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Balancing Operating Revenues and Occupied Refurbishment Costs 1: Problems of defining project success factors and selecting site planning methods

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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) was a research project aimed at addressing this problem. The objective of the research was to develop a decision protocol facilitating optimisation of overall project value to the client's business. This paper (the first of two) presents a framework for considering public disruption in occupied refurbishment using two case studies in large railway stations as examples. It briefly describes new tools which (combined with existing techniques) assist decision making in the management of disruption. It links strategic with site-based decision making and suggests how public disruption may be treated as a variable to be jointly optimised along with traditional criteria such as time, cost and quality. 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 spatio-temporal site decision-making, effective and efficient tools now exist to model both sides of the construction site boundary.

Keywords: construction planning, multi-criteria decision-making, occupied refurbishment, pedestrian modelling, stakeholder management

Introduction

This is the first of two papers dealing with decision-making problems in occupied refurbishment both at the strategic and site planning levels. Little by way of previous research is available to synthesise decision-making at both levels. The key problem relates to projects carried out in publicly accessible areas. In carrying out phased occupied refurbishment, the publicly accessible spaces are disrupted, and, therefore so is the pedestrian movement behaviour. This can have deleterious effects on retail revenue and operating efficiency.

Two cases studies both set in major railway stations are described and certain key processes and outcomes are noted. As these appear to be sub-optimal in minimising pedestrian disruption, an alternative approach is suggested. Additionally, one of the problems facing site planners has been the lack of tools to assist spatio-temporal site planning within site boundaries and a variety of tools to model pedestrian behaviour outside the site boundary. In the former case, such tools are now available and reference to the relevant literature on these is presented. In the latter case the traditional tools of pedestrian capacity and evacuation modelling are necessary but insufficient to model changes in pedestrian behaviour which affect operational

efficiency and retail revenue. An additional tool is briefly described and explored in more depth in Kelsey (forthcoming).

It was impossible to 'test' the proposed alternative procedures within the confines of the research project without essentially changing the character and organisation of the client (particularly as the client was placed in administration during the course of the project). However some empirical evidence is presented in Kelsey (forthcoming) supporting the efficacy of the additional pedestrian modelling tool.

The occupied refurbishment problem

As the age of the built stock increases, owners are increasingly faced with decisions to rebuild or refurbish or dispose of individual constructed assets. However, this is not merely a problem of physically ageing assets. Work carried out at the same time as this research (Male *et al*. 2003) found that retail clients refurbish physically sound stores to reposition their business strategy either in the context of the growth of a retail chain or, for more mature retailers, to maintain or increase competitive advantage. Refurbishment becomes, as the authors put it, 'an enabler to the business' (Male *et al*. 2003 p6-7). Further drivers as to timing include seasonal variation, availability of finance and the management of a cyclical upgrading programme. (Male *et al*. 2003 p107).

However, they are also aware that major refurbishment can lead to significant loss of revenue which may take 1-2 years to recover. Accordingly, when carrying out reconstruction or improvement works, retailers and related stakeholders aim to minimise the impact as far as customers are concerned.

One well-known retailer has a policy of minimal disruption in carrying out refurbishment works to its outlets. The ‘white wall’ vertical retail space is maintained at a maximum during construction works (through the use of temporary partitions) and attempts are made to keep visual, oral and olfactory disturbance to a minimum. The contractors in turn attempt to maximise use of their limited construction space by planning the refurbishment so as to minimise the relocation of payment points and other facilities requiring the disturbance of mechanical and electrical services.

In addition to large stores and shopping centres, a number of transport undertakings such as BAA and Network Rail have significant retail space within their passenger terminals. They have additional problems in that refurbishment can disrupt their normal transport operations as well as retail revenue. For operators such as London Underground, stations can be closed for refurbishment. BAA cannot close Heathrow and Network Rail cannot close a major station in the same way - for financial reasons if no other. In the case of some of Network Rail's stations they cannot even take a decision to rebuild since many of these stations include listed buildings of significance for transport history and/or cultural heritage. As the construction of railways increased throughout the world during the 19th and early 20th centuries, this is of international interest as significant refurbishments in recent years show such as (for example) those at Union Central (USA), Hannover Central (Germany), Prague (Czech Republic) and Dunedin (New Zealand). However, recent restructuring and privatisation of railways have complicated the process as will be shown later.

Previous research work

Apart from the research quoted above there is little published research work on this question. Work has been done on the general problems of refurbishment (Egbu *et al*. 1998). Given the potential disruption caused by refurbishment, pedestrian modelling techniques are important and there is an extensive literature on these which will be referred to later. However, nowhere do we find the high level decision making regarding such projects brought together with the lower level problems of planning refurbishment and minimising operational disruption although one early attempt at the latter, Whiteman and Irwig (1988), does provide a useful general approach to the problem. In addition there is some literature on the problems of managing highway refurbishment to minimise disruption but the problems there are of an essentially different nature.

The research

To find a framework for looking at these questions, University College London (UCL) looked at the development of a decision protocol (or set of procedures) assisted by industrial partners under an EPSRC-funded project. Two refurbishment projects were investigated in large stations (London Victoria and Manchester Piccadilly – the client for both projects was Railtrack plc - now Network Rail) 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 was called RaCMIT (Refurbishment and Customer Movement Integration Tool).

The field work consisted of:-

a) semi-structured interviews with project management staff at various stages during the projects,
b) attendance at a number of project meetings and
c) pedestrian modelling of affected areas using the Space Syntax methodology

The research questions

The research questions were:-

1) Are there problems in the project (particularly requirements) management processes which hinder the incorporation of disruption as a variable (rather than a mere constraint) into refurbishment project decision-making? If so, can an amended framework for decision-making be suggested?

2) Can configuration-based diagnostic tools currently used for predicting pedestrian flows in the built environment be applied to temporary changes in configuration brought about by changing site boundaries impinging on previously publicly accessible space? If so, can a set of guidelines be suggested for clients and contractors for minimising pedestrian disruption during phased occupied refurbishment works?

The first question and the framework for the second is presented in this paper. The second is dealt with in detail in Kelsey (forthcoming).

The UK passenger rail industry context

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

UK Passenger Rail Industry Structure (2001)

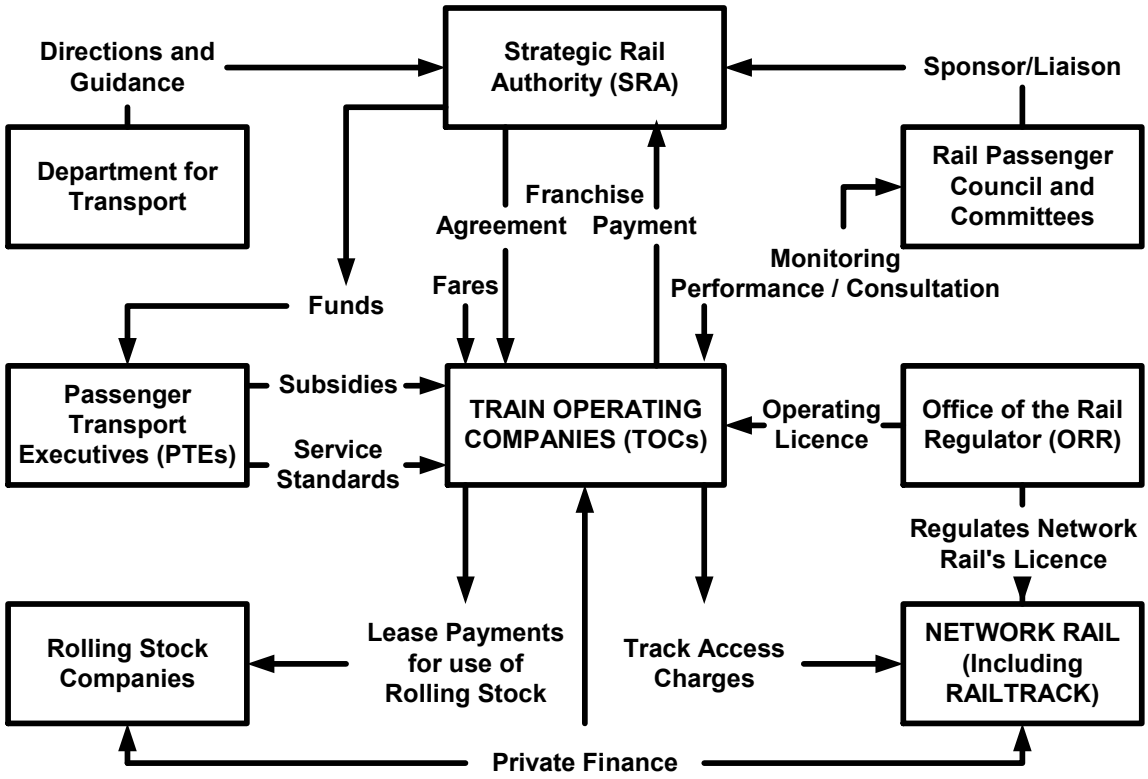

Figure 1 (adapted from SRA 2003)

The main bodies for the purpose of the research were 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 were 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 ran all stations apart from the 14 (now 17) 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 set the financial framework and the overall agenda for industry development (now re-absorbed within the Department of Transport).

The Office of the Rail Regulator (ORR) (now the Office of Rail Regulation) – 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 (now being absorbed into the ORR).

Railway Passenger Council (RPC) – this is a forum to represent passenger views

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

Framework for major station changes (2001)

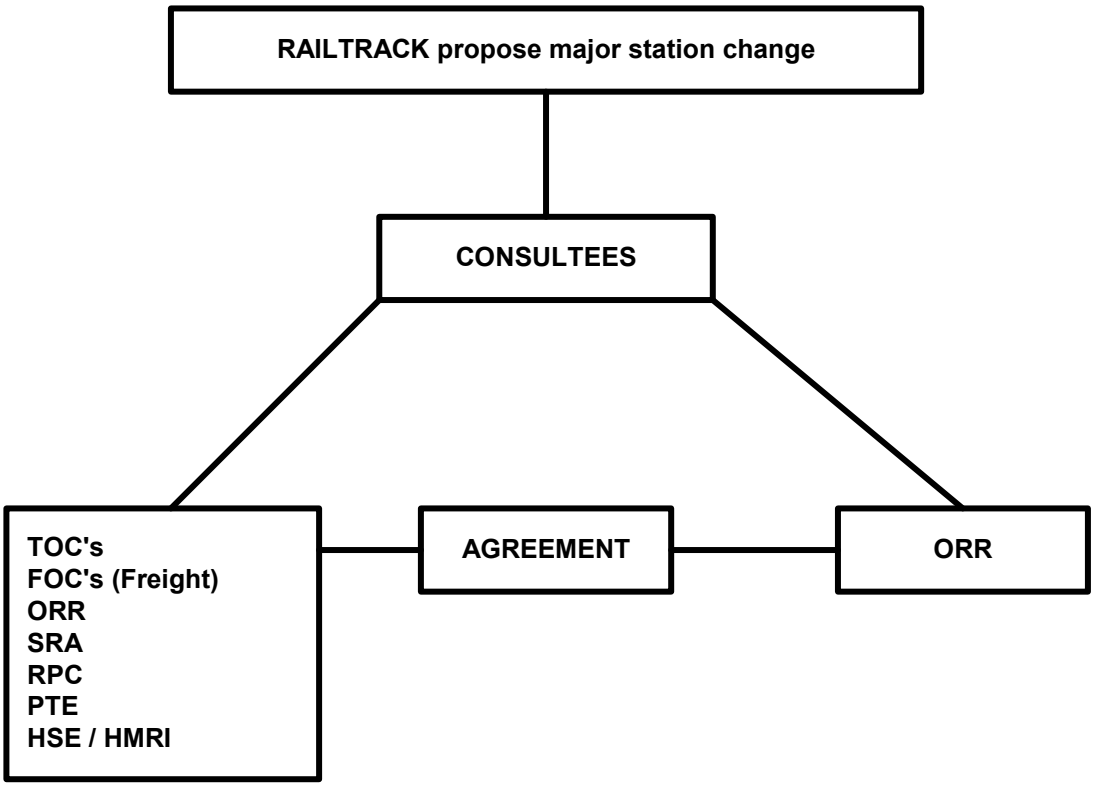

Figure 2 (adapted from information supplied by Railtrack in 2001)

The case study 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	Major but 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 (although there were Grade 1 listed structures which had to be retained). 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 then 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 in any way 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. The disruption caused to the general public appears to have been considerable as could be gauged from BBC interviews (BBC 2002).

The effect of alternative actions on financial accounts

According to financial management economists (for instance Brealey and Myers 2000), a rational profit-maximising client will try to maximise the Net Present Value of cash flows provided by the changed revenues, operating and capital costs of the changes brought about by the refurbishment project and its effects (both short- and long-term) on operations.

However according to the relevant Financial Reporting Standard 15 (Accounting Standards Board 1999):-

FRS 15.06 states:

> 'A tangible fixed asset should initially be measured at its cost.'

FRS 15.07 states:

> 'Costs, but only those costs, that are directly attributable to bring the asset into working condition for its intended use should be included in its measurement.'

FRS 15.09 states:

> 'Directly attributable costs are:
> (a) …….
> (b) the incremental costs to the entity that would have been avoided only if the tangible fixed asset had not been constructed or acquired.

FRS 15.11 states:

> 'Abnormal costs (such as…….) and costs such as *operating losses that occur because a revenue activity has been suspended* during the construction of a tangible fixed asset are *not* directly attributable to bringing the asset into working condition for its intended use.' (Author's italics)

So it would appear that lost revenue caused by a project cannot be capitalised but the additional project cost of avoiding that lost revenue can be capitalised. (There are also asymmetric tax effects although space does not permit them to be examined here.)

The accountants might argue that FRS 15.09(b) should, in theory, cover this but the wording is open to a wide range of interpretation and it is the experience of this author when working as an accountant that no attempt has been made to identify additional refurbishment costs attributable to avoiding lost revenue. The main argument (if any) with the Inland Revenue is normally about maximising the stated repair element (which can be written off against operating revenue) that is inevitably part of any refurbishment project.

There is an additional financial factor to be considered in that the client in this case (Railtrack) was only affected by a portion of the changes in retail revenue so this consideration needs to be factored into the financial calculations.

Capital budgeting and operating divisions

The foregoing section hints at a general problem in large organisations namely that capital expenditure decisions are made and executed through procedures which are largely isolated from day-to-day operational decisions (even if the operational managers have been consulted about the capital projects themselves).

So the manager referred to above who saw his priority as keeping within the authorised capital budget cannot be faulted. He was merely doing his duty within the limits of the remit given to him. Any other factors were 'constraints' within which he had to operate.

A suggested decision protocol or procedure framework

The key outcome of examining the decision-making process is that pedestrian disruption was essentially treated as a constraint which had to be minimally satisfied and within which other factors such as time and cost had to be optimised.

The approach suggested by Whiteman and Irwig (1988) of using a joint maximisation (or cost minimisation - including lost revenue) model is the alternative approach taken here although as will be seen, it is not a purely financial problem. The losses caused by disruption have to be considered in both financial and non-financial terms -

particularly for a railway operation where the financial effect of station-based pedestrian disruption may be difficult if not impossible to quantify.

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

The problem of allocating space between construction and the ongoing business

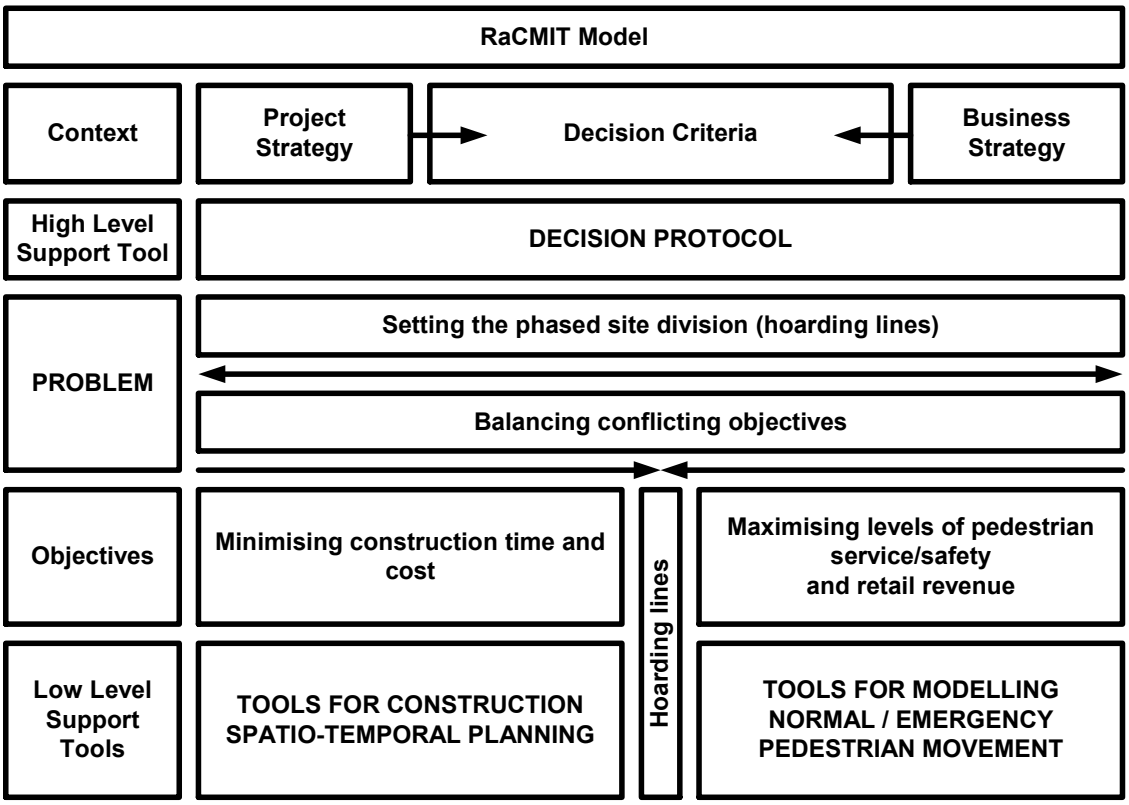

Figure 3

The high level (requirements management/feasibility) 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, their desired project outcome criteria and relative weight in power and interest,
b) establishing the place of continuing operational requirements within the strategic briefing process,
c) establishing decision criteria value / ranking from a) and b) above.

a) Selecting decision criteria – stakeholders

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) and the relevant required actions or status as follows (Figure 4):-

Stakeholder mapping for station changes/refurbishment

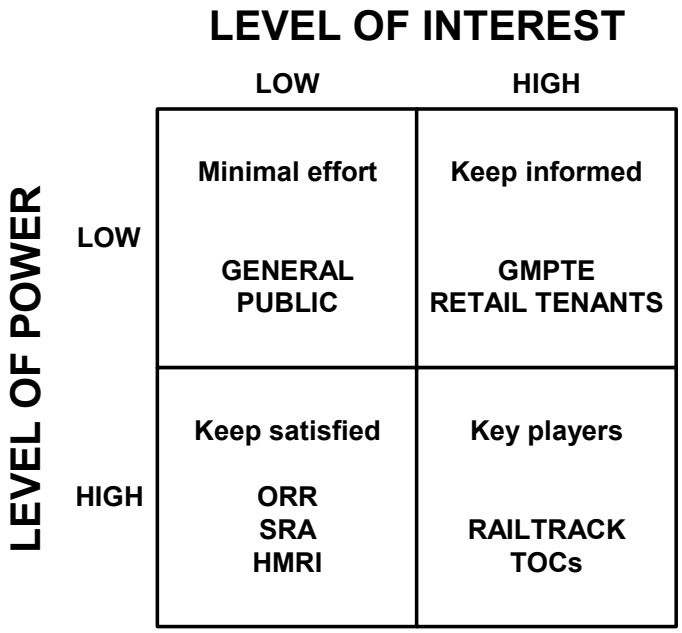

Figure 4 (adapted from Winch 2002)

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' (TOCs, 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 TOCs 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 was *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 held in Manchester in 2002 (GMPTE 2001). Completing on time was ultimately preferred to achieving limited pedestrian disruption. As those in the legal profession might express it 'time was of the essence'.

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*. 1985) or similar 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*. 2003) 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, it is assumed that a project will already have passed some form of financial feasibility study or private/social cost-benefit analysis. Looking beyond purely financial considerations 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 was 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). Other techniques such as the Analytical Hierarchy Process (Saaty 1980) may be employed. 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).

Finally 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/constructability review(s) (if any) followed by the construction planning and execution stages.

How to measure the level of disruption

In order to incorporate disruption as a variable into decision making, there needs to be agreement on the indicator of the severity of disruption.

i) Revenue-based indicators

Clearly one of the aims of minimising disruption is to try and prevent loss of revenue to retail outlets and Train Operating Companies (TOCs – in the case of a station). There are, however, problems with this. Given that the retail outlets are often managed by businesses who are tenants of the refurbishment client, they will want to reveal as little as possible about their retail revenues to their landlords (or anyone else). One indirect measure is the change in the number of people entering an outlet which might well serve as a reasonable proxy variable (this was indeed used in the field research). However, it would be difficult (without considerable further research) to use this for *predicting* revenue loss for decision-making purposes.

ii) User complaint-based indicators

In the case of the TOCs, the disruption is less likely to cause direct revenue loss than increases in customer complaints and/or increases in measures of customer dissatisfaction in passenger surveys. A passenger survey during the refurbishment could give an indication of changes in customer satisfaction arising from the disruption. However that might also reflect other changes in the individual TOC's performance given that ease of movement through the station is one of a number of factors affecting a traveller's journey satisfaction. Such attitudes may also be revealed in the standard procedures used by both TOCs and station infrastructure provider for monitoring complaints. As for i) above, however, it would be difficult to use this as a *predictive* tool (without a sizeable body of previous evidence).

iii) Reduced public space capacity- and configuration-based indicators

The reduction of publicly accessible space reduces the number of pedestrians who can pass through a particular area. This can be measured and indeed *must* be predicted (through capacity modelling) in order to ensure that such a reduction does not pose a safety hazard.

An additional approach is to gauge the negative impact of reduced public space on desirable configuration patterns. This approach is described in detail in Kelsey (forthcoming) and was used in the field research.

The low level (site planning) 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 complementary residual public spaces (i.e. the other side of the hoarding) in terms of:
    a. predicted pedestrian movement behaviour
    b. pedestrian safety in terms of security, evacuation, fire movement

   using pedestrian / fire movement modelling tools,
c) selection/modification of alternatives according to the agreed decision criteria (resulting from the high level task above) and the time/cost/space estimates and their associated risks identified in the construction planning and pedestrian modelling processes.

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

The current approach to spatio-temporal planning by construction planners is set out in Kelsey *et al*. (2001) and Winch and Kelsey (2005). This also outlined their requirements for a computer-based spatio-temporal planning support tool as part of another research project called VIRCON. This tool was tested and evaluated by a number of construction planners (North *et al*. 2003). This is a development assisted by wider research on construction planning of space-related, quality, resource-constrained tasks and the development of 'n-dimensional' site product and process modelling (for example, Burch 1985, Thomas and Smith 1990, Tommelein et al 1991, Thabet and Beliveau 1994, Riley and Sanvido 1995/1997, Goldratt 1997, Ballard and Howell 1998, Zouein and Tommelein 1999, Koo and Fischer 2000, Akinci, *et al.* 2002a/b and Lee *et al.* 2005)

As Critical Path Analysis tools allowed planning in time, 'Critical Space Analysis' tools allow planning in both space and time (Winch and North 2006). While this work 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 (Kelsey *et al.* 2001).

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. In order to jointly maximise construction efficiency and pedestrian movement efficiency, tools are required for *both* sides of the hoarding.

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 movement and 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). This is explored further in Kelsey (forthcoming).

- 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) Passenger security at railway stations has been investigated by Cozens *et al*. (2004). They find that CCTV/lighting/transparent shelters have a significant effect on perceived passenger security. In terms of configuration, such factors require long sight lines and convex areas the nature of which is explored in Kelsey (forthcoming).

5) 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 an experienced architect would avoid. Possible 'configuration-induced' problems may arise in the event of fire from the creation of:

a) pedestrian corridors with insufficient height (or other means) to effect smoke dispersal (Hinkley 1971)
b) narrow pedestrian corridors which increase the opportunity for flashover through cross-radiation (Hottel and Sarofim 1967)
c) fully or semi-enclosed inclined pedestrian corridors (including temporary wooden staircases) which are vulnerable to very rapid fire spread (via the 'trench effect' first identified in investigating the Kings Cross Underground fire in 1987 – Woodburn and Drysdale 1997).

c) Selection of alternatives

This is a (potentially messy) mediation process and is 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.

Conclusions

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 instructions (and 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. 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 *for both sides of the contractor's site boundary* to reduce the effort required for spatio-temporal construction planning inside the boundary and also to enable pedestrian modelling (the latter with the assistance of consultants) of disrupted areas outside the boundary. 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' 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.

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