Building Services in Use: some lessons for briefing, design and management

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Introduction

Buildings are complex systems in which many variables are statistically associated, particularly when physical and human elements are taken together. Sometimes such associations have been too eagerly reported as cause-and-effect. For the occupant, the influences of the building, its systems, and its management are inseparable. For example, if the systems are good and the management is attentive and responsive, occupants can report good perceived control even where they have few control facilities. Quests - often fruitless - for single "causes" (e.g: of building-related ill-health) are therefore making way to studies of wider aspects of systems performance. This paper outlines some preliminary conclusions from two recent collaborative research projects from the DETR's (formerly DoE's) Partners in Technology research programme:

- Probe (an acronym for Post-occupancy Review of Building Engineering);
- Reset (improving energy performance by better use and setting of controls).

Probe (principal investigators HGa Ltd and WBA, with Building Use Studies Ltd for occupant surveys) included rapid dissemination of results by the "industrial sponsor", the Building Services Journal, with eight case studies and three overview articles published over the past two years [1-11]. The principal investigators for Reset are ECD Energy and Environment, sponsored by a club of building occupiers, controls manufacturers, and facilities management and maintenance companies.

Some results from Reset

Energy is often wasted in offices because systems run too liberally: if only the controls could be set as the designers had intended! As facilities managers know, the answer is often not that simple: maybe the designers did (or could) not foresee the way occupiers would want to use the building, the installed systems did not operate quite as anyone intended, or the BEMS was obscure or capricious.

Nevertheless, there are a lot of savings to be had (10 per cent to 30 per cent of HVAC energy costs in offices surveyed by the Reset team [12]) by avoiding over-liberal provision, excessive running hours, and plant inefficiencies, including complete nonsenses such as boilers, humidifiers and frost protection operating on the hottest days of the year! But this is where the good news stops: the project aimed to implement the recommended measures, monitor their achievement, and spread the good news. In fact, few operators of the surveyed buildings wanted to pick the ten-pound notes off the floor! Many adopted a defensive attitude and did not welcome the information provided.

Why this market failure? What is going wrong? In these buildings - as in many others - organisations were satisfied with their existing service provision and charges and lacked the motivation to upset the status quo. The dice were loaded to service rather than to economy. Why bother to run systems more efficiently when it is not in your contract or job description, and when doing so means extra work for you, and extra trouble if someone complains?

Analysis of the motivation of all parties involved revealed many reasons for not taking action, with only three key motivations for wanting to run systems efficiently:

1. Tenant organisation's desire to save money.
2. Tenant's, Landlord's or Facilities Manager's desire to demonstrate best practice.

3 Individual's or contractor's professional pride.

Better mechanisms are needed to improve motivation and promote action. Often there are gaps in the chain of provision. For example, an organisation with a policy to minimise energy use or environmental impact may well have nothing in its facilities management contracts to reflect this. Reset is now investigating how contractual and informal links can be improved, both in theory and through case studies of buildings and organisations which have achieved good performance.

The importance of management

Earlier studies have already identified examples where it has been done. For instance, [13] showed that occupant satisfaction and energy-efficiency could go together. However, there was no simple management formula or technical quick fix. The best results were achieved by committed managers with clear objectives involved in effective briefing (or evaluation and modification of rented space prior to occupation), constant monitoring of performance, and rapid response to problems and complaints in a culture of continuous improvement.

Interestingly, in buildings surveyed to date, pre-lets often seem to get better all-round results than owner-occupied or particularly speculative buildings. One possible explanation is that tenants of pre-lets can concentrate on aspects which are really important to them, and leave the rest to the developer's team. Indeed appropriate "ownership" of problems seems to be critical to good performance. For instance, clients often hope that designers can magic away all the constraints. Designers, however, can sometimes only relocate them. For example, a quest for "flexibility", intended to reduce the necessity to make alterations from time to time, may in turn create solutions which require constant vigilance - which may be more labour-intensive in the long run!

Some results from Probe

Probe has looked at technical performance, occupant satisfaction, management perspectives, and energy performance of interesting buildings first occupied between two and five years before the study. Of the first eight buildings:

Figure 1: Briefing strategies.

		Technological complexity	
		More	**Less**
Building management input	**More**	Type A Effective but often costly	Type D Rare type
	Less	Type C Risky with chronic performance penalties	Type B Effective, but often small-scale

- Four were AC offices, representative of completions in the early 1990s.
- Three had advanced natural-ventilation (ANV), using stack effect & motorised openings.
- One, a medical centre, was more traditionally naturally ventilated (NV), though with heat recovery mechanical ventilators (now in disuse), plus comfort cooling added in two rooms.

Two buildings had particularly good occupant satisfaction: Tanfield House, a sophisticated deep-plan AC office which demanded - and received - a high level of management; and the low-energy, predominantly NV, Woodhouse Medical Centre, which occupants liked despite some deficiencies in lighting, ventilation and summertime temperatures.

Two of the ANV buildings had very good energy performance (but with scope for further improvement), but all had shortcomings in occupant satisfaction owing to problems with control, commissioning, usability and management - just like many AC buildings. More care needs to be devoted to these aspects, otherwise simpler, more forgiving solutions may be preferable.

The results indicate the need for better briefing; more robust solutions with downside risks considered and minimised; buildings which do not make heavy demands upon management, plus management to suit; better industry support to occupiers after handover; and intrinsically efficient systems with usable controls. Figure 1 shows some basic briefing strategies which result from this analysis, reduced for clarity to four basic types, with technology less and more complex and management low and high input. Of these, Type A and B yield buildings with higher chances of satisfied occupants, while Type C is risky. Type D is rare, and largely occupied by people who were actively involved in designing and building them and understand them inside-out: they can perform very well, but are not easily emulated.

Type A is exemplified by Tanfield House [2], a large AC office with very deep floorplates and a high proportion of clerical staff. In the 1980s, this would have been at high risk of being found to be "sick". In fact, it is the very opposite because Standard Life have deliberately provided enough FM and engineering resources to manage the complexity inherent in the building's space, use and technology. Some people would say it was overmanned, but in return the building delivers the high level of functionality that the occupier requires, and its responsive management constantly makes improvements. Energy use for its building services is, however, average for this type of building and some five times greater than in the three low-energy buildings studied; though since the Probe study FM team has already achieved significant savings.

Woodhouse Medical Centre [7] is a Type B, a relatively simple small-scale low-energy building with a payoff in low environmental impact. Perceived levels of occupant comfort are good, partly because with simple, comprehensible, self-managing systems which occupants can adjust and relate to, occupants tend to forgive the occasions when objectively it does not work all that well, especially in hot, humid spells.

Many other buildings, particularly AC ones, are often Type C, in which demands arising from their technological complexity are not matched by the management provided. Indeed, the management of one AC building [3] knew that they could do more to improve both comfort and energy-efficiency, but said that they had achieved a cost-effective balance [3], even though it fell short of the expectations of the designer. Problems which arise in this situation are often exacerbated because controls, both manual and automatic, either do not work properly or are not well understood (or easily understandable) and used (or readily usable) by the occupiers. This does not only apply to AC buildings: all three Probe ANV buildings had Type C problems, at least at the time of the surveys. This was perhaps as much a matter of unfamiliarity as complexity, but the effort required to deal with it had taken designers and occupants and controls specialists by surprise.

Falling energy prices have reinforced the tendency not to chase potential energy savings. However, with government now setting more ambitious targets for cutting carbon dioxide emissions, energy saving will inevitably return to the FM agenda. Probe has revealed the need for and importance of post-commissioning monitoring to ensure that design intent is being implemented, and that where there are unforeseen requirements and difficulties that the building industry and its clients can learn rapidly from them. It has also exposed the paucity of provision and use of metering, even in ostensibly low-energy buildings; the lack of useful and appropriate design and performance benchmarks; and major shortcomings in the deployment and use of control systems.

Forgiveness

People's overall impressions of a building are more than the sum of its parts. If the design raises the spirits, and the management and the systems are responsive, occupants may tolerate some shortcomings in detailed performance. BUS has developed an index of "forgiveness" [11]: the score for overall comfort divided by the mean of six principal comfort variables. In the better-performing buildings high forgiveness contributed to high overall comfort scores. Design and management for high forgiveness may sometime be a more effective (and cost-effective) approach than attempting to improve comfort by engineering methods - particularly if they risk confusing or alienating the occupant by driving the building into Type C territory.

Control

Control is key to better performance and can improve occupant satisfaction, particularly if circumstances become adverse [13]. It allows:

- systems to operate efficiently according to need;
- management and occupiers to intervene as necessary to adjust programmes and settings;
- individuals to obtain the services they require, when they require them.

People like control and rapid response, particularly when they experience a "crisis of discomfort" [14]. Current trends, however, can tend to take control away from them, for example putting them in open-plan spaces with interlocked furniture which does not allow the working position to be moved (to avoid local glare or draughts, for example), and choosing automated systems with no (or poor) manual over-rides. This can create a dependency culture, in which management has to solve problems which individuals might have been able to deal with themselves. Without good, attentive, and responsive management, this can easily start to unravel.

We are not yet good at designing systems to be usable, manageable and controllable. We think the following rules would help improve both occupant satisfaction and energy efficiency:

1 Automatic systems should provide safe, healthy background conditions economically.

2 Where appropriate, any decision to boost conditions should be made by occupants as close as possible to the point of decision.

3 After boosting, the decision to switch off (or revert to the background state) should be either manual, or automatic if manual action has not taken place after a reasonable interval.

4 The operation of automatic control should where possible be imperceptible to the user.

5 Where automatic operation is perceptible to occupants at their workstations, e.g: switching lights, moving blinds, or opening windows, user over-ride with rapid response is essential.

As one occupant of one of the ANV buildings commented "The computer is supposed to know what is best for us but, unlike me, it does not sit in the draught it causes." The appropriate user interfaces depend on the occupancy context, as discussed in [15] for lighting controls. Control systems surveyed often broke these rules. For example, automated windows could swing open and introduce draughts, noise, traffic fumes and insects, but had no local user over-rides. So-called "intelligent" luminaires turned on lights unnecessarily. Abnormal usage required staff to telephone a "help desk", which was only staffed from 9 to 5!

Revenge effects

In a recent book [16], Tenner discusses how new technologies can bring new problems, sometimes more severe than those which they were intended to resolve. Buildings contain good examples: Table 1 outlines some revenge effects identified in recent post-occupancy surveys.
Designers, naturally enough, tend to look on the bright side of their innovations. However, a more circumspect approach might deliver more robust and effective results:

- Don't be too optimistic.
- Think carefully about the possible downside risks of a proposal. Try to minimise them.
- Keep things as simple as possible, but not more so.
- Seek comment and where appropriate undertake pilot projects.

Strategic conclusions

For briefing.

Too many buildings appear to end up more complicated, more difficult to manage and less appropriately serviced and controlled than they might be. Designers and clients have sometimes unwittingly conspired in this by striving for flexibility or optimum performance without clearly assessing the solutions for usability, robustness and manageability. Briefs should not only articulate the strategic objectives (the mission statements for the building or the tenancy), and fitting into wider corporate, risk, and environmental management strategies; but get the assumptions out into the open. If not, these may be wrongly second-guessed by the designers. For example, in a recent major project it only emerged well into construction that the designers had envisaged routine occupancy hours while one of the client's key reasons for wanting a new building was to obtain efficient support of irregular, round-the-clock operation!

For design and construction

"Designers are not users, though they often think they are" [17]. Designs need regular review against strategic objectives for the building and the needs of occupants, or possible occupants. For example, ANV and mixed-mode servicing offer good prospects but need more development, more management, education and fine-tuning. If the achievement of optimum performance requires added complication or unfamiliarity, this may increase the risk of both technical failure and occupant dissatisfaction: simpler, more robust, intrinsically efficient solutions may be better. In seeking to improve comfort, one must balance any predicted improvements in physical conditions against possible losses in occupant tolerance, adaptive opportunity, or increases in management-dependence. Design (and FM) which aims to improve "forgiveness" could potentially be effective, cost-effective, and energy-saving. How can controls be designed to be more understandable and usable by management and individual occupants?

At and beyond handover

Present contractual arrangements also seem to hinder rather than assist the resolution of teething problems: how can we improve them? Not enough can be taken for granted, from airtightness to controllability: we need better and more appropriate benchmarks, and demonstrations of compliance. Optimum performance requires both good design and installation, plus commitment in use. The commendable ambition to get things "right first time", however, can implicitly deny making sensible plans to nurse the building through its infancy. While standards and specifications must be improved, "zero-defects" is usually inappropriate for some aspects of a context-rich situation. Sometimes only in hindsight can the emergent properties of a new system be understood and the associated problems and unintended consequences be identified. Where innovation runs ahead of the knowledge base, it is especially important to set objectives and benchmarks, to undertake appropriate monitoring (including metering), and to seek and take account of feedback (including post-occupancy surveys!).

Building management systems are seldom being used to monitor energy efficiency and to check that systems are operating broadly on accordance with design intent. Reasons include the low priority currently being given to energy management and to controls and BMSs not being configured to provide the required information in a user-friendly format. With suitable attention to detail, both problems could be made to disappear rapidly, but designers, clients and occupiers will need to insist on this.

For facilities management

In an AC building - and others where performance is critically dependent on engineering systems - excellence in design, execution and management is essential. Rapid and effective management or system response also appears to be key to maintaining good occupant satisfaction. Some organisations will welcome this as reinforcing an image of excellence in managing complexity, quality and service; and affordable through greater public awareness, staff satisfaction and productivity. On the other hand, many might be happier with lower-cost, low-management solutions which aims to maximise "forgiveness". It should also be noted that innovative, "greener" solutions (such as ANV) may require a significant FM input to fulfil their potential, particularly at the early stages when problems with both technical (and particularly controls) performance and occupant understanding are likely to occur.

On outsourcing contracts

Routine activities like maintenance, cleaning and security are important monitoring and feedback mechanisms, which can reinforce policies of continuous improvement. When outsourcing, it is important to maintain this feedback - both formal and informal - in support of the facilities management task, to set the right objectives, and to have appropriately-worded contracts.

References

1 P Ruyssevelt, W Bordass and R Bunn, July 1995, Probe - Post-occupancy review of building engineering, Building Services 14-16.
2 W Bordass & A Leaman, September 1995, Probe 1: Tanfield House, Building Services 38-41.
3 M Standeven, R Cohen & W Bordass, December 1995, Probe 2: 1 Aldermanbury Square, Building Services 29-33.
4 M Standeven, R Cohen and W Bordass, Probe 3: C&G Chief Office, Building Services 31-34.
5 R Asbridge and R Cohen, April 1996, Probe 4: Queens Building, de Montfort University, Building Services 35-39
6 M Standeven and R Cohen, June 1996, Probe 5: Cable & Wireless College, Building Services 35-38.
7 M Standeven, R Cohen and A Leaman, August 1996, Probe 6: Woodhouse Medical Centre, Building Services 35-38.
8 W Bordass, A Leaman and J Field, October 1996, Probe 7: Homeowners Friendly Society, Building Services 39-43.
9 R Cohen, A Leaman, D Robinson and M Standeven, December 1996,

Probe 8: Queens Building, Anglia Polytechnic University, Building Services 27-31.
10 W Bordass, R Cohen & M Standeven, April 1997, Probe 9: Energy and Engineering Technical Review, Building Services, 37-41.
11 A Leaman, May 1997, Probe 10: Occupant Survey Analysis, Building Services 37-41.
12 J Doggart and Z Grant, June 1997, Reset: Why controls are wrongly operated Paper to the second international conference on Buildings and the Environment, Paris.
13 W Bordass, K Bromley and A Leaman, February 1995, Comfort, control and energy-efficiency in offices, BRE Information Paper 3/95.
14 D Haigh, 1981, User response in environmental control, in D Hawkes and J Owers (eds), The Architecture of Energy, 45-63, Construction Press/Longmans.
15 A I Slater, W T Bordass and T A Heasman, 1996 People and lighting controls, BRE Information Paper 6/96
16 E Tenner, 1996, Why things bite back: Technology and the Revenge Effect, London: Fourth Estate.
17 J Nielsen, 1993, Usability Engineering, London: Academic Press.

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TABLE 1: SOME REVENGE EFFECTS IN BUILDINGS				
Measure	**Intended consequence**	**Revenge effect**	**Possible solution**	**Comments**
GENERAL:				
Improve comfort provision and energy efficiency	Automated windows, blinds, lights etc. can be controlled to provide optimum conditions.	Reduced occupant tolerance. Increased dependence on management. More complaints.	Include occupant over-ride facilities.	Imposition of automatic control can be very irritating. Try not to sacrifice adaptive opportunity.
Increase technology to provide added "flexibility"	Less management input necessary to make alterations from time to time.	More management input to look after the additional systems. Still requires some alterations too.	More realism. Better integration between physical and human systems.	Careful discussion of brief and design options to avoid fantasies.
Increased BEMS control	Better control and management information provided.	More load for operator, who may not be fully familiar. Local interventions more difficult.	Don't over-centralise. Allow for local decisions on over-rides etc..	Particularly important to have local over-rides in mult-tenanted buildings.
Outsourced facilities management and BEMS operation.	Professional service. Leaves occupiers to concentrate on their core business.	Business requirements for environmental services not so well understood, so systems run generously, wasting energy.	Tighter contractual requirements or retain in-house control of operation.	Third parties often not on site out-of-hours when anomalies tend to occur. Don't outsource the feedback loop!
LIGHTING:				
Occupancy-sensed lighting in offices	Lights switched off when people absent.	Lights switch on unnecessarily when occupant does not need it, or for passers-by.	Include manual ON switches, except where lighting is required for safety or convenience.	Also include manual OFF switches if possible. Control lighting of circulation routes separately.
Occupancy-sensed lighting in meeting rooms.	Lights come on only when required.	Can't switch lights off for slide presentations etc.	Include local over-ride switches.	Local manual control plus absence sensing only may be preferable.
Automatically dimmed lighting	Reduces artificial illuminance level when daylight is sufficient.	Increases artificial illuminance level when daylight fades.	Bring on at a low but reasonable level. Try to leave adjustments to increase brightness to the occupants.	Constant illuminance may also bring dissatisfaction owing to eye adaptation. Photocells sometimes confused by reflections.
Local switching of lighting	Greater responsiveness to need	Difficult to switch off lights left on inadvertently.	Absence sensing or "last out-lights out" facility at the exit.	In large spaces, this switch at the entrance should only re-activate circulation and safety lighting.
High intensity discharge lighting	Efficient point source.	Run for extended hours owing to extended run-up and particularly restrike times.	Use instant restrike ballasts or substitute fluorescent lighting.	Compact fluorescent fittings can also take some time to run up to reasonable brightness.
Lighting to suit VDUs	Reflected glare minimised.	Dreary-looking environment.	Added wall-washing etc.	Uplighting also worked well.
HVAC SYSTEMS:				
Displacement ventilation	Reduces cooling loads	Increases air tempering loads	Heat recovery	Minimise parasitic losses and avoid recovering unwanted heat.
Generous provision of cooling capacity	Deals with possible increases in internal gains.	Oversized systems can operate inefficiently and may cause discomfort.	Contingency planning, or systems which work effectively and efficiently at low capacity.	Needs care in design and management.
Full fresh air systems	Improves air quality	Increases heating loads and makes humidification likely.	Avoid over-ventilation and consider heat recovery, including latent.	Cleanliness may be more important. Don't operate ventilation just to provide heating or cooling.