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Assessing building performance in use 4: the Probe occupant surveys and their implications

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The main findings from the Probe occupant surveys are assessed. The emphasis is on the consequences for strategic thinking on how best to design and manage buildings to improve conditions for occupants and users, taking examples from the Probe studies. Comfort, health and productivity of occupants are positively associated statistically; and all are easily undermined by chronic, low-level problems. Improvement may not necessarily require raising overall environmental standards – particularly if this requires more energy or reduces perceived control, which occupants think has been falling steadily in recent years. Noise-related problems are also growing with today's trend to more open, more diverse and often more reverberant environments. For the occupant, 'satisficing' may be better than optimizing; and big benefits can come from minimizing the main causes of discomfort, ill health and low productivity – for example by designing and managing to help individuals to choose how to overcome local problems when they occur. Perhaps the greatest enemy of occupant satisfaction is where a building and its systems have become too complicated for its managers – even if this has often occurred initially at their request. Its greatest friends are simplicity, intelligibility, managed feedback, respect for people's comments and rapid response.

Keywords: comfort, design factors, discomfort, facilities management, feedback, noise, occupant satisfaction surveys, perceived control, productivity, quality control, satisficing, strategies, usability

Les auteurs évaluent les principaux résultats des enquêtes Probe sur les occupants et mettent l'accent sur les conséquences pour la réflexion stratégique de la meilleure façon de concevoir et d'exploiter des bâtiments en vue d'améliorer les conditions pour les occupants et les utilisateurs en prenant des exemples tirés des études Probe. Le confort. l'hygiène et la productivité des occupants sont associés de manière positive sur le plan statistique; tous ces aspects sont aisément sapés par de petits problèmes chroniques. L'amélioration n'appelle pas nécessairement une élévation des normes globales d'environnement – surtout si cette option exige davantage d'énergie et réduit le contrôle perçu – que les occupants estiment d'ailleurs en baisse constante depuis quelques années. Les nuisances sonores sont aussi en augmentation par suite de la tendance actuelle en faveur d'environnements plus ouverts, plus diversifiés et souvent avec davantage de réverbération acoustique. Pour les occupants, être satisfaits est peut être plus important que de vouloir optimiser. D'importants avantages peuvent résulter de toute tentative de minimiser les causes principales de l'inconfort, de la mauvaise santé et d'une faible productivité; on peut, par exemple, concevoir des bâtiments et les exploiter en aidant les occupants à choisir comment résoudre les problèmes locaux lorsqu'ils surgissent. Le plus grand obstacle à la satisfaction des occupants vient peut être du fait qu'un bâtiment et ses systèmes sont devenus trop complexes pour les gestionnaires, même si ce sont eux qui, à l'origine, ont demandé de tels équipements. Au contraire, les meilleurs atouts de la satisfaction des occupants sont la simplicité, l'intelligibilité, le retour contrôlé d'informations ainsi que le respect des commentaires des autres et une réponse rapide.

Mots clés: Confort, facteurs de conception, inconfort, gestion des installations, retour de l'information, bruit, études d'évaluation de la fonctionnalité après emménagement, contrôle perçu, peroductivité, contrôle qualité, satisfaisant, utilisation.

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Introduction

There have been countless studies of building occupants' likes and dislikes, so much is known about their preferences, attitudes and likely behaviour in given circumstances. Early work was often prompted by health and safety considerations, or by acute threats like fire or disease. A great deal is also known about human comfort – often from the controlled conditions of laboratories and, more recently, computer-modelled predictions. Field studies, however, have produced rather different results, particularly in buildings with openable windows.

In the 1990s, interest has been rising in linking findings on health and comfort with productivity at work; and how people react to changes in their indoor environment, not just from theoretical standpoints but in the real world. This is partly because buildings are now more mission-critical. An organization's fate is increasingly governed by how their buildings cope with increasing volatility in requirements, locational preferences, business practices and lifestyles.

Real-world research

The Probe studies share this growing interest in real-world outcomes (Robson, 1993; Young, 1988). Bill Allen, who was chief architect at the UK's Building Research Station in the 1950s, used to say 'building research should be no more than one step away from a design decision'. Over the years, much research seems to have moved away from this.

The Probe occupant surveys follow this tradition by examining how people perceive their indoor environment, studying some of the consequences and learning lessons from them. We adopt Bill Allen's maxim but say 'design or management decision' to emphasize their linkages. We are less interested in theory or hypotheses than in understanding and helping to minimize the risks involved in designing and managing things in certain ways. Paper 1 in this series (Cohen *et al.*, 2000) outlines how the occupant surveys are carried out, and how they fit into the Probe studies. The Probe buildings are referred to by the three-letter codes used in Table 1 of paper 2 (Bordass *et al.*, 2001), which also outlines their main characteristics. Further details can be found in the original reports in *Building Services Journal*.

Differences

The approach in Probe differs from other occupant studies in three ways:

- each building is benchmarked against a broader dataset, giving an idea of how it compares with others.
- they are combined with technical and energy studies, and an exploration of the design and management context of the building project and of the occupier's activities.
- the results have been published with all buildings named (18 to data, 16 reviewed here; more to come), so it is possible to follow up topics in more detail and to learn from the experience.

For the reasons described in paper 1, we do not attempt to cover all possible issues. Buildings are complex total systems, and one has to draw the line somewhere. Otherwise, we would be overwhelmed by the amount of data, the analytical effort of finding significance in it, and the difficulty of reporting it all. Occupants also get fed up with long or repeated questionnaires, and cease to answer them carefully, if at all. We do not include attitudes to jobs because it makes it much harder for managers to agree to the questionnaire – they are frightened of the answers! We have recently added attitudes to cleaning and furniture, but they are not yet fully benchmarked.

Exception reporting

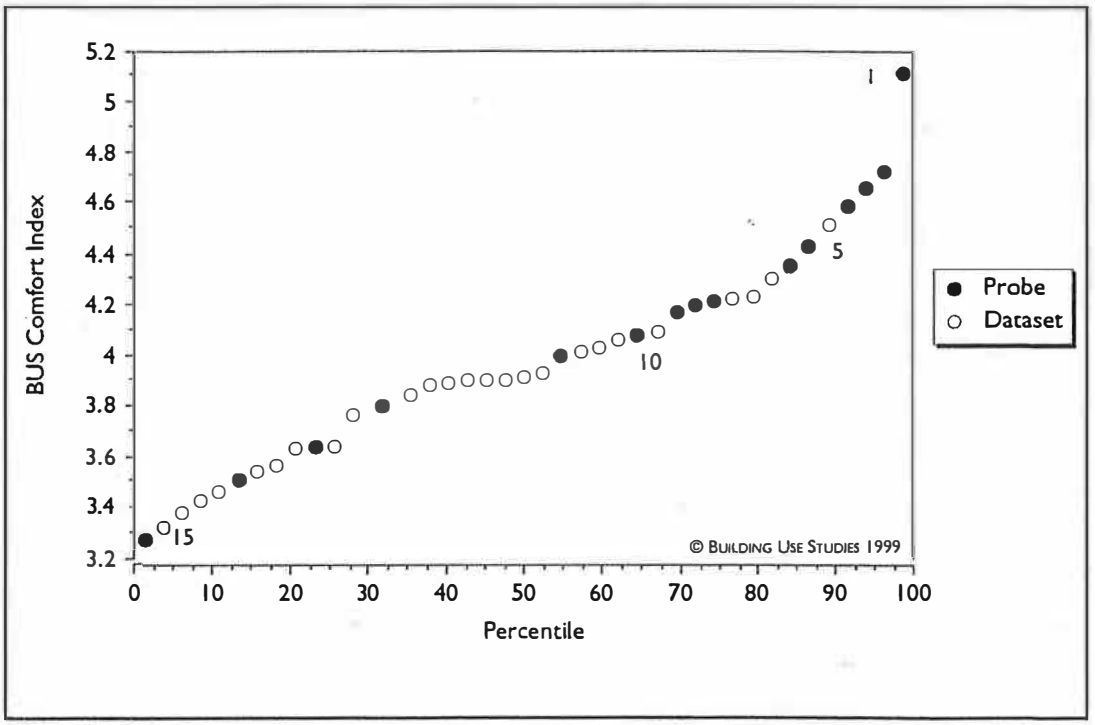
To keep the outputs manageable, we adopt an approach based on exception reporting. We concentrate on things that make a particular building different from the others, rather than features (e.g. buildings should be clean) that are known already. Because we do not want to discover the same things over and over again we use (e.g. in questionnaires) methods which aim to bring out differences to best effect. For example, we ask only one question each on health and perceived productivity. Whole questionnaires can be devoted to these topics alone (e.g. Raw, 1995).

An overall picture

For an initial indication of occupant responses, Probe now uses two summary indexes: one based on comfort (scores for summer and winter temperature and air quality, lighting, noise and overall comfort, see Figure 1); the other on satisfaction (based on ratings for design, needs, productivity and health, see Figure 2). In response to market demands, we have recently added a third indicator which combines these two. These indexes provide snapshots of how well a building works for its occupants, and are a first step in presenting results. For example, a building may score highly for satisfaction and less well for comfort (e.g. MBO); well on both (e.g. permanent staff at FRY); or less well on both (e.g. permanent staff at APU at the time of the survey, when it emerged that the automated natural ventilation had not been working in accordance with the design intentions).

Detailed reporting where necessary

Each survey covers 43 variables. These are presented in detailed tables – outputs from a database which uses the questionnaire scores as inputs. The tables include benchmarks and information from basic statistical tests (including confidence intervals both for the study building and for the benchmarks). These can be portrayed graphically, if needed, for individual buildings or for groups of buildings.



Comfort index score

1	FRY	5.12
2	TAN	4.73
3	C&G	4.66
4	RMC	4.59
5	MBO	4.44
6	WMC	4.36
7	HFS	4.22
8	CAB	4.20
9	POR	4.17
10	CRS	4.08
11	ALD	4.00
12	Benchmark	3.96
13	DMQ	3.81
14	CAF	3.64
15	APU	3.51
16	C&W	3.27

Based on seven variables using scale
1=Uncomfortable; 7=Comfortable

Figure 1 Comfort index showing Probe buildings and the BUS dataset

Satisfying all the varied audiences can be the hardest part, especially boiling findings down without losing the essential contextual information which different audiences require. For instance, some people only want a broad picture (e.g. building managers want to know how their building compares with others, and to identify any particularly strong and weak points); others will need statistical detail (e.g. researchers carrying out their own studies). To some extent this is a Catch 22: one audience wants the essence and is impatient with anything they regard as 'not relevant; the other is only convinced by detail.

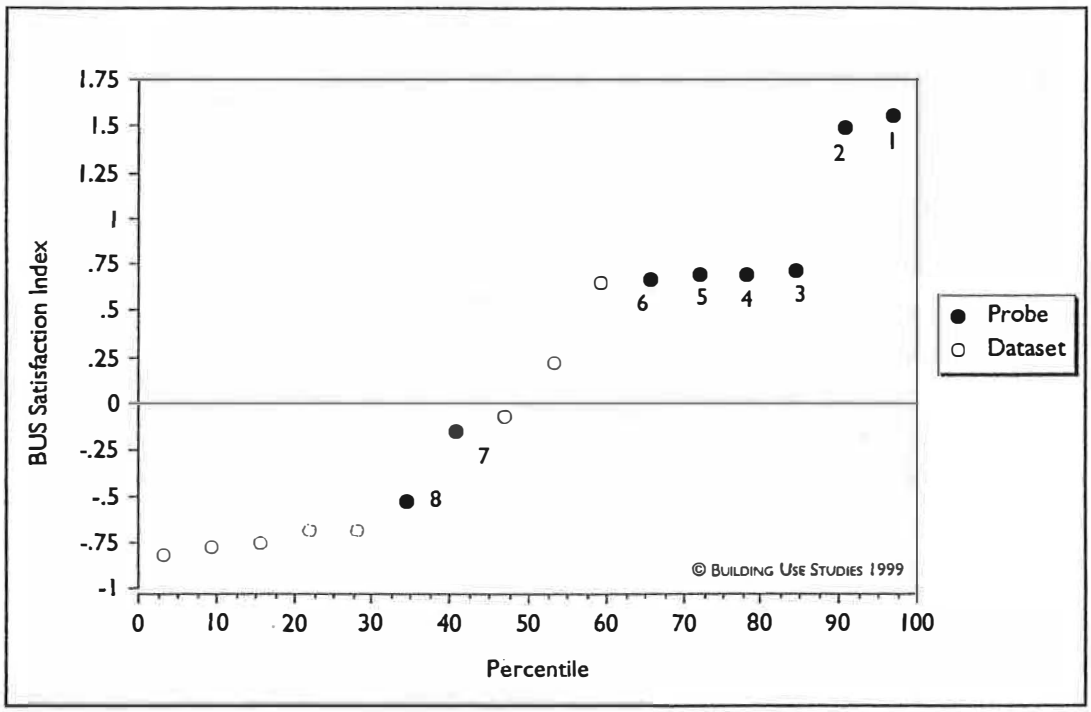
We take pains to describe contexts clearly, not just because contextual factors (like site or construction quality) are usually the most important, but also to allow readers to adjust their interpretations of the findings through their own reading of the context. For example, occupant satisfaction in the offices at FRY is exceptional, but how much allowance should we make for its straightforward and relatively undemanding uses? Because it is impossible to second-guess readers' interests, we never normalize Probe results: we present as simple a statistical picture as we can muster, then let readers make allowances and judgements from their own perspectives.

Overview

Given Probe's real-world agenda, what findings from the occupant surveys will help to inform future strategy? Four things stand out. All are known about already, but we think they deserve more prominence:

- the persistence of chronic problems
- the importance of 'satisficing' behaviour
- simple ways of adding value without increasing effort
- 'non-linear' outcomes, where the effects (outputs) can be much larger than the inputs.

These are discussed individually below.



Satisfaction index score

1	MBO	1.56
2	FRY	1.49
3	RMC	0.72
4	CAB	0.70
5	CRS	0.69
6	POR	0.68
7	CAF	-0.15
8	APU	-0.52

Based on standard z-scores

Figure 2 Satisfaction index showing Probe buildings and the BUS dataset

Persistence of chronic problems

Almost every building we have studied – Probe or not – has chronic deficiencies to some extent. This is inevitable: it is unrealistic to expect everything to work well everywhere, all the time. However, with more forethought, the most harmful consequences could often be lessened.

For the occupants, the surveys reveal that noise and thermal comfort have been getting worse (as has perceived control, see later). Conversely, the 1980s problems associated with chronic building-related ill-health have now received some attention and appear to be declining, though by no means eradicated. Of course, noise, poor comfort and ill-health are all linked: they cannot be treated as having entirely independent causes and effects. As with many things in buildings, improvements in one area can have virtuous knock-on benefits elsewhere; and vice-versa.

Noise is worsening owing to:

- Intensified space use, along with higher occupancy densities.
- More open-plan working, often with poorly thought-out space planning and desk arrangements and intrusive circulation routes.
- More verbal communication in teams, on telephones and now with computers.
- Absence of any single design 'solution'. Coping with noise involves integrating measures throughout the design and occupancy process. Noisiness may therefore be a symptom of weak integration between professional/client teams across the design process as a whole.

- Increasing use of thermal capacity, leading to floors, walls and ceilings which are less noise absorbent; atria, and through-ventilation (and hence sound) paths between different spaces.

- More intrusive equipment noises, especially telephones, computers and their peripherals.

Noise nuisance is not directly related to physical measurements. For example, noise from activities of team colleagues may be acceptable, or even liked as it conveys useful information, whilst that of an adjacent team can be very annoying. Many people also accept – and may even like – some external noises, as masking and to remind them of the world outside.

Thermal comfort is still close to the top of the list of chronic complaints despite (or perhaps because of) the increased use of computer-controlled systems. Perpetual problems include:

- Overheating in summer, and also winter (though this is less serious). The best buildings for thermal comfort tend to be perceived as better in summer than winter, and sometimes slightly on the cool side. Cooler buildings also have better occupant ratings for healthiness.

- Conditions which are too variable, and thereby difficult for occupants to predict from day-to-day. This leads to seemingly trivial – but unmanageable – complaints like 'We don't know what to wear'. Conditions may also become uncomfortable – perhaps too cold and draughty in one area, and too hot in another, with no consistency. This tends to infuriate occupants, especially if they have no effective means of control (see below).

Users are satisficers not optimisers

'Satisficing' was coined by the economist and polymath Herbert Simon (1981) to describe economic behaviour which adequately meets perceived needs without going to extremes. This applies just as well to building occupants. Most people want the conditions they work in to be 'good enough', and only in exceptional cases 'just right'. They tend to tolerate offsets: indeed, offsets may even be welcomed (Williamson and Riordan, 1998) as long as they get something in return. That something is a degree of control over what they are doing and how they achieve it.

The importance of this is rarely appreciated by designers and managers who often follow their own rationalist precepts. As a result, controllability (from e.g. openable windows) is removed and replaced with control strategies, often linked to computer-controlled automation, which are supposed to provide optimal conditions but seldom do with consistency. This is the design version of the optimizing economic behaviour which Simon has shown to be so rare in real life. The Probe occupant surveys show (along with other contemporary studies (e.g. Baker, 1996; Oseland, 1997)) that it is vital to give occupants power of intervention to control, override or at least trade-off some of the main heating, cooling, ventilation, lighting and noise parameters; not so much to optimize their comfort as to reduce local sources of discomfort to tolerable levels. If means of direct physical control are not available, then their absence should be compensated for by an excellent and highly responsive facilities management service with a motivated and proactive help desk that treats people's complaints seriously, does something about them quickly, and does not go home before the occupants do! This type of compensation is particularly important in larger, more complex buildings, as discussed later.

Simple ways of adding value without increasing effort

The importance of occupants' 'satisficing' behaviour cannot be overstated. If understood and used creatively, it can be used to add value without undue extra effort. With many things which people find important – comfort, safety and their wider needs – one must think not just what to provide, but what to do when boundary conditions are breached. Crises of discomfort, unsafe situations and absence of provision – the antitheses – are ultimately more important to user perceptions.

'It is often a mistake to allow automation to remove occupants completely from feedback and control loops'

This is demonstrated time and again by occupant behaviour. Even in the best buildings surveyed, 65% of occupants say that they are unhappy (i.e. rate a variable in the bottom three points of the seven-point scales) with some aspect of heating, cooling, lighting, ventilation and noise. On average this is 86% across the Building Use Studies UK dataset; and slightly lower (84%) for the Probe buildings, which are better than average. This shows that 'just right' conditions are rare. 'Good enough' can however be achieved by giving occupants the means to alleviate their discomfort, rather than to rely solely on automated or management support systems to do it for them. Simpler systems with usable controls and interfaces for occupants can give better results in terms of user satisfaction than more elaborate (and often more energy-consuming) systems with control interfaces which are poor in function, location, clarity and responsiveness, or even absent.

Recent buildings often deprive occupants of choice, increasing dependence on management and technical systems. Usability is usually recognizable when three conditions are present:

- Predictable and reasonably acceptable 'default' states, which form the normal background to what people are habitually doing.

- Opportunities to make interventions or corrections if requirements or conditions alter.

- Ability to act quickly and to know immediately that an appropriate response has occurred.

Usability requires a satisfactory combination of all three, not just the last. The background context is just as important.

Simplicity and convenience of intervention are paramount. This does not necessarily mean low-technology. Well-designed computer-assisted intelligence can be particularly good at:

- establishing (and especially restoring) safe, comfortable, convenient and efficient default states

- providing effective integration of control actions (unlike at POR, where library windows returned to their automatically-controlled state just one minute after a manual intervention!)

- improving user interfaces

- providing feedback to users and managers

It is often a mistake to allow automation to remove occupants completely from feedback and control loops, except in public and visitor areas in which user intervention is inappropriate; in operating plant etc. behind the scenes; and of course in avoiding conditions becoming unsafe. Occupants get frustrated:

- When they cannot change physical settings from an undesirable existing state to a preferred new one (e.g. by interlocked furniture which prevents them from moving at all to escape from glare from the setting sun in winter; or a downdraught from a ceiling grille).

- When working in non-standard situations (e.g. outside normal hours) they have to tolerate substandard conditions (e.g. too cold or too dark) because they cannot sensibly or safely override the defaults. Can the default states and the facilities for intervention cope? Or – as often happens – will the systems either be insufficiently responsive or instead default-to-on wastefully over a wide area?

- If they receive poor support in stressful situations either personally, or in an imposed emergency.

- If they are unable to achieve speedy and effective response from their own actions, control systems, or other people (typically facilities management).

- If victims of adverse effects over which they have little influence (e.g. draughts from grilles or distant windows; sun glare through a manager's glass partition; occupancy-sensed lights in peripheral vision; banging doors; near circulation routes; or random intrusions from nearby semi-public areas like kitchens or photocopiers).

- If unable to choose the lesser of two evils (e.g. between increased ventilation or less noise when it is hot and humid).

Worse still, occupants can be completely infuriated when subject to seemingly arbitrary changes in system status which they can perceive but cannot override (e.g. from automatic sun blinds which come down when the sun comes out – some people may want to see the sun on a spring day); or from automated windows which open to cause draughts or let in noise, fumes or insects. Codes and passwords can also be frustrating, particularly if they are inconsistent and constantly changing.

Some strategic implications are:

- Look at whole situations including the background states with their defaults . . . not just people-machine interactions.

- Consider the full range of users and contexts, e.g. staff at their workstations, other staff, visitors, cleaners, security, contractors, and passers-by. Do not focus on a subset or an average (especially a caricature of a 'typical' user, workgroup, task or department).

- Put people in the control loops . . . but only where this makes good sense: gratuitously adding local control for its own sake can be as problematic as taking it away.

- Take default states seriously. Systems will spontaneously tend to adopt the states which give everybody the least trouble, but are not necessarily either comfortable nor efficient. (Typical ones are blinds closed – lights on, which does away with the problem of glare; and a bit hot, which means that the coldest people complain less and the warmer ones – usually men – remove their jackets). Will this be what you want? If not, what do you have to do to avoid it?

- Provide good facilities for intervention. People who can get out of trouble by and for themselves tend to be happier, more productive . . . and less of a headache for management.

- If you remove opportunities for individual adjustment . . . how will you replace what you take away? To get closer to those elusive perfect conditions may well require an awful lot more design time, money, and management effort than you think.

- Monitor performance and set up managed feedback streams of information.

Non-linear outcomes

Many things connected with occupant behaviour are non-linear in that they can have:

- small inputs, but much larger consequences (e.g. 'the straw that breaks the camel's back')
- self-reinforcing cycles which may be either 'virtuous' (i.e. mutually improving); or more usually 'vicious' (i.e. mutually destructive)

Given these, it becomes important to:

- encourage virtuous processes through management and design
- understand properly the circumstances and thresholds which may trigger behaviours (e.g. when occupants actually decide to turn on the lights) or the circumstances in which they become angry or frustrated (e.g. by vandalizing a device which does not do what they want – this is not uncommon in buildings).

High occupant satisfaction is easier to achieve when the following features – or most of them – are present in the total system: these either help 'virtuous' processes to develop, or give occupants better control – which ultimately improves their tolerance:

- shallower plan forms and depths of space
- cellularization
- thermal mass
- stable and comfortable thermal conditions
- controlled background ventilation without unwanted air infiltration
- openable windows
- views out
- usable controls and interfaces
- a non-sedentary workforce (including relatively low VDU usage)
- predictable occupancy patterns
- well-informed, responsible and diligent management
- places to go at break times inside or away from the building

The tendency for things to become unmanageable, and for occupants' tolerance to decline, can be made worse by some or all of the following:

- deeper plan forms
- open work areas
- larger workgroups
- greater mixes of activities
- higher densities
- longer working hours
- people tied to one place
- long hours at computers
- presence of complex technology
- irrelevant or intrusive noise
- ineffective, absent or bossy facilities management

Ends before means with a targeted strategy

Knowing about and acting on these (and other) risk factors is not enough. Crucial factors for success include:

- a targeted strategy, preferably expressed in a jargon-free brief
- constant review of actual performance against objectives during design, handover and occupation
- not mixing up ends and means

Clients for modern office buildings (sometimes unwittingly) put fashionable image or workplace factors – like open planning or higher densities – before performance criteria (e.g. for energy efficiency, comfort, health or productivity). Design briefs frequently include liberal sprinklings of references to image and appearance, space planning, more openness in the physical plan, flexibility and adaptability, increased occupant densities, and less hierarchical organizational structures (open plan is, often mistakenly, used as a metaphor for a more liberal and open culture). These all serve as means to broader ends, but are often, wrongly, treated as ends in themselves.

Buildings created with means put before or confused with ends (e.g. higher space densities before comfort, flexibility before a realistic assessment of management resources) often create potentially revengeful problems later on (comfort is compromised and the promised flexibility does not emerge because it proves too costly in management time and resources). Difficulties often lie not with the eventual space layout or appearance of the building, but with less visible interactions between performance, operation of technical systems and their manageability in use.

Technology-management interactions

Designers and clients often mistakenly assume that technology will take care of the basics – comfort, health and productivity amongst them – and that this will impose little or no burden on facilities management. Our experience is the opposite: added technology tends to make things more difficult for management; and if not properly managed can reduce overall effectiveness. We therefore advocate simpler buildings where possible; and more complex ones only where simplicity cannot fulfil the requirement, and where the magnitude of the consequent management task is appreciated, accepted and budgeted for in the long-term. But true simplicity can require much sophisticated effort.

Detailed findings

Health-comfort-productivity interactions

Occupants who perceive that they are comfortable, also tend to say that they are healthy and productive at work, so health, comfort and productivity are often surrogates for each other. To illustrate this on a building-by-building basis, we have split Probe respondents' satisfaction scores into those that say they are uncomfortable (that is those who rate the overall comfort variable as 1, 2 or 3 on the scale) and neutral or comfortable (4, 5, 6 or 7). The uncomfortable staff then report average productivity losses averaging 8.8% and the comfortable staff gains of 4.0%, a difference of 12.8 percentage points. The exact numbers do not matter as much as the magnitude of the productivity difference between comfortable and uncomfortable occupants. The implication is that much is to be gained from understanding and seeking to eradicate the main causes of perceived discomfort, ill health and low productivity. This often means identifying and where possible eliminating adverse effects and providing occupants with the means of dealing with unsatisfactory situations. Productivity ratings for the Probe buildings are shown in Figure 3.

Perceptions of speed of response

Probe has confirmed that respondents' perceptions of performance are linked to how rapidly they think that buildings' systems respond to their needs. The faster the better, as Figures 4 and 5 show.

Figure 4 has ratings of quickness of system response (bottom axis) with overall comfort (vertical axis). This is a significant positive relationship, i.e. the faster the perceived response, the better the comfort scores (we have not split the observations by ventilation type owing to the small samples of Advanced Natural Ventilation and Mixed Mode).

Figure 5 has ratings of effectiveness of response once a complaint has been made to management. The association is similar: the more effective people perceive the response to have been, the more comfortable they say they are. In other words, demand-responsive buildings tend to work best in the eyes of their occupants.

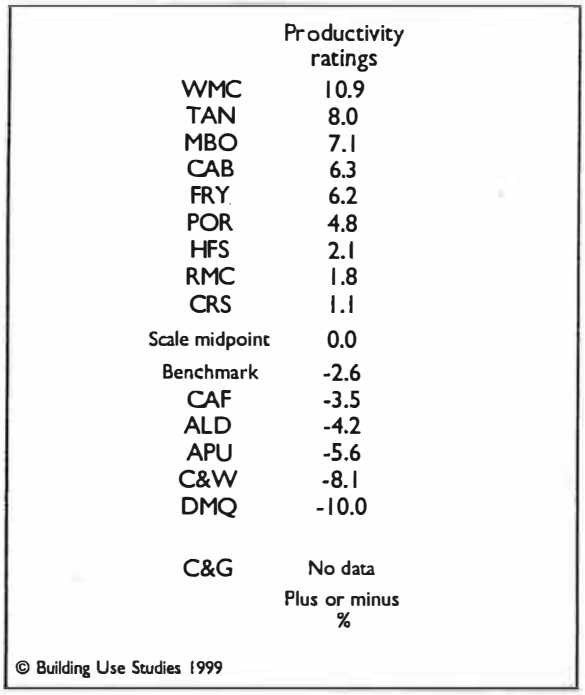


Figure 3 Perceived productivity ratings: Probe buildings

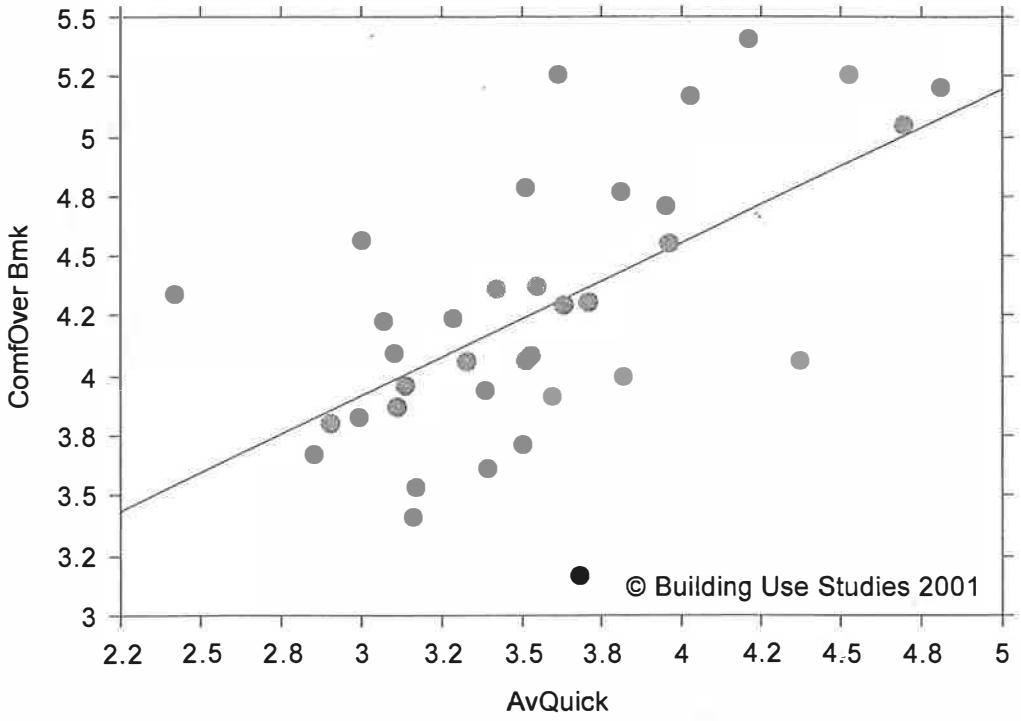
Perceived control

Many designers know about the importance of perceived control to building occupants. Nevertheless, in occupant surveys undertaken by BUS over the past decade, ratings of perceived control have been in continuous decline. In the BUS dataset the average rating from the seven-point scales for perceived control for all buildings is a low 2.69, split by Air Conditioned = 2.13, Advanced Natural Ventilation (engineered natural ventilation, often with natural buoyancy motorized and automated control and not always using windows) = 2.90, Naturally Ventilated = 2.92 and Mixed Mode (buildings which combine openable windows with mechanical ventilation and/or cooling) = 3.10.

Probe buildings are identified by three-letter codes in Table 1 of paper 2 (Bordass *et al.*, 2001). Those with the highest control ratings are WMC = 4.4, RMC = 3.9 and POR = 3.4 (see Figure 6). Lowest perceived control amongst the Probe set are HFS = 1.3 and ALD = 1.6, both extremely low. Although high levels of perceived control are normally associated with better comfort, health and productivity scores, this is not invariably so, because background default conditions vary; and because excessive, confusing, or poorly functioning controls can be even more problematical.

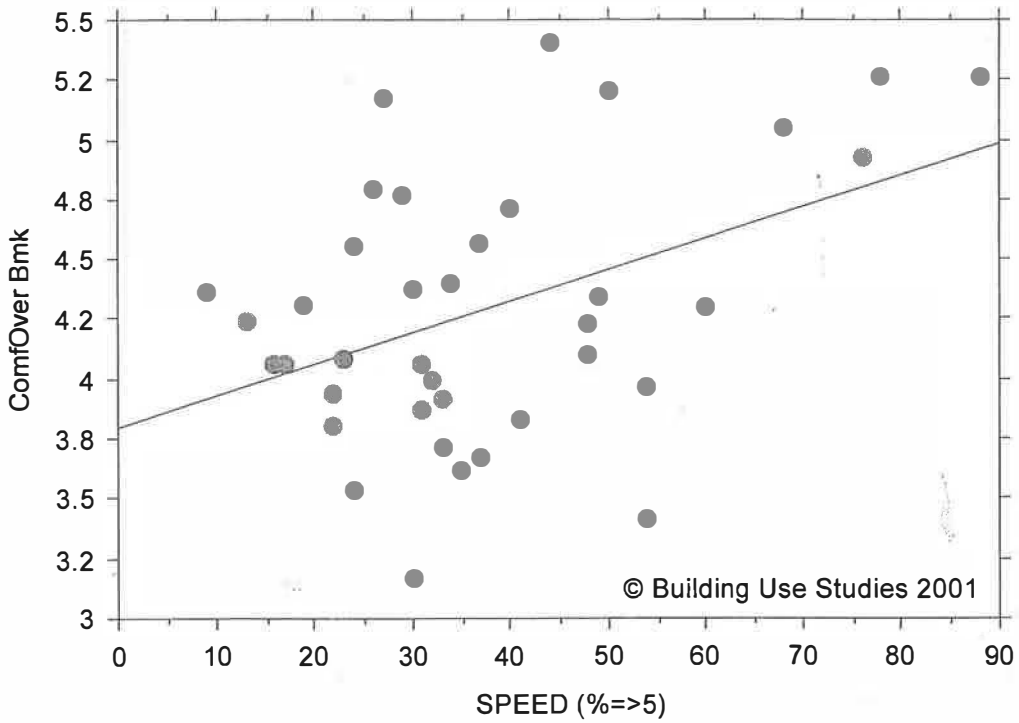
Lighting

One of the emerging findings from Probe (it has yet to be tested more fully) is that lighting – unless it is very good or very poor – has little influence on occupants' rating of overall comfort or associated variables. In Figure 7, the



ComfOver Bmk = 2 + .64 * AvQuick; R^2 = .35

Figure 4 Quickness of response and overall comfort: BUS dataset



ComfOver Bmk = 3.8 + .01 * SPEED (%=>5); R^2 = .18

Figure 5 Effectiveness of response and comfort: BUS dataset

relationship is driven by the buildings at the extremes (top right and bottom left): the rest of the distribution is almost random. With the outliers removed, the correlation coefficient halves. Buildings like MBO were disproportionately affected, because occupants found the capricious operation of its automatic lighting controls intrusive. Conversely, simple, responsive lighting controls tend to lift occupant ratings – as at FRY, where simple switches by the office doors helped to make its office lighting the best rated in the BUS dataset.

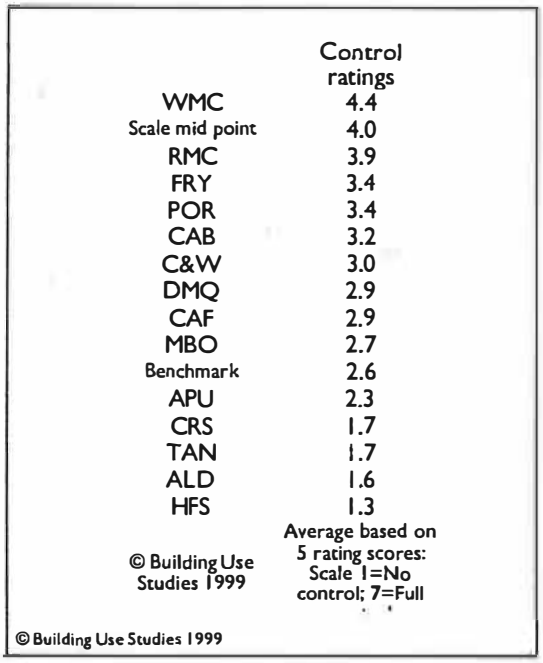


Figure 6 Perceived control ratings: Probe buildings

Figure 8 shows scores for satisfaction with lighting. Other questions ask occupants to rate whether they have too much (1 on the scale) or too little (7 on the scale) natural and artificial light. They often report too little natural and too much artificial. If the scores are subtracted (i.e. natural minus artificial) the air conditioned buildings (C&G, CRS, ALD, HFS and TAN) show the highest differences (see Figure 9): partly owing to their deep plan forms. Contrarily, amongst these, TAN – which has the deepest plan form (see Figure 13) – has the least difference. This shows how thoughtful design can compensate to some extent, even in challenging circumstances.

Noise

Next to thermal comfort and personal control, occupants usually complain most about noise and its consequences. Noise is particularly difficult to deal with because relevant

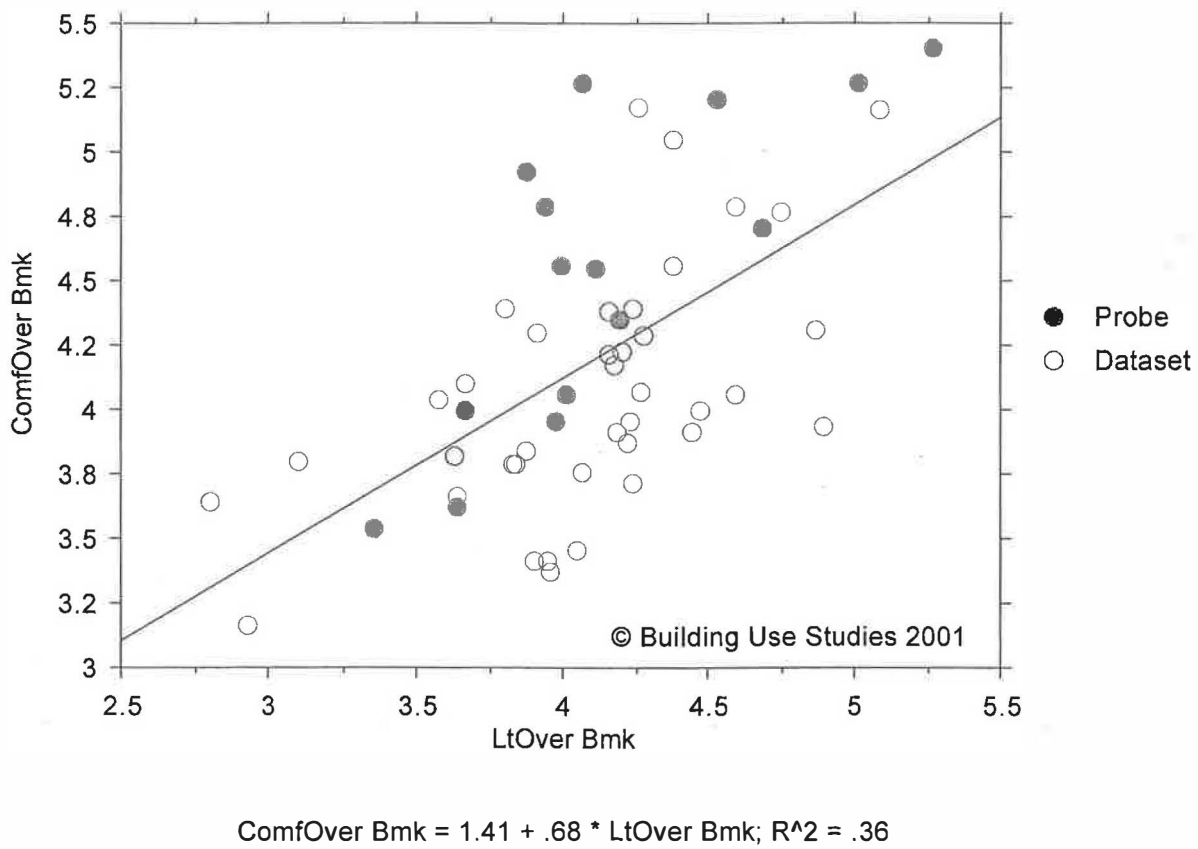


Figure 7 Lighting and overall comfort: BUS dataset and Probe buildings

noise (perhaps workgroup colleagues' conversations) is acceptable to many, while random noise or irrelevant conversion is not. Not surprisingly, the buildings with the most cellularization (WMC and FRY) score well (see Figure 10).

Figure 11 gives percentages of staff who were dissatisfied with noise or satisfied/neutral. Across all the Probe buildings, 42% of staff were dissatisfied. Satisfaction was best in HFS (low density) and WMC (cellular); and worst in DMQ (where academic staff who had been used to individual offices – with space, security, privacy and personal control – had instead been given cramped workstations in open plan offices in the new building).

Figure 12 shows the relationship between perceived productivity and noise levels, again split into unsatisfied and satisfied/neutral. Productivity differences of 15 percentage points are reported at POR, C&W and ALD. At POR, the satisfied/neutral staff make the most difference – they report positive productivity gains. At C&W and ALD,

Lighting ratings	
FRY	5.26
TAN	5.01
CAB	4.68
RMC	4.52
HFS	4.20
POR	4.12
WMC	4.07
Benchmark	4.06
DMQ	4.01
Scale midpoint	4.00
CRS	3.99
ALD	3.98
MBO	3.94
C&G	3.88
CAF	3.67
C&W	3.64
APU	3.36

1=Unsatisfactory; 7=Satisfactory

Figure 8 Perceived overall lighting ratings: Probe buildings

Noise ratings	
WMC	5.07
FRY	5.05
HFS	4.73
CAB	4.72
C&G	4.40
MBO	4.35
TAN	4.33
Scale midpoint	4.00
CRS	4.00
Benchmark	3.99
RMC	3.86
ALD	3.55
APU	3.54
CAF	3.36
POR	3.29
C&W	2.96
DMQ	2.74

1=Unsatisfactory; 7=Satisfactory

Figure 10 Perceived noise ratings: Probe buildings

Original scale: 1=Too much 7=Too little	Differences in ratings of natural and artificial light (natural mean scores minus artificial)
C&W	-0.21
CAB	0.21
POR	0.84
APU	0.86
DMQ	0.86
WMC	0.97
RMC	1.00
FRY	1.18
MBO	1.21
TAN	1.34
CAF	1.54
CRS	1.60
ALD	2.13
HFS	2.32
C&G	2.66

Figure 9 Differences in ratings for natural and artificial light: Probe buildings

	% staff	
	Dissatisfied with Noise	Neutral / Satisfied
HFS	18.6	81.4
WMC	20.0	80.0
FRY	22.5	77.5
CAB	25.5	74.5
MBO	31.5	68.5
C&G	31.9	68.1
TAN	33.9	66.1
CRS	42.5	57.5
RMC	42.9	57.1
ALD	45.5	54.6
APU	52.6	47.4
CAF	55.4	44.6
POR	60.0	40.0
C&W	63.6	36.4
DMQ	72.9	27.1
Total	42.4	57.6

Figure 11 Staff satisfaction and noise: Probe buildings

	% Productivity		
	Dissatisfied with noise	Neutral / satisfied with noise	Difference
POR	-3.0	12.8	15.8
MBO	4.3	8.2	4.0
TAN	7.7	8.1	0.4
CAB	2.0	7.5	5.5
FRY	1.3	7.0	5.8
WMC	1.7	4.4	2.8
RMC	0.8	3.3	2.5
C&G	-3.0	3.1	6.2
CRS	-2.6	2.4	5.0
HFS	2.7	1.9	-0.8
C&W	-14.0	1.3	15.3
DMQ	-14.2	0.6	14.8
ALD	-9.2	0.4	9.6
CAF	-4.1	-2.6	1.5
APU	-6.0	-5.3	0.7

Buildings ranked by reported productivity of staff satisfied/neutral with noise.

Figure 12 Noise and perceived productivity: Probe buildings

the dissatisfied staff make the difference, reporting losses. Only three buildings are the differences negligible: HFS and APU – both open plan but low density; and the very deep-plan TAN.

Occupant satisfaction with noise is not just a matter of whether or not people have their own office away from open areas: occupants report that task, acoustic treatment, density, absorption, layout (e.g. of kitchens, meeting areas), circulation routes (e.g. cutting through clusters of work-stations), poorly integrated and badly located workgroups, proximity to streets, car parks, loading bays and railways, opening windows, noisy colleagues and lack of attention to detail with e.g. telephone ringing, doors banging and computer feedback noises can all take their toll.

Improving conditions for occupants

Concern about occupant satisfaction first came to the fore in the 1980s, when it was found that some chronic ill-health was building-related (i.e. reported symptoms like lethargy, head-aches, dry eyes and dry throat appeared during the day and went away some time after people left the building). These clusters of chronic symptoms were most often found in deep-plan, air-conditioned offices, so it was naturally concluded that air-conditioning was the cause. Indeed, in some buildings investigations have pinpointed the influence of poor air quality, and bacterial and fungal organisms in ventilation systems.

However, the association with air conditioning is not inevitable. For example, TAN (Figure 13) has many of the risk factors associated with chronic ill-health (very deep plan form, air-conditioning, open office layout). However, the questionnaires show the staff regard TAN as comfort-able, healthy, and productivity-raising. FRY also scores very well on occupant comfort, but – unlike TAN – it has many of the characteristics which tend to correlate with good scores – cellular offices, exceptionally stable comfort conditions, reasonably effective acoustic separation, openable windows and so on. It also has more part-time staff, and academic staff who may not always be present in the building during the hottest part of the year – factors which help to lever satisfaction scores up even more.

Although it is tempting to focus on design and technical features for explanations of good occupant satisfaction, the real reasons are often more connected with how design and management factors interact to create a virtuous total system. Better performing buildings all end to have good ratings for quickness of response (Figure 14): this is itself associated with comfort and productivity, irrespective of their type, plan form, or ventilation design; though mixed-mode buildings including RMC (Figure 15), FRY, POR and CAF do quite well.

Speed of response has several sources: all are desirable but they do not all need to be present in a good building. They include:

- usable controls which are easy for occupants to under-stand, deliver acceptable performance and can be seen to be obviously working
- a diligent facilities management team backed up by a proactive help desk which deals with complaints sensitively and rapidly

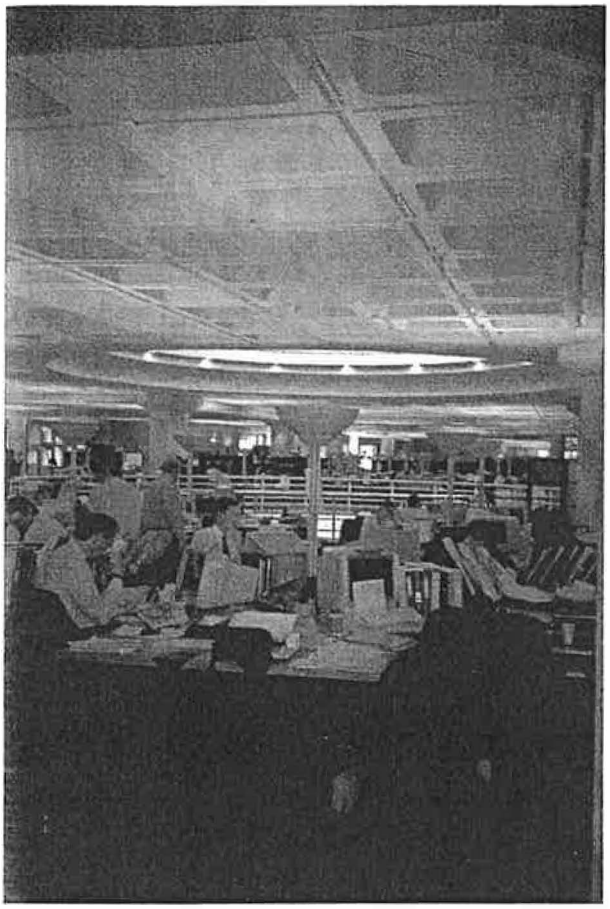


Figure 13 Tanfield House. *Photo:* Bill Bordass
Notes: This very deep-plan air-conditioned office, containing largely administrative and clerical staff on routine tasks, has many of the risk factors for occupant dissatisfaction an ill-health. However, the survey revealed that occupant perceptions were good. Factors for success included a professional and committed client, a good and imaginative design, and excellent facilities and maintenance management.

- comfortable default conditions for most of the time, with the ability for occupants to trim if things alter for the worse (this is where openable windows and mixed mode strategies help)

- a space plan which accommodates workgroups properly to maximise within-group requirements and minimize between-group conflicts (e.g. people within a group can decide for themselves how the window blinds are set, without affecting the preferences of the adjacent group)

- a management culture which takes staff needs seriously and strives to achieve them, even if everything is not always working in their favour.

The last point may be the most important. This is illustrated by MBO, which scores quite well on the confort index (ranked fifth in Figure 1), but was first in the satisfaction

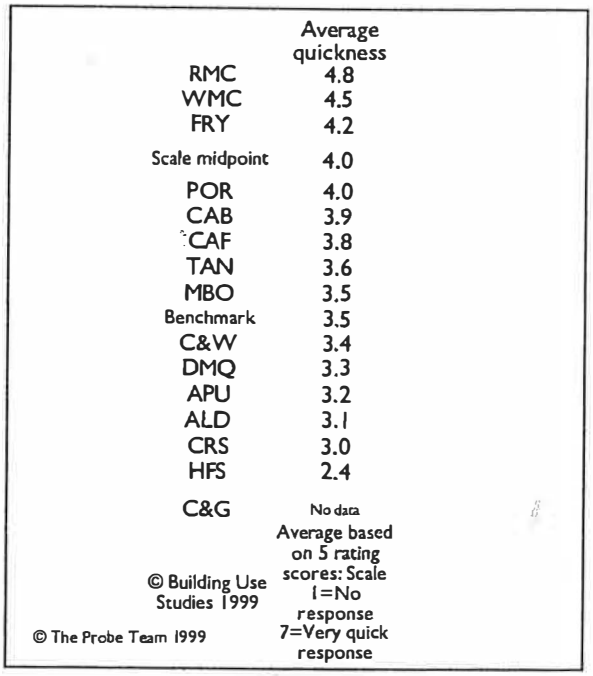


Figure 14 Perceived quickness of response: Probe buildings

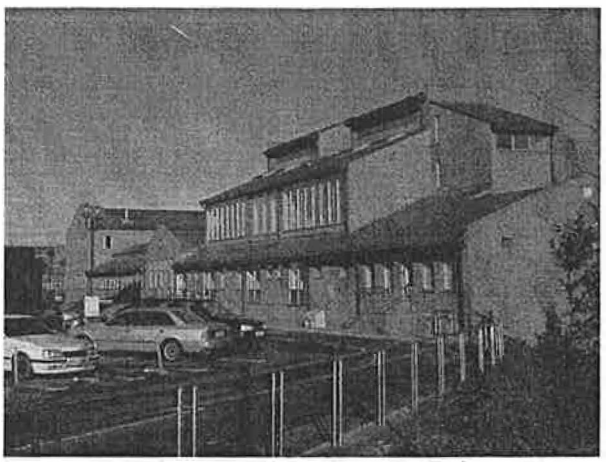


Figure 15 Rotherham Magistrates Courts. *Photo:* Bill Bordass
Notes: The mixed-mode buildings in Probe (which had both mechanical systems and openable windows) had generally better scores for quickness of response, with the support staff at RMC reporting the highest levels (see Figure 14). The magistrates themselves were even more satisfied. Mixed mode buildings and particularly RMC also tend to have good scores for perceived control.

index (Figure 2 – this was introduced halfway through the Probe project, so the earlier buildings are not included).

MBO's satisfaction level may reflect not just its design philosophy. The occupier's management was committed to the Investors in People programme, and proud of its achievements in it. Hence they involved all their staff – albeit modestly – in decisions during design, construction and

handover. The developer also strove to ensure that its clients perceived value in the buildings it supplied; and routinely commissioned post-occupancy surveys to review and improve the outcomes. Shortly before MBO was occupied, there were meetings for all the staff in the new building at which the management, the architect and the developer explained the design and how it was supposed to work, and responded to questions.

FRY comes out best on most performance indicators and as a result has received most of the plaudits. However, MBO – in spite of some flaws and disappointments (in particular poor airtightness and unfriendly lighting controls) – is a good all-round example of how developer, client, architect, management and staff, working to modest budgets and with the added constraint of a large warehouse alongside, helped to create value and performance in a building which has exceeded most expectations.

Improving conditions for occupants is not just a question of:

- better tactics, accounting for risk factor checklists, such as deep plan and lack of control
- more enlightened design, e.g. more humane workgroup layouts and space plans
- better environmental performance – because the design and monitoring activities that lead to it also carry-over into occupants' comfort, health and productivity

It is more vitally connected with strategic foresight in perceiving the right links between:

- the ends (such as business goals, staff satisfaction and energy efficiency)
- the available means to meet those ends – budget, cost, quality, perceived constraints etc.

This involves putting emphasis in the right places (on both ends and means, rather than just means as can often happen; or confusing the two by treating means as ends). This theme, which embeds design issues in a much broader picture of technological and management consequences, is explored more in paper 5 (Bordass *et al.*, 2001).

Conclusions

Probe – and previous studies – have confirmed that chronic occupant problems are widespread in British buildings. Many of these never come sufficiently high on anyone's priority list to get fixed, so slamming doors, glare from sun and sky, hot offices, poor controls, noise disturbance and suchlike are the norms for occupants everywhere. They may seem trivial, but the effects on occupant satisfaction and perceived productivity are not. It is therefore important to identify the persistent problems and to make sure that they are addressed.

When we discover exceptions, we want to explore the factors for success and try to make them widely applicable; and to identify common problems and try to eliminate them. However, there is usually no magic formula: contexts and circumstances change; and what works well in one may not be readily transferrable to another. The current quest for standardisation in buildings tends to seek to destroy context; but many buildings which have stood the test of time have both responded to and created their contexts.

'The real reasons for occupant satisfaction are often connected with how design and management factors interact to create a virtuous total system'

The sensitivity of buildings to contexts make them different from consumer products like cars. Success often emerges from a combination of clear-minded foresight and a happen-chance of factors, which may well not be repeatable on the next job (at a Probe seminar the designers of FRY themselves reported that – three years after its completion – they had not yet encountered or been able to create a team/client relationship which offered similar chances of a success).

Because of volatility and the difficulty of predicting outcomes, strategic thinking in the early stages eventually becomes more important than finger-in-the-dyke tactics later on. A well-structured brief with clear targets and a programme of reality checks throughout the procurement process protects the occupants' interests, by keeping ends within range. Especially vital is a constant evaluation and re-evaluation of performance outcomes against targets as a project progress.

Noise is a particularly important illustration of this in action. Only at FRY and WMC – both highly cellular – did occupants think that noise was reasonably under control. At WMC – a medical centre – privacy is obviously a major issue; in the academic environment of FRY it is important, but less so. Cellularization delivers privacy and freedom from distraction by default; but it also has the disadvantage of cutting people off from constant and direct physical interaction (though interaction through electronic media still works!)

Increasingly, clients (any many designers) think that the perceived benefits of greater communication (and space saving through higher occupant densities) can be traded off against lack of privacy; opting for more open – and so potentially noisier – environments. In some cases the risk is low (e.g. MBO) in others (e.g. DMQ with academic staff moving from individual to open-plan offices) higher.

Although outcomes are mostly predictable, lack of foresight at briefing stage, and poor evaluation procedures, mean that occupancy noise criteria are seldom checked against likely outcomes. So no-one 'owns' the noise problem, and, as a result, many buildings are unnecessarily noisy. As noise can be clearly shown to affect productivity bottom lines, the client's design brief manager needs to be sure that its likely effects are being kept under review as a design develops.

Many things occupants want in buildings are obvious, e.g. comfort, health and safety. Many clients will not even think of asking for them in a project plan or brief because they will assume that the industry will take care of them automatically. However, as the Probe buildings show, delivering occupant satisfaction is not always formulaic: the best-laid plans can be undermined by a leaky fabric – as at HFS and CAF; rogue lighting controls (MBO); too much noise (e.g. POR or APU); or too few usable controls (e.g. ALD). At each stage of the design, and during the early stages of occupancy, basic issues of risk and relevance need to be set against perceived occupant performance.

'A constant evaluation and re-evaluation of performance outcomes against targets is vital as a project progresses'

Best results occur when:

- Features such as shallow plan depths, openable windows, comfortable thermal conditions (especially in hot, humid periods), acoustic separation and good views out are all present. Ideally, as at FRY and WMC, there should be no need for excessive management intervention to achieve an acceptable working environment.

- If any of these features are missing for whatever reason (e.g. because the building is large, complex and deep-plan) their absence must be compensated for by all-round excellence in design; and in responsive facilities services, e.g. cleaning and help desk (TAN, C&G, CRS).

- These also need to be underpinned by a stream of managed feedback about performance, not just relating to occupants' main preoccupations like comfort, but also with data on topics such as cost-in-use, space utilization, energy, cleaning and maintenance outcomes.

- This managed feedback stream creates the self-fulfilling loops so necessary for quality control (e.g. at TAN). Outcomes should be constantly re-assessed against benchmarks and/or in-house targets (e.g. FRY which was monitored by a research team) and remedial action taken where necessary (e.g. TAN, which after Probe improved its already good responsiveness to problems and increased the priority it gave to energy management).

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More information on Probe, the process, the studies and the conclusions, including data and downloadable reports may be found on the Probe website: *http://www.usablebuildings.co.uk/Probe/ProbeIndex.html*