University of Brighton, UK

Drawing the hoarding line: balancing the spatial requirements of customer and contractor in occupied refurbishment of railway stations

John M. Kelsey
Bartlett School of Construction and Project Management, University College London
Wates House, 22 Gordon Street, LONDON WC1H 0QB, UK

In planning an occupied refurbishment the spatial needs of the contractor and of the ongoing business have to be balanced. For the refurbishment of railway stations, a particular concern to retailers and train operators is the disruptive effect of construction works upon pedestrian movement. RaCMIT (Refurbishment and Customer Movement Integration Tool) is a research project aimed at investigating this problem through concentration on decision criteria/processes of the client and models/observations of pedestrian movement. The objective of the research is to develop a decision protocol and decision support tools, which assist both the client and the construction planner in addressing these problems and which allows overall optimisation of project value to the client's business. The practice of spatial decision-making in station refurbishment projects has been investigated in two case studies. This paper concentrates on one case study where pedestrian movement was observed before and during the refurbishment. Research observations as well as current literature suggest that a) for overall decision-making, opportunities may be lost (under current practice) for minimising joint project cost/revenue (or other) disruption and b) for spatial decision-making, temporary station configuration during construction may be a significant variable

Keywords: construction planning, decision-making, occupied refurbishment, pedestrian modelling, urban morphology

INTRODUCTION[1]

In replacing existing built facilities, updating an existing asset can be a cheaper option (as long as the full life cycle costs of so doing are taken into consideration) and is often more acceptable to local planners. Where the demand for services (to which the asset contributes) depends on large numbers of pedestrians passing through the built asset then there is an additional set of problems. Facilities cannot just be shut down for several months while the construction work is carried out. Customers will go elsewhere and may not all come back when the works are finished. If the facility is a UK railway station then the Rail Regulator, the Train Operating Companies and at least some of the retail tenants may not permit the option of temporary station closure.

A decision then has to be made as to how best carry out the refurbishment works while still continuing to operate to an acceptable level. Clearly the works have to be broken up into phases. The problem is into how many phases should a project be divided and where should the boundaries be for each phase? The focus here is on minimising disruption to pedestrian movement in public areas (balanced against the achievement of the other usual time-cost-quality project objectives).

To find a framework for looking at these questions, University College London (UCL) has been developing a decision protocol (or set of procedures) assisted by industrial partners under an EPSRC-funded project. They have investigated two refurbishment projects in large stations (London Victoria and Manchester Piccadilly – the client for both projects was Railtrack plc) to see how the practical problems, which arise in planning refurbishment works might be matched with the problems of keeping an ongoing business running with substantial public access. The research project is called RaCMIT (Refurbishment and Customer Movement Integration Tool).

The main field work has consisted of:-

a) Qualitative research through interviews with project management staff (at various stages during the projects), attendance at some project meetings and examination of relevant project documentation,
b) Quantitative research through observation of pedestrian movement through affected areas using the Space Syntax methodology

This paper concentrates on b) carried out at Victoria.

CASE STUDY DECISION FRAMEWORK

Victoria Railway Station, London, UK ; 1999-2000; partial redevelopment of retail area

The project sponsors – Railtrack Major Stations – identified a medium term tactical business opportunity from the re-development of some of its existing retail space at Victoria Station, London.

The objective function *for project evaluation purposes* can be thought of as the net present value of the cash flows set out in Table 1.

No	Cash flow source	Cash flow type
1	Share of revenue from new retail units	Inflow
2	Capital cost of works	Outflow
3	Share of revenue from old retail units to be redeveloped	Outflow
4	Share of revenue of nearby retail units disrupted by works	Outflow

Table 1

It is assumed here that there were no other significant financial gains or losses arising from the refurbishment.

Since, in practice, the retail units being redeveloped had to cease trading at the commencement of the project, Railtrack could only expect to have any control over the timing and level of items 1,2 and 4. So once the decision to proceed had been taken, item 3 effectively became a ‘bygone’ which was subsequently ignored.

The *actual* decision-making process only took items 1-3 into consideration as there were no decision support tools available to estimate item 4. (Heuristic reasoning suggested that it would be sensible to relocate a non-revenue earning facility nearest to the works to minimise the outflow under item 4 and this is what Railtrack did.)

Heuristic reasoning also suggests that within certain limits:-

The greater the space available to the contractor, the cheaper and faster will the works be completed and *vice versa*. (This is also supported in principle by Thomas and Smith 1990.)

The effect of this can be seen in Table 2.

Space		Cash Flow		
Contractor	**Public**	**Item**	**Timing**	**Amount**
More	Less	1 New revenue	Earlier	No effect
More	Less	2 Capital Cost	Earlier	Decrease
More	Less	4 Disruption losses	Earlier	Increase??
Less	More	1 New revenue	Later	No effect
Less	More	2 Capital Cost	Later	Increase
Less	More	4 Disruption losses	Later	Decrease??

Table 2

The effect on flow amounts against item 4 are questionable since although the effect *per time period* might be safely stated, the variable duration of the refurbishment works makes for uncertainty in the overall effect on revenue disruption. (There might, for example be more revenue disruption but for a shorter period.)

There is a further complication since there is anecdotal evidence from retailers (who are understandably reluctant to openly quantify commercially sensitive matters) that a significant percentage of trade lost through disruption by refurbishment works remains lost for some time and may take a considerable period to be restored or replaced.[2] Not surprisingly, therefore, in-store retail refurbishments aim at minimising disruption to customer movement.

It needs to be stressed that the problem of disrupting pedestrian movement in public areas is not just a financial matter but has wider stakeholder implications. However for this particular case study, the financial considerations were paramount. (The sums involved in retail revenue in London stations are highly significant.) In the other case study (not considered here) it was the non-financial stakeholder considerations that were most important.

A heuristic approach is necessarily limited. To progress further what is needed is:-

A) A spatio-temporal construction planning tool which can model various combinations of area, configuration and duration to optimise construction schedule and costs.
B) A pedestrian modelling tool which shows how pedestrian flows are disrupted by the configuration of site boundaries (i.e. the hoarding line).

The spatio-temporal planning tool under A) has been developed under another research project called VIRCON (Kelsey *et al*. 2001, North *et al*. 2003).

The focus of this paper is on the application of pedestrian modelling tools under B).

PREVIOUS RESEARCH

Urban morphology is not normally an area of focus for construction researchers. However, refurbishment works in an area where pedestrian movement is ongoing, necessarily causes a change in the configuration of that space. Hoardings arising from major refurbishment works can be in place for months or even years. While the construction planner may choose the spatial layout to optimise construction, the effect on pedestrian movement can be significant.

This requires an understanding of the relationship between urban form and the movement of people. Hillier and Hanson (1984) demonstrated that the spatial layout of urban forms and buildings could be largely explained by social considerations. In particular, the probability of encounter with other people, complexity of wayfinding and social organisation were held to be important determining factors.

They distinguish the 'axial' and 'convex' organisation of space. The axial organisation can be thought of as the relationship between the space you are in and its 'route-finding' relationship to the larger setting in which it is located via the roads in an urban environment or the corridors in a building. The convex organisation can be thought of as all the points that are visible from where you are located – this describes the local space you are in. (A set of points where all points can be seen from any other is necessarily convex.) The convex space is related to buildings (or other parts of a building) through entrances and to the wider environment via the axial lines running through it.

For example (Hillier and Hanson 1984), an analysis of the road system of the City of London (in which the ability to navigate movement is paramount) for instance shows that very few of the major axial lines (of potential movement) strike a building at right angles but instead mostly at very oblique angles. This means that, although many of the streets are very narrow, they are *visibly* interconnected in a way which aids navigation. It is interesting that much of the road system of the City is unplanned in that it arose out of the post-fire reconstruction of the late 17th and early 18th century.

In contrast, the 20th century Barbican adjoining the City is shows the reverse pattern. There are plenty of open spaces to walk through but they are not obviously interconnected with one another. You can see people walking across your line of vision at a different level without being able to see how to get to where they are. Consequently many visitors to the Barbican get lost and a yellow line has had to be painted on the ground in order to guide people from the various entrances to the concert hall.

In the City of London, building entrances tend to be connected to spaces with convex properties and the larger open spaces which work best (i.e. in which people tend to freely congregate) are those which not only have good convexity but are physically and visually well-connected with the axial network.

In the design of urban spaces the dominant idea has been that of attractors and generators of urban movement. However Hillier et al (1993) show that an alternative model of movement can be presented. This is based on configuration. In particular it aims to show that it is the axial and convexity properties of configuration which help determine the location of 'attractors' of pedestrian movement (such as shops) and not the other way round. It is argued that configuration generates a pattern of 'natural' movement relatively independent of attractors.

The problem then exists to turn these observations about the relationship between space and movement into tools for analysing spatial configuration and its relationship to observed movement. Such tools have been developed and their application to the Victoria case study can now be described.

OBSERVATIONS OF PEDESTRIAN MOVEMENT AT VICTORIA

During the carrying out of the refurbishment works, the contractor (having already experienced a degree of frustration in working within a very confined space) proposed the closure of the adjacent station entrance in order to create more working/storage space and thus facilitate the earlier completion of the project and thus earlier occupation of the revenue-earning retail units. The client agreed to the proposal which caused changes in the pattern of pedestrian movement in that part of the station. This in turn affected the number of pedestrians visiting existing retail units/other nearby station facilities,

Pedestrian movement was observed prior to and during the closure of one of the station entrances. The actual observations were compared with those given by an initial forecast based purely on the change in configuration using the Space Syntax methodology (Space Syntax Ltd 2001).

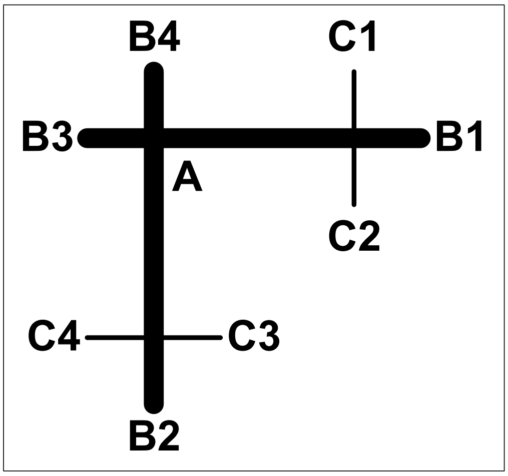

Figure 1

The Space Syntax methodology uses two principal techniques – axial analysis and visibility graph analysis.

In axial analysis, the longest and fewest straight lines or 'lines of sight' (that pass through all the 'accessible' space in a building or urban environment) are drawn. (Figure 1 shows a very simple road or corridor system to which this has been applied.) This information is processed to show how many lines any point must use in order to reach any other point. (Another way of thinking about it is how many times do you have to *turn* to reach another point.) Those requiring the *fewest* lines are treated as more integrated lines with higher values. So in Figure 1, Lines B1-B3 and B2-B4 (the thicker lines) are more integrated than lines C1-C2 and C3-C4. In this system the most integrated point is at A which can be considered as the 'live centre' of the system. One of the variables that 'integration' measures is the relative complexity of navigation in any route system. A more integrated line is more easily accessible in terms of navigation. Because of this a more integrated line is more likely to 'attract' pedestrian movement.

By way of contrast Visibility Graph Analysis uses a grid of spaces within any building or urban environment and tests the relative visibility of any point from any other point

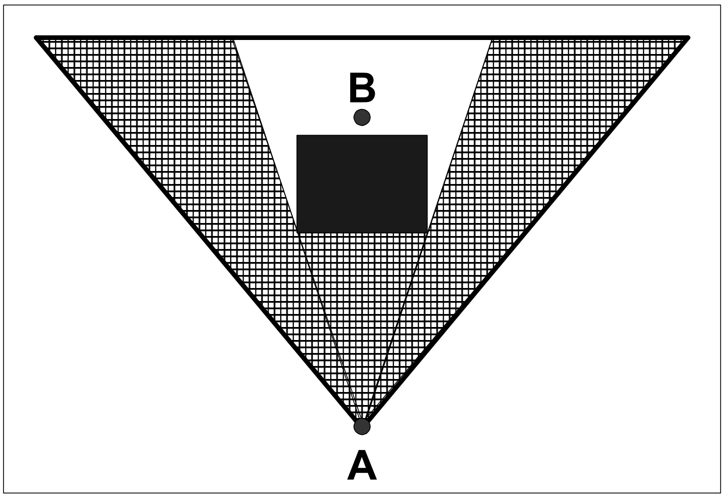

Figure 2

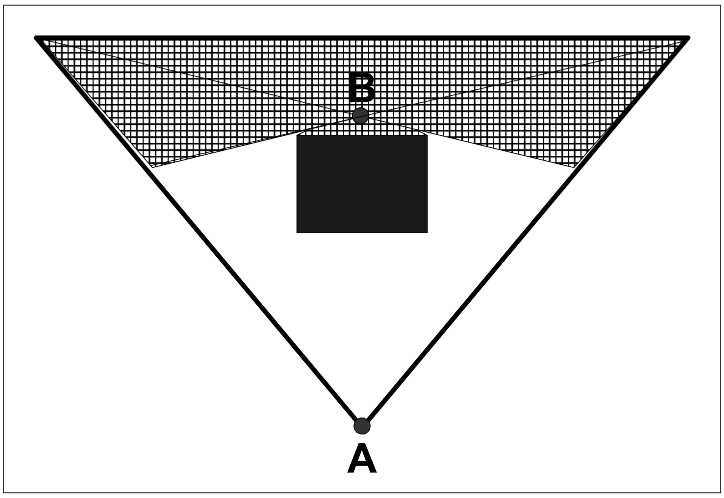

Figure 3

within any given configuration. Thus in Figures 2 and 3 it can be seen that point A is relatively more visible than point B (where the triangle represents an enclosed space and the black square some form of obstruction such as a column). So in any Visibility Graph Analysis A will appear with higher values than B. Again, like low navigational complexity, high relative visibility gives a high integration value and is regarded as an attractor of pedestrian movement.

Space Syntax output is normally presented in the form of complex, highly coloured maps of buildings and urban areas with red areas/lines representing highly integrated areas/routes and blue/indigo/violet representing poorly integrated or segregated areas/routes. (Likewise intermediate colours on the spectrum show intermediate integration values.) In addition, a loglinear regression analysis can demonstrate the relationship between observed movement and movement predicted by relative integration values in the form:-

$$\ln(y) = a + b(\ln(x)) + e$$

where y is a measure of mean observed movement through any point, x is the relative integration value of any point, e is an error term and a, b are constants. For movement through various observation points inside Victoria station the following values were obtained:-

$$\ln(y) = 3.786 + 3.268(\ln(x)) + e_i \; (R^2 = 0.731)$$

before the closure of one of the entrances and

$$\ln(y) = 4.051 + 2.825(\ln(x)) + e_j \; (R^2 = 0.672)$$

after the closure of one of the entrances during the refurbishment works.

To recap, Space Syntax does not claim that configuration explains all pedestrian movement – what it does claim is that configuration is a major causal factor in movement (Hillier and Hanson 1984) and this is a claim which has been robustly demonstrated in many consultancy studies outside of this research project (Space Syntax 2003). Table 1 shows the effect of the entrance closure on entrance usage before and during the refurbishment works (entrance 4 was the one closed).

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

Table 1

This tends to show (not surprisingly) that most of the traffic denied to entrance 4 was shifted to adjoining entrances 5 and 6. While some of the variations could be due to sampling error, clearly there was a demonstrable effect on the overall pattern of movement in the entrances adjacent to the closed entrance.

The numbers visiting selected retail outlets and other facilities (inside the Victoria concourse) in the vicinity of the closed entrance were observed as shown in Table 2. Now some caution is required in interpreting these figures. There was an overall decrease of some 15% in overall movement rates inside the station (which will have also had its effect on overall entrance usage) during the observation period when the refurbishment works were taking place compared with the period when no works were taking place. Some variation may, again, be due to sampling error. However it is

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

worth noting that the outlet most affected (H) was the one closest to the closed entrance albeit that it was a non-retail facility that would be most used by visitors unfamiliar with the normal station layout.

The observations show demonstrable effects on general movement caused by the closure. Space Syntax does not claim to predict how many people will visit given retail outlets in a particular area. Some retail outlets (such as newsagents, convenience stores etc.) are far more prone to the disruption of pedestrian movement than others (such as more specialist retail outlets). But understanding the effects on general movement (including areas where people tend to congregate and remain static) can assist experienced retail clients to gauge the effect on their own businesses. If the closure of a single station entrance (where there are a substantial number of alternative entrances) can have this sort of effect on pedestrian movement, clearly more major refurbishment works could have potentially very significant effects both on pedestrian movement in general (and possibly retail income as well).

CONCLUSIONS

1) For an occupied refurbishment within a retail environment, the client is faced with a decision framework involving multiple cash flow sources – this includes the acceleration of new revenue streams together with the joint minimisation of:

a) time and/or cost of construction and
b) level and/or duration of revenue disruption

2) Real refurbishment projects have an above average tendency to depart from their original plans (Egbu *et al*. 1998) which in the case of occupied refurbishment may lead to the changing of originally planned phasing and/or hoarding lines (as indeed happened at Victoria). In general construction planning, Ballard and Howell (1998) have argued that planning needs to have a flexibility which allows frequent (weekly) adjustment of plans to enable the performance of 'quality tasks'.

Clearly it is unlikely that the hoarding line will be changed every week. However, having spatio-temporal modelling tools for occupied refurbishment inside and outside the site would make the re-planning of works within the 'lookahead' planning period (4-12 weeks) a real possibility.

3) Hitherto there have been no decision support tools to model *both* the efficient spatio-temporal planning of construction works *and* the effect of different hoarding positions upon pedestrian movement.

Without such tools:-

> a) Construction planners will not consider the effort in modelling alternative spatio-temporal construction plans to be worthwhile. With such tools, it becomes practical to model alternatives and the resulting site boundaries can then be output and converted to files of alternative temporary configuration plans of public space (on the other side of the hoarding) which can in turn be subjected to the sort of pedestrian movement modelling tools used at Victoria.
>
> b) There is incomplete support available for the sort of decision exemplified by the one to close a station entrance at Victoria. If there is no means of predicting the pedestrian disruption caused by such a closure, then the decision maker has to fall back on the revenue timings, construction costs and heuristics as the decision support basis.

4) Experience from other projects (Space Syntax 2003) suggests that while there may be direct construction cost/revenue disruption conflicts facing the decision maker, there are other quite small adjustments to site boundaries (cutting corners in particular) which could achieve significant improvements to pedestrian movement at minimal cost.

FUTURE WORK

Further research is needed in the practical application of such tools to different types of occupied refurbishment projects and to the question of the effect on the movement of client workers (as well as the general public). Some form of action research is also needed on the possibilities of realigning site-based project management objectives.

During the course of the research project (but after the work done at Victoria) agent-based modelling tools were developed at UCL which allowed incorporation of both Space Syntax-type behaviour and more direct attractor-based behaviour which forms the basis of origin-destination pedestrian modelling. By experimenting with differing combinations of influences, it is hoped that even greater accuracy in predicting pedestrian movement can be achieved (Penn and Turner 2001 and 2002).

ACKNOWLEDGEMENTS

[1] The author acknowledges the support of the EPSRC (Grant No. 02917/01) in carrying out this research. Assistance has also been provided by Alan Penn, Andrew Edkins, Graham Winch and Peter McLennan, together with employees of Railtrack plc (now part of Network Rail Ltd), Laing Construction Ltd (now Laing O'Rourke), British Land plc and Space Syntax Ltd. The author, however, remains solely responsible for any shortcomings in the paper.

[2] The author is grateful to Peter McLennan for this observation.

REFERENCES

Ballard G and Howell G (1998) Shielding production: essential step in production control *Journal of Construction Engineering and Management* **124**

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

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

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

Kelsey, J M, Winch, G M, and Penn, A (2001) *Understanding the project planning process: requirements capture for the virtual construction site* Bartlett Research Paper No. 15, University College London, a VIRCON report

North, S, Winch, G M, Dawood, N, Heesom, D, Kelsey, J, Sriprasert, E and Mallasi, Z (2003) *Technical Evaluation: VIRCON Task 12 Report* UMIST, a VIRCON report.

Penn A and Turner A (2001) *Intelligent modelling of public spaces*, International Patent Application No PCT/GB01/03763, UKPO, London

Penn A and Turner A (2002) Space syntax based agent models in Schreckenberg M and Scharma S (Eds) *Pedestrian and evacuation dynamics* Springer, Heidelberg 99-114

Space Syntax Ltd (2001) *RaCMIT Case Study – Victoria Station – report on the Space Syntax study* London, a RaCMIT report

Space Syntax Ltd (2003) – web site www.spacesyntax.com

Thomas H R Jnr and Smith G R (1990) *Loss of construction labor productivity due to inefficiencies and disruptions: the weight of expert opinion* PTI Report No 9019 Pennsylvania Transportation Institute, Pennsylvania State University