Kelsey J M (2003) Drawing the line: balancing the spatial requirements of customer and contractor in occupied refurbishment ***Proceedings of 'Knowledge Construction' Joint International Symposium of CIB Working Commissions: W55 (Building Economics), W65 (Organisation and Management of Construction) & W107 (Construction in Developing Countries)*** **21st - 24th October, National University of Singapore**

Paper Title	Drawing the line: balancing the spatial requirements of customer and contractor in occupied refurbishment
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Drawing the line: balancing the spatial requirements of customer and contractor in occupied refurbishment

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ABSTRACT

In planning the refurbishment of railway stations the spatial needs of the contractor and of the ongoing business stakeholders have to be balanced. A particular concern is the disruptive effect of construction works upon pedestrian movement.

RaCMIT (Refurbishment and Customer Movement Integration Tool) is a research project aimed at addressing this problem through combining the knowledge of the client project manager, the construction planner and the pedestrian modelling expert.

The objective of the research is to develop a decision protocol (based on problems encountered in two case studies) facilitating optimisation of overall project value to the client's business.

Research observations as well as current literature suggest that:

- for overall decision-making, opportunities may be lost (under current practice) for minimising joint project cost/revenue disruption and
- for spatial decision-making, temporary station configuration during construction (and not just overall pedestrian capacity) is a significant variable for both business and safety outcomes.

*Keywords***:** construction planning, decision-making, occupied refurbishment, pedestrian modelling, stakeholder management, value maximisation

INTRODUCTION

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 a level which is acceptable to key stakeholders. 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).

After briefly describing the research work, the paper will present an outline of the case studies and a suggested framework for looking at the disruption problem.

RESEARCH WORK

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) interviews with project management staff at various stages during the projects and
b) pedestrian modelling of affected areas using the Space Syntax methodology

THE UK PASSENGER RAIL INDUSTRY CONTEXT

The industry context in which the projects took place is shown in Figure 1.

UK Passenger Rail Industry System

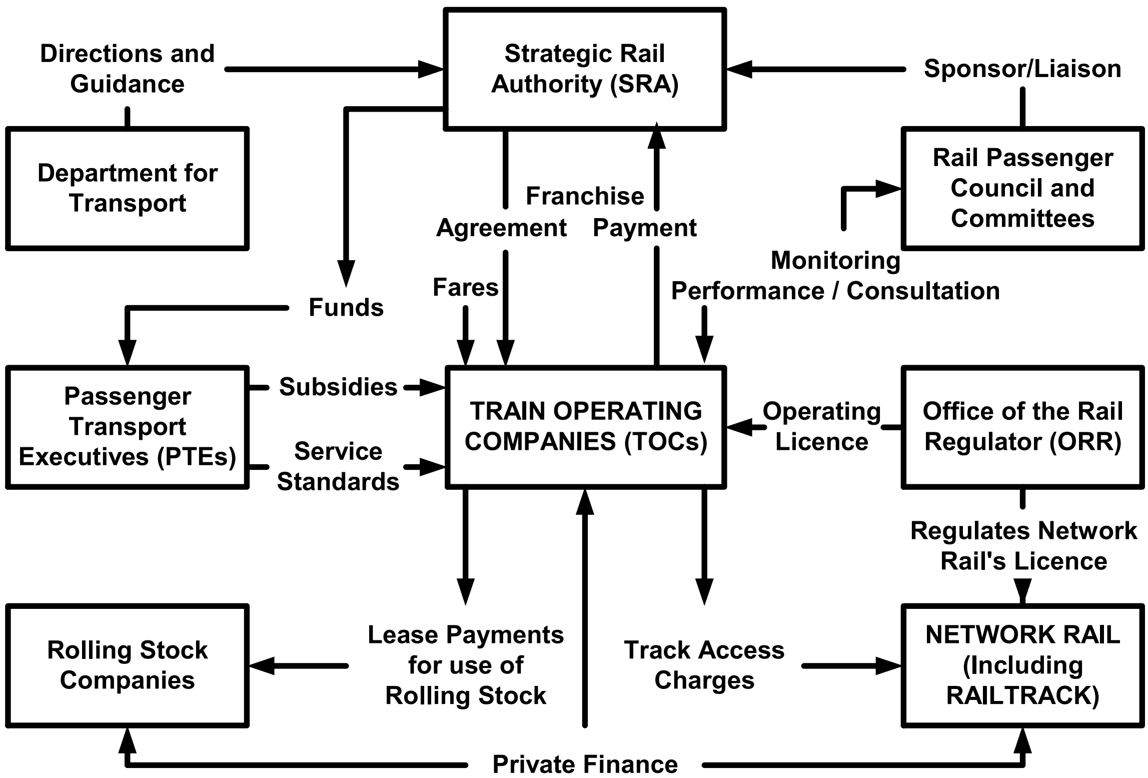

Figure 1 (adapted from SRA 2003)

The main bodies for the purpose of the research are as follows:-

Railtrack plc – originally a privately funded private sector company responsible to the ORR, it owned the track, signalling equipment and 14 major stations on the UK rail network. The UK government placed it in administration in September 2001. In October 2002 it was acquired as a wholly-owned subsidiary of a new company called Network Rail Ltd.

Train Operating Companies (TOCs) – these are responsible to the Office of the Rail Regulator and the Strategic Rail Authority in operating passenger services on sections of the rail network under franchise. They also run all stations apart from the 14 major stations run by Railtrack/Network Rail.

Passenger Transport Executives (PTEs) – these operate in seven major metropolitan areas and are responsible for setting standards and managing subsidies.

The Strategic Rail Authority (SRA) – a Government Agency which sets the financial framework and the overall agenda for industry development.

The Office of the Rail Regulator (ORR) – appointed by government, the ORR oversees the performances of the TOCs and Network Rail under their operating licences.

Her Majesty's Rail Inspectorate (HMRI) – this is the rail industry division of the Health and Safety Inspectorate.

The framework for major station changes is shown in Figure 2.

Framework for major station changes

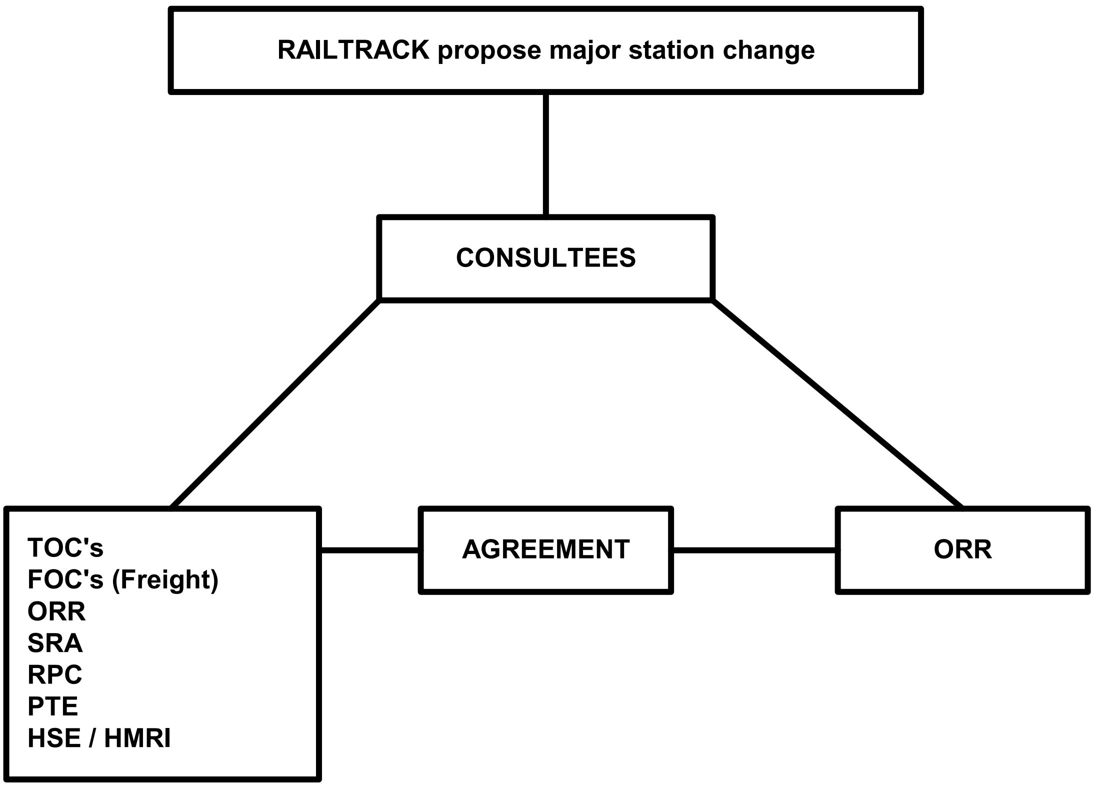

Figure 2 (adapted from information supplied by Railtrack in 2001)

THE PROJECTS

Relevant issues, decision criteria and stakeholders are set out in Tables 1 and 2.

Performance framework / criteria / disruption in the projects

Issue	London Victoria	Manchester Piccadilly
Project nature	Tactical affecting only part of the station for a short time	Strategic affecting the entire station over substantial periods
Station major change procedure	Not required	Required
Key project decision criteria:		
Completion date	Significant	Overriding importance
Capital cost	Significant	Next most important
Retail revenues	Significant	Insignificant
Effect on TOCs	Insignificant	Significant constraint
Evacuation times	Insignificant	Significant constraint
Pedestrian disruption	Moderate but significant	Major

Table 1

Project Stakeholders potentially affected by disruption

Stakeholder	London Victoria	Manchester Piccadilly
Railtrack internal Stakeholders:		
Major stations/ Project Delivery	KEY stakeholder and project managers	KEY stakeholder and project managers
Commercial Property	Not involved	Significant constraint
External Stakeholders:		
SRA	Negligible	Important with veto power
ORR	Negligible	Important with veto power
TOC's	Negligible	Important with KEY veto power
HMRI	Negligible (for disruption)	Important with veto power
PTE	N/A	Significant
Retail tenants		
Existing	Important (only during the construction phase)	Insignificant (apart from two who had to be relocated under their existing agreements)
New	Insignificant	Insignificant
General public	Negligible	Significant only as a constraint

Table 2

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

Railtrack identified a medium-term business opportunity in a small scale re-development of retail facilities in one corner of the station. This consisted of the partial demolition of existing facilities and replacement by three new retail units. This was successfully achieved. Three issues arising during the project are of particular note:-

i) During the carrying out of the works, the contractor 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,

ii) Retail tenants who were not involved in the planning of the scheme advised the client during the works that part of the proposed demolition included services which were essential to their continuing operation – the need to relocate these delayed the construction phase by three weeks (which was significant in terms of the overall project schedule).

2) Piccadilly Railway Station, Manchester, UK; 1997-2002; comprehensive reconstruction of the station; main concourse redevelopment phase

This project involved the phased demolition of much of the station and reconstruction to a new design. It was deemed to be particularly important that the new station should open in time for the Commonwealth Games held in July-August 2002. The project was successful in achieving a largely open station for the intended date. Three issues arising during the project are of particular note:-

i) In the middle of the station stands an office block controlled by Railtrack's commercial property division (i.e. not under the control of the rail operating or project delivery departments). Urgent refurbishment works to this office block (not part of the station redevelopment project) were delayed and 'sterilised' areas of the concourse below required by the construction manager on the main refurbishment. After inter-departmental negotiation, these works were eventually brought under the control of the station redevelopment team. However, the delay on the separate office block refurbishment works affected the overall station programme and the results that were achieved required substantial schedule acceleration and additional resources elsewhere.

ii) The leader of the client's project management team stated quite clearly that his prime objective was to finish the project within the capital cost and time constraints imposed on him. The level of ongoing pedestrian movement was a constraint – not a variable to be jointly maximised with other project objectives.

iii) The period of maximum constraint on pedestrians allowed only a comparatively small corridor through the works. This was somewhat smaller than had been originally envisaged (although it had been modelled for pedestrian capacity for evacuation purposes). This 'maximally constrained' configuration lasted for several months.

DECISION PROTOCOL OR PROCEDURE FRAMEWORK

A suggested framework for dealing with public disruption is shown in Figure 3.

The problem of allocating space between construction and the ongoing business

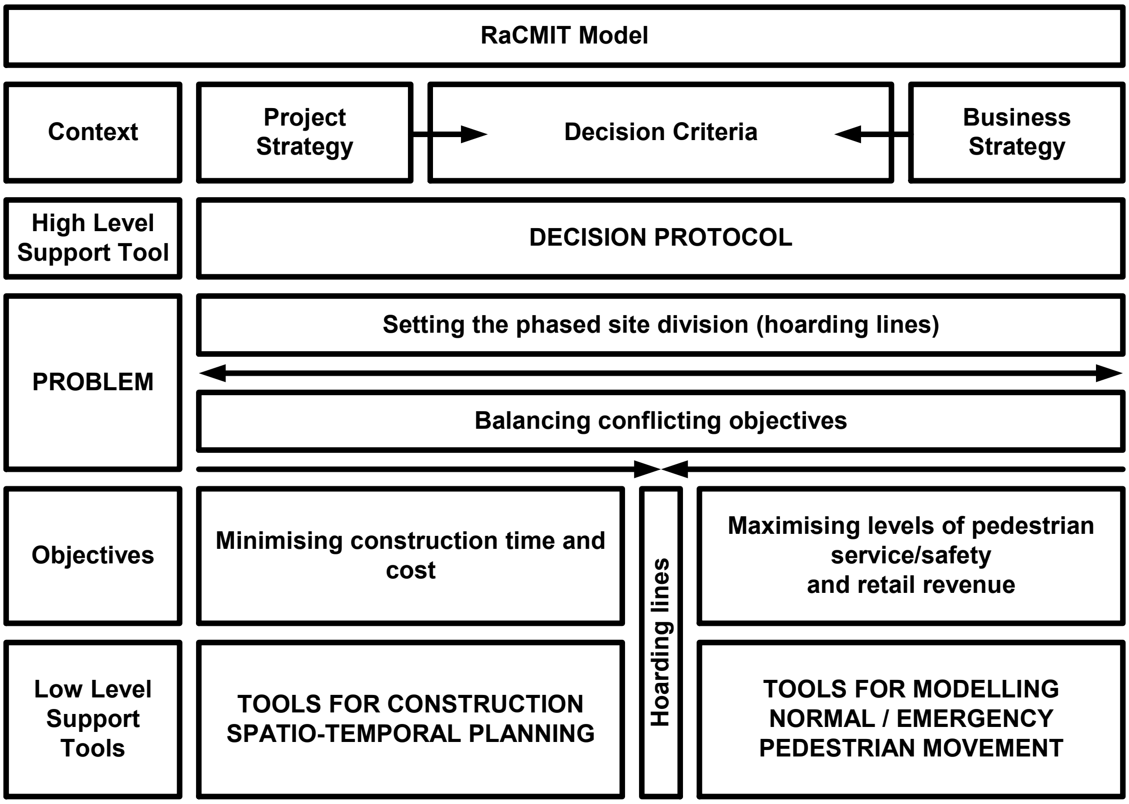

Figure 3

The high level task

Establish, evaluate and select criteria/preferences relevant to the location, timing and division of the project construction phase (Figure 3)

This process involves:-

a) establishing the identity / status of project stakeholders and their desired project outcome criteria,
b) establishing the place of continuing operational requirements within the strategic briefing process,
c) establishing decision criteria value / ranking from a) and b) above.

<u>a) Selecting decision criteria – stakeholders</u>

According to Winch (2002) the key attributes of stakeholders are their relative power or influence and interest in the project. Taking the project at Piccadilly as an example we can classify the stakeholders (Table 2) as follows:-

Key Players (Higher influence, Higher interest) – Railtrack, TOC's
Those who must be kept satisfied (Higher influence, Lower interest) – ORR, SRA, HMRI

Those who must be kept informed (Lower influence, Higher interest) – PTE, Retail tenants
Those who require minimal effort (Lower influence, Lower interest) – General public

Now this is not to suggest that the general public were uninterested or ignored during the Piccadilly refurbishment – rather that they were represented during the major station change approval process by those whom Winch (2002) refers to as their 'institutionalised interests' (TOC's, ORR, SRA, HMRI, PTE).

The plans for the temporarily re-configured station during refurbishment had to be submitted to the SRA/ORR as part of the Major Change approval process (Figure 2). While nominally the SRA and ORR have the power and the PTE has influence, it is the TOC's who, in practice, have the greatest say and, without their approval, it is unlikely that a scheme will be passed (and they have a considerable interest in minimising disruption to pedestrian movement). However, this is a one-off process at the planning stage and in the end the process was governed by the overwhelming pressure put on Railtrack to complete in time for the Commonwealth Games (GMPTE 2001). Completing on time was ultimately preferred to achieving limited pedestrian disruption.

b) Selecting decision criteria – client strategy

Nutt (1993) notes the deficiency of the traditional briefing process in addressing the immediate occupancy needs of the client while ignoring the whole life occupancy of a built facility (from a 'design for use' rather than a maintenance viewpoint). He points out that the briefing process needs to address the dynamic and uncertain nature of business/organisational development and change.

In contrast, briefing in occupied refurbishment runs the risk of ignoring the *pre*-completion occupancy except as a constraint on the construction project. Assuming that clients have some level of operational service quality as part of their strategic aims (such as the SERVQUAL model – Parasuraman *et al*. 1988) then the impact of the refurbishment works needs to be incorporated in the brief. It might be assumed that the promise to customers of new, improved facilities in the future will induce them to tolerate a large level of disruption beforehand. The best retailers already know that this is not the case[2].

In addition, the brief needs to address whether the refurbishment project is part of a programme of disruptive projects which runs the risk of alienating the customer (or other stakeholders) through 'disruption fatigue' which creates uncertainty about the reliability of the service being offered. Such might be the case in a multi-phase reconstruction of a shopping centre or upgrading an entire Railway line (including stations). In such cases it may be better to a) regard refurbishment as a core activity and have it more fully integrated into the business (Male *et al*. forthcoming) and b) evaluate the problem of disruption (as far as possible) on a 'whole programme' basis.

c) Evaluating multiple decision criteria

In comparing the values arising out of stakeholder management and strategic briefing processes, two broad approaches will be mentioned. (It is assumed that a project will already have passed some form of private or social cost-benefit analysis.) Firstly Kaplan and Norton (1992) introduced the concept of a 'balanced scorecard' which takes in the current financial/business targets alongside those for customer, internal and learning processes. Neely *et al*. (2002) go beyond this in arguing for a wider stakeholder satisfaction (and contribution) approach to setting strategic performance measures. They stress the importance of gaining sufficient relevant data about customer service requirements (including 'failure mode analysis') in order to set appropriate and measurable targets. Customers would include (for a railway station operator) Train Operating Companies and concession retailers as well as the general public.

Secondly, the view of the Strategic Rail Authority on the value of station facilities is as follows:-

> ‘Station facilities comprise a wide range of features, each of which individually may have relatively little impact on passengers' decisions to use rail, but when combined as a package may significantly influence their perceptions. As with rolling stock, station facilities can be measured and valued using 'priority evaluator' and 'stated preference' techniques, with the aggregate value of any improvements varying according to the standard of the station and the facilities provided before and after the improvements.’ (SRA 1999)

An example of the ‘priority evaluator’ technique in the rail context can be found in Harrell (1990). ‘Stated preference’ techniques are described in DTLR (undated A) and Louviere *et al.* (2000). These are techniques which come under a wider heading of Multi-criteria decision analysis for which a useful overview can be found in DTLR (undated B).

Disruption needs to be treated as an additional variable to be co-evaluated with other more familiar variables in equations, preference rankings, scorecards or other means used to support the comparative evaluation of strategic objectives. These value orderings then need to be used as inputs into the low level task starting with value management/buildability review(s) (if any) followed by the construction planning and execution stages.

The low level task

Establish, evaluate and select construction alternatives (Figure 3)

This process involves:-

a) establishing a manageable set of alternative construction phase plans using spatio-temporal construction planning tools,
b) modelling the alternative residual public spaces in terms of:
    a. predicted pedestrian movement behaviour
    b. pedestrian safety in terms of evacuation and fire movement

    using pedestrian / fire movement modelling tools,
c) selection/modification of alternatives according to the agreed decision criteria and the risks identified in the construction planning and pedestrian modelling processes.

<u>a) Construction planning support tools using spatio-temporal simulation/visualisation</u>

The current approach to spatio-temporal planning by construction planners is set out in Kelsey *et al*. (2001). This also outlined their requirements for a computer-based spatio-temporal planning support tool as part of another research project called VIRCON. This research project is nearing completion and the tool has been tested and evaluated by a number of construction planners (North *et al*. 2003). While the development was not part of the RaCMIT research, its availability is important. RaCMIT can be used most effectively when there are effective tools to model alternative spatio-temporal construction plans with a reasonable degree of speed. Without such tools planners will not consider the effort expended to be worthwhile. Boundaries of these construction plans 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 subjected to pedestrian/fire movement modelling.

b) Modelling pedestrian / fire movement

Only the method under 2) below has been used in the RaCMIT research. The others are, however, relevant and available. Therefore they need to be included in the overall framework.

1) The maintenance of a certain pedestrian flow through a particular space can been obtained using Origin-Destination pedestrian models, which are very effective for demonstrating pedestrian movement *capacity*. Railtrack had (for other purposes) already modelled Victoria Station using PAXPORT (Barton and Leather 1995). The contractor at Piccadilly used PEDROUTE (Buckmann and Leather 1994) to demonstrate the evacuation viability of the pedestrian areas created by the proposed site boundaries. The capacity metric used is that of 'level(s) of service' (Fruin 1971) which comprise a set of capacity-based congestion measures widely used in the design of permanent station structures (Ross 2000). However, while such models use configuration as part of the determination of pedestrian movement *capacity*, they ignore it as a causal determinant of pedestrian movement *behaviour*.

2) The Space Syntax method for analysing pedestrian movement was developed at UCL (Hillier and Hanson 1984) and has a proven track record in forecasting change in movement behaviour when the *configurations* of pedestrian space are disrupted. It is particular effective in examining browsing behaviour in various urban environments (including retail situations). Key analytical techniques include Axial Analysis measuring the relative complexity of pedestrian environments and Visibility Graph Analysis, which measures the relative visibility within areas (in terms of the visibility of each point in an area from any other point in that area) (Turner and Penn 2002, Turner 2003).

- The results of modelling the disruption caused by the entrance closure at London Victoria demonstrated that configuration changes induced significant alterations in the behaviour of pedestrians visiting retail units / facilities in the vicinity of a comparatively small construction project.

- Further modelling of restricted configurations at Manchester Piccadilly showed alternatives that might have been used to facilitate pedestrian movement with only small increases in the area conceded by the contractor. (In practice, the contractor was obliged to stick to a maximally constrained area by the very tight requirements of the construction schedule.)

- Agent modelling was used on the same Piccadilly configurations and broadly confirmed the configuration-based findings. Such techniques allow agents with both Origin-Destination behaviour and Space Syntax configuration-based behaviour to be modelled simultaneously thus allowing the best of both approaches to be combined into a single tool (Penn and Turner 2001). These techniques, however, only became available late in the research project.

3) Pedestrian evacuation modelling techniques show the effect of both *configuration* and *capacity* on pedestrian movement in emergency situations. However Railtrack's contractor at Piccadilly was only required to use Origin-Destination modelling for the purposes of pedestrian evacuation at Piccadilly. Potential limitations of this approach and other available methods are set out in Gwynne *et al*. (1999). Pedestrian movement behaviour in emergency situations differs substantially from that normally observed and some of the above techniques enable the movement of 'agents' with given behavioural characteristics to be modelled under different conditions.

4) Dynamic fire modelling techniques (Drysdale 1998) show the effect of *configuration* (often combined with materials selection) in assisting or retarding the spread of fire. In creating site boundaries, the construction planner is, in effect, temporarily redesigning the station and must be careful not to create configurations which are potentially dangerous and which an experienced architect would avoid.

c) Selection of alternatives

This is a (potentially messy) mediation process and is more likely to be an iterative rather than a single cycle process as even self-evidently preferable alternatives may benefit from minor adjustments. Furthermore, situations may arise during the construction phase, which require major revision of the phase plans (as happened at both London Victoria and Manchester Piccadilly). It should be particularly noted that not all changes which improve pedestrian flow entail significant additions to construction cost or time.

FINDINGS AND CONCLUSION

1) Occupied refurbishment projects are rarely carried out on purely economic criteria and decision making processes in occupied refurbishment projects must incorporate the ability to consider all significant criteria in planning project delivery (including disruption).

2) Those decision criteria that are included in project evaluation must also be carried through to decision making processes at planning and execution stages – regardless of functional divisions (between capital works and operations departments). Project costs, revenues and other decision variables must be broadly defined in order to give managers incentives to take decisions, which are jointly optimal for the client's project objectives *and* the ongoing business.

3) Occupied refurbishment projects require the identification *and control* of all spaces *affected by or which affect* the refurbishment works. This requires a joint decision-making framework, which includes the primary space controller (the station owner in the case studies), the contractor and all space-holding stakeholders. (A project observation is that those failures to do this, which had a significant impact on project schedules, did not happen out of a lack of will or competence but rather that no single participant in the process could actually identify all the relevant spaces – a framework to do this must therefore be put in place.)

4) Consideration of the disruption of pedestrian-occupied space must consider *configuration* disruption as well as *capacity* disruption. Failure to do this can lead to both unnecessary disruption costs and/or additional safety hazards in evacuation scenarios.

5) Planning occupied refurbishment requires significantly more planning resources by contractors than that required to plan a new building of equivalent contract value. (For a study of planning and control processes in refurbishment see Egbu *et al*. 1997) Additional resources are required in management of the on-site *planning* relationship with the client and other stakeholders. The procurement processes of the *client* must take this requirement seriously when awarding contracts in order that decision processes involving the contractor can be effectively implemented. Accepting lowest price tenders, which do not allow for sufficiently large planning resources may be counter-productive.

6) Tools are now available both to reduce the effort required for spatio-temporal construction planning and also to enable pedestrian modelling (the latter with the assistance of consultants) of disrupted areas. These tools can allow the estimation of measurable effects (on both construction cost/time and pedestrian movement) of different

refurbishment phases/configurations and allow customer-oriented strategic objectives under the heading of 'disruption' (or as part of 'negative' customer satisfaction) to be incorporated into practical, site-based decision making processes.

7) In order that such tools can be effectively used, however, the mindset of project and construction managers needs to change to accommodate disruption as a variable rather than as a constraint.

This paper has presented a framework for considering public disruption in occupied refurbishment using two case studies in large railway stations as examples. It has briefly described new tools which (combined with existing techniques) assist decision making in the management of disruption. It has linked strategic with site-based decision making and suggested how public disruption may be treated as a variable to be jointly optimised along with traditional time, cost and quality criteria.

NOTES

[1]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.

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

REFERENCES

Barton, J. and Leather, J.A. (1995) PAXPORT – Passenger and crowd simulation *Passenger Terminal '95* 71-77

Buckmann, L.T. and Leather, J.A. (1994) Modelling station congestion the PEDROUTE way. *Traffic Engineering and Control* **35** 373-377

Drysdale, D.D. (1998) *Introduction to fire dynamics* (2nd edition) John Wiley & Sons, Chichester

DTLR (undated A) *Economic Valuation with Stated Preference Techniques: Summary Guide* http://www.dtlr.gov.uk/about/economics/

DTLR (undated B) *Multi Criteria Analysis: A Manual* http://www.dtlr.gov.uk/about/multicriteria/

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

Fruin, J.J. (1971) *Pedestrian planning and design* Metropolitan Association of Urban Designers and Environmental Planners Inc., New York

GMPTE (Greater Manchester Passenger Transport Executive) (2001) "Transport chiefs demand Piccadilly Rail Station works completed in advance of 2002 Games" Press Release 14/11/2001

Gwynne, S., Galea, E.R., Owen, M., Lawrence, P.J. and Filippidis, L. (1999) A review of the methodologies used in the computer simulation of evacuation from the built environment *Building and Environment* **34** 741-749

Harrell, L. (1990) *The effect of intangible attributes on rail passenger demand with special reference to ride quality* PhD Thesis, Centre for Transport Studies, Cranfield University http://homepage.virgin.net/dr.lawha/bnrcons/PhD.pdf

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

Kaplan, R.S. and Norton, D.P. (1992) The balanced scorecard – measures that drive performance *Harvard Business Review* January-February 71-79

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 15 University College London

Louviere, J.J., Hensher, D.A. and Swait, J.D. (2000) *Stated choice techniques: analysis and application* CUP, Cambridge

Male, S.P., Gronqvist, M., Kelly, J.R., Damodaran, L., and Olphert, W. (forthcoming) *A good practice framework for high street retail client refurbishment* (provisional title) Thomas Telford, London

Neely, A., Adams, C. and Kennerley, M. (2002) *The performance prism: the scorecard for measuring and managing business success* Pearson Education, Harlow

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.

Nutt, B. (1993) The Strategic brief *Facilities* **11** 28-32

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

Ross, J. (2000) *Railway stations: planning, design and management* Architectural Press, Oxford (Chapter 5)

SRA (1999) *Planning criteria - A Guide to the Appraisal of Support for Passenger Rail Services* http://www.sra.gov.uk/sra/publications/other/1999_06_16/CRITERIA section 6.35

SRA (2003) Strategic Rail Authority Website http:/www.sra.gov.uk/

Turner, A. and Penn, A. (2002) Encoding natural movement as an agent-based system: an investigation into human pedestrian behaviour in the built environment *Environment and Planning B: Planning and Design* **29** 473-490

Turner, A. (2003) The visual dynamics of spatial morphology *Environment and Planning B: Planning and Design* (forthcoming)

Winch, G.M. (2002) *Managing construction projects: an information processing approach* Blackwell Science, Oxford (Chapter 4)