PROBE STRATEGIC REVIEW 1999

FINAL REPORT 4: Strategic conclusions

A confidential report to DETR

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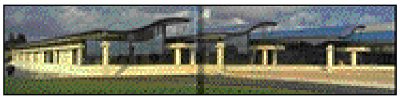
August 1999

#1 TAN Tanfield House

#2 ALD 1 Aldermanbury Square

#3 C&G Cheltenham and Gloucester

#4 DMQ De Montfort Queen's Building

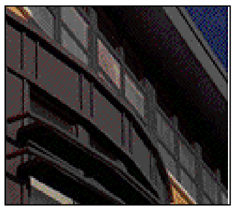


#5 C&W Cable and Wireless

Probe 1 and 2 buildings with article sequence numbers

#6 WMC Woodhouse Medical Centre

#7 HFS Homeowner's Friendly Society



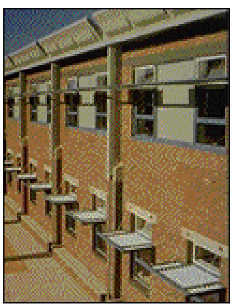
#8 APU Anglia Polytechnic University Queen's Building

#11 CAB John Cabot CTC

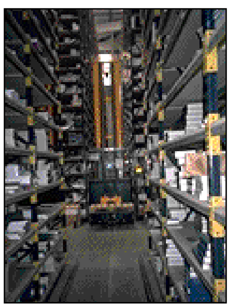
#12 RMC Rotherham Magistrates' Courts

#13 CAF Charities Aid Foundation

#14 FRY The Elizabeth Fry Building



#16 MBO Marston Books Office



#16 MBW Marston Books Warehouse

#17 CRS Co-operative Retail Society

#18 POR The Portland Building

PROBE STRATEGIC REVIEW 1999
REPORT 4: Strategic Conclusions
GET REAL ABOUT BUILDING PERFORMANCE

Final report to DETR

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PROBE STRATEGIC REVIEW 1999 REPORT 4: STRATEGIC CONCLUSIONS

GET REAL ABOUT BUILDING PERFORMANCE: Conclusions from the Probe surveys, and their implications

by Bill Bordass, William Bordass Associates
Adrian Leaman, Building Use Studies Ltd
and Paul Ruyssevelt, Energy for Sustainable Development

SUMMARY

The Probe studies in 1995-98 were Partners in Technology projects, co-funded by *Building Services* - the CIBSE Journal (BSJ) and DETR, to investigate the performance of recently-completed buildings and to publish them individually in BSJ.

Published findings for named buildings can have a more immediate impact than research statistics, and engage new audiences. Probe has helped to increase the awareness of the building industry and its clients of factors for success in building performance, and where things can go wrong. Sometimes relatively minor issues affected achieved performance substantially, for better or worse. Simpler was sometimes better, new techniques and technologies could have unintended consequences, energy performance was sometimes very good but more often disappointing, and usability and manageability often left much to be desired. Many of the findings support the results of earlier research, or ring true with anecdotal experience.

Some say that Probe has told us little new ... but perhaps that is the whole point: why has the knowledge of some players not been shared and faster improvement not occurred? A reminder at this stage is particularly relevant with the new agendas of the Egan Report, sustainability, the Kyoto agreement, and the quest for better, healthier, more efficient and more productive buildings. If we genuinely want better all-round performance, we need to appreciate and tackle the chronic problems and create a base of sound practice. Progress requires not just innovation (as some seem to think) but also steady consolidation and improvement to overcome chronic problems.

In 1999 DETR EEWD commissioned the Probe team to review the findings from the 16 buildings surveyed. Reports 1 to 3 describe the survey process; the technical findings, the occupant surveys, and the conclusions reached. Report 5 gives descriptive background on the buildings surveyed.

The first six sections of this Report 4 bring together the main conclusions of Reports 1 to 3. There are many detailed findings. However, owing to the diffuse nature of the building industry, its clients, and particularly building users, we have tried to keep the conclusions strategic. In this way, we hope to get closer to common goals which can be shared by the various players jointly and then applied in their particular ways to their individual roles. The final three sections of this report are therefore conclusions of conclusions, and presented at three levels, as outlined below.

LEVEL 1: FACTORS FOR SUCCESS
Section 7 reviews things which can help buildings to be successful, and things which can get in the way. These include:

- Buildings and management which are able to respond to the needs of occupants.
- Procuring buildings which are not too complicated for their management.
- Comfort and energy efficiency are not in conflict, but to happen they need to be clear twin objectives in briefing, design and management.
- Get the essentials right, so that any necessary innovations can be built on firm foundations. For example, problems with uncontrolled air infiltration and with controls were widespread, and often avoidable - at least in hindsight.
- While as much as possible should be right first time, in some ways buildings are more like ships than cars. A “sea trials” period should be planned for where necessary.
- Aim for continuous improvement, otherwise buildings can easily go into circles of decline.
- The importance of not leaving anything to chance.

LEVEL 2: ENDS AND MEANS IN PROCUREMENT, ALTERATION AND MANAGEMENT

Section 8 considers how the means (what a building is like, what it provides and what it demands), can be brought better into line with the ends of the commissioning and user clients and of other stakeholders. The providers of buildings (e.g. designers and builders, and sometimes even property departments) can easily come to regard a means (for example the use of a particular technique) as an end, and lose sight of the true objectives. A lack of clarity can often develop about problem "ownership". For example, a client may assume (with or without the designer's encouragement) that a particular technology will make life easier for them, and that the designer will take care of the specification and effective installation. In fact, what is proposed may require a considerable investment in fine-tuning and day-to-day vigilance and support to extract the value; but this only gradually becomes clear once the building is occupied.

Probe indicates a need for good "linking tools", which can relate the ends and means more closely throughout the process. These should include:

- Reality-checking. Design brief management with regular review of the developing solution against the briefing requirements, and vice-versa; and a testing of proposals for possible downside risks.
- Experience-sharing. In today's rapidly-changing world, it is vital for everybody to learn on the job and not to leave feedback to others. The industry and its clients will need to encourage this and to develop efficient and insightful methods for collecting and reviewing the information collected.
- Cradle-to-grave monitoring, reporting and benchmarking. Ways of measuring and comparing intended and achieved performance. For example, the Probe team has found that many of the factors influence the energy performance of occupied buildings are often not considered at the design stage; or the design assumptions can differ substantially from the in-use situation, for example with systems defaulting to ON. Much closer connections need to be established, using a common language which runs through briefing, design, specification, and into operation; which permits assessments at any stage; and which allows discrepancies to be more easily spotted and successes more rapidly built upon.

LEVEL 3: WHERE MIGHT EVERYONE START?

Probe and its results have proved particularly timely, since buildings and the building industry are suddenly being asked to respond radically to major pressures for improved product quality, sustainability and business performance: a triple bottom line in which buildings and their management can create simultaneous economic, social and environmental benefits. An important part of this is to bring producers and users closer together. Section 9 identifies actions by the range of interests concerned, for example:

- Clients who build: clarify objectives, undertake reality-checks, identify management resources
- Design team: improve usability, manageability and intrinsic efficiency. Review downsides.
- Building team: no-surprises industry standards which help to avoid widespread problems. Provide better after-sales support, including "sea trials" after handover.
- Property advisers: seek to understand what adds real value for users.
- Occupier clients: seek more information on the likely performance of buildings you are thinking of occupying. Don't lose touch with sources of useful feedback.
- Facilities management: strive for rapid response. Establish and manage feedback streams improve service, performance, and understanding of client requirements.
- Professional institutions. Improve collaboration and data sharing. Tackle problems collectively. Encourage rapid improvements.
- Government: beware single issues, seek all-round improvement. Expand Egan into post-handover performance. Encourage cradle-to-grave benchmarking; but as means not ends.

FUTURE PROBE TEAM ACTIVITIES

The Probe team also plans to apply the findings itself. A programme of dissemination of results is proposed in Appendix C, for which assistance from DETR is sought. This will include targeted efforts, e.g. collaboration with selected industry bodies. Partners in Innovation funding has also recently been granted to Probe 3 which - in addition to conventional Probes, will also undertake "intervention studies" in which selected projects (at various stages from briefing to operation) will be reviewed, and the influence of these reviews assessed and reported in BSJ.

PROBE STRATEGIC REVIEW 1999 REPORT 4: STRATEGIC CONCLUSIONS

GET REAL ABOUT BUILDING PERFORMANCE:
Conclusions from the Probe surveys, and their implications

by Bill Bordass[1] , Adrian Leaman [2] and Paul Ruyssevelt [3]

INTRODUCTION

1 Probe (Post-occupancy Review Of Buildings and their Engineering) is a unique collaboration between a journal publisher, an independent multidisciplinary research team, and government. Probe obtains feedback on performance of recently-completed buildings; publishes it rapidly study by study in BSJ - the *Building Services Journal;* and reflects on the results from time to time, in BSJ, at conferences, and in other traditional and electronic publications. Figure 1.1 lists the published surveys. Appendix A gives the full list of articles.

2 Starting in 1995, and building upon previous research results and survey techniques, Probe has helped to increase the awareness of the building industry and its clients to factors for success in building performance. It has also drawn attention to where things can go wrong. Many of these (e.g. manageability, air infiltration, and occupant responses to technology) had been identified in other research. However, a Probe study of a familiar building seemed able to capture a reader's attention more readily than research statistics and unattributable generalisations and anecdotes.

3 Probe has identified some of the downside risks of new techniques and technologies (such as automated natural ventilation), pinpointing areas which need further attention by the industry and its clients if their promise is to be properly realised. Relatively minor issues (e.g. controls interfaces), may not be high on anybody's agenda (client, designer, contractor, manufacturer, agent, investor, occupier or manager), but they can have major effects (for good or ill) on performance in practice.

4 Probe and its results have proved to be particularly timely, as buildings and the building industry are suddenly being asked to respond radically to major pressures for change from several directions:

- Product quality and value including benchmarking[4].
- Sustainability. To reduce environmental impact and especially greenhouse gas emissions[5].
- Business performance, reducing costs in use and adding value through increased productivity.

It is best to approach these not as single (and potentially conflicting) issues, but as contributors to a triple bottom line in which buildings and their management can create simultaneous economic, social and environmental benefits. Figure 1.2 shows how findings from post-occupancy surveys and monitoring can be incorporated into strategies for procuring, occupying and managing a building, so helping to create virtuous circles of continuous improvement.

5 This review of Probe's results and their implications has been undertaken for DETR's Energy Efficiency and Waste Directorate. It is underpinned by three detailed internal reports: Report 1 on the Probe process; Report 2 on the technical findings; and Report 3 on the occupant survey findings; plus Report 5, which is a short illustrated description of the buildings and some of their principal features. Wider dissemination plans for the material in these reports are proposed in Appendix C..

This report has the following sections:

1 *Background to Probe.* How the idea came up.
2 *The Probe initiative*. The team and approach that was put together.
3 *Conclusions on the Probe process*. How the work was carried out, and its implications.
4 *Technical survey findings.* Key conclusions.
5 *Energy performance and carbon dioxide emissions.* Key conclusions.
6 *Occupant survey findings.* Key conclusions.

There are three concluding sections (conclusions of conclusions, so to speak), as follows:

7 *Overall conclusions 1.* Factors for success. Strategic and technical issues.
8 *Overall conclusions 2.* Ends, means and feedback. How to improve understanding.
9 *Overall conclusions 3.* What Next? Suggested actions for the various parties involved.

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3 Energy for Sustainable Development, paul@esd.co.uk, formerly with Halcrow Gilbert Associates

4 The report of the Construction Task Force - Rethinking Construction - of July 1998 "The Egan Report"on improving the quality and efficiency of UK construction is being taken forward with some enthusiasm by industry and government; and has led to further initiatives in benchmarking, innovation and best practice.

5 The British government has a policy commitment to reduce carbon dioxide emissions by 20% on 1990 levels by 2010. A 12.5% reduction is legally binding as Britain's part of the EU's treaty obligations under the Kyoto agreement.

Figure 1.1 The buildings investigated in Probe

Probe 1 Buildings investigated

Sequ #	Full name	Location	Site	Short name	3-letter	Type	Gp	HVAC	Article	#
1	Tanfield House	Edinburgh	IC	Tanfield	TAN	Large administrative centre	O	AC/(MM)	Sep-95	1
2	1 Aldermanbury Square	London	CC	Aldermanbury	ALD	UK Head office (speculative)	O	AC	Dec-95	2
3	Cheltenham & Gloucester	Gloucester	BP	C&G	C&G	Large head office	O	AC	Feb-96	3
4	de Montfort Queens Building	Leicester	IC	de Montfort	DMQ	University teaching	E	ANV	Apr-96	4
5	Cable & Wireless	Coventry	BP	C&W	C&W	Company training college	M	ANV/NV	Jun-96	5
6	Woodhouse Medical Centre	Sheffield	IC	Woodhouse	WMC	Medical surgeries	M	NV/(MM)	Aug-96	6
7	HFS Gardner House	Harrogate	BP	HFS	HFS	Principal office	O	AC	Oct-96	7
8	APU Queens Building	Chelmsford	IC	APU	APU	Learning Resources Centre	E	ANV	Dec-96	8

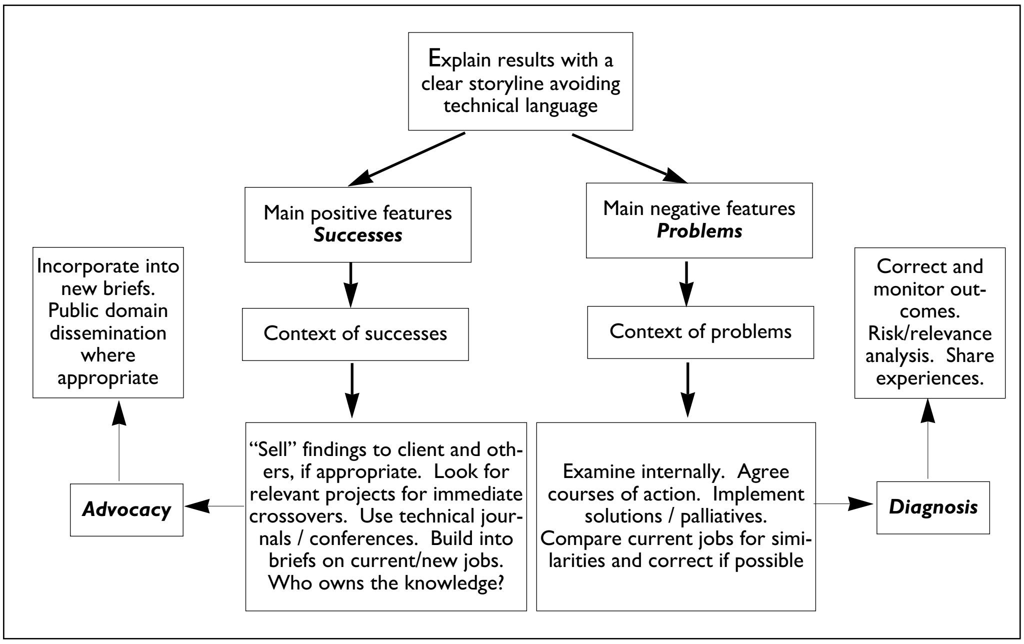
Probe 2 Buildings investigated

Sequ #	Full name	Location	Site	Short name	3-letter	Type	Gp	HVAC	Article	#
9	John Cabot CTC	Bristol	IC	Cabot	CAB	Secondary education	E	NV/ANV	Oct-97	11
10	Rotherham Magistrates Courts	Rotherham	IC	RMC	RMC	Courtrooms and offices	M	MM	Dec-97	12
11	Charities Aid Foundation	West Malling Kent	BP	CAF	CAF	Principal office (per-let)	O	MM	Feb-98	13
12	Elizabeth Fry Building	Norwich	UC	Elizabeth Fry	FRY	University teaching	E	MM	Apr-98	14
13	Marston Books Office	Abingdon	BP	MB Office	MBO	Principal office (per-let)	O	NV/(ANV)	Aug-98	16
14	Marston Books Warehouse	Abingdon	BP	MB Warehouse	MBW	Warehouse (pre-let)	M	NV	Aug-98	16
15	Co-operative Retail Services	Rochdale	BP	CRS	CRS	Large head office	O	AC/(MM)	Oct-98	17
16	The Portland Building	Portsmouth	IC	Portland	POR	University teaching	E	ANV/MM	Jan-99	18

Site: BP=Business Park or similar; CC=City Centre; IC=Inner City; UC=University campus
Group: E=Educational; M=Miscellaneous; O=Office

HVAC: AC=Air Conditioned; NV=Naturally Ventilated; ANV= Advanced NV; MM=Mixed Mode (Bracketed if minor influence)

Figure 1.2 Feedback into the briefing process



1 BACKGROUND TO PROBE

1.1 The 1980s were a time of major change for buildings. In particular:

- Pressures from competition, government and clients were forcing the design and production side of the industry to improve speed and quality and reduce costs.
- Buildings and the building industry had to adapt to the needs of information technology.
- Buildings were used more intensively and changeably, and so could require more air conditioning; a trend reinforced by social, technical, and marketing changes.
- The facilities management profession began to establish itself.
- Falling fuel prices reduced the importance of energy costs for occupiers, but
- a growing concern for all aspects of environmental performance also kept energy efficiency on the design agenda.

Buildings in use also began to be studied more consistently, starting with largely single-issue studies, for example of energy performance; internal environment; and occupant satisfaction, health and comfort. Major gaps were often found between client and design expectations and achieved performance. Research was also undertaken into building-related ill-health, and the term “sick building syndrome” coined.

1.2 In the early 1990s the industry was tackling these new agendas, for example by means of:

- computer models and advanced natural ventilation (ANV) to avoid air-conditioning;
- building fabric and glazing systems with better thermal and daylight performance;
- more efficient air-conditioning (AC), e.g. with displacement ventilation and static cooling;
- mixed-mode (MM) solutions, combining natural with mechanical ventilation and cooling;
- plant efficiency and control improvements of all kinds.

Clients were also broadening their interests, and giving more attention to indoor environments, occupant health, productivity of staff, and higher level strategic business issues. However, reports from the field continued to indicate that gaps - sometimes large - between expectation and achieved performance persisted; and that better feedback was required to consolidate the benefits and to identify and correct any problems.

1.3 New buildings incorporating some of these innovations were regularly reported in BSJ: *Building Services Journal*[6] . In 1994, its editorial review panel suggested that BSJ should report on how these actually worked in practice. To fund the necessary independent investigations, BSJ submitted a project proposal under the newly-announced Partners in Technology scheme, in which BSJ would edit and publish feedback articles if the government were to match the costs of this by paying for the technical investigations.

6 This is the journal of CIBSE, the UK Chartered Institution of Building Services Engineers.

2 THE PROBE INITIATIVE

2.1 The result was PROBE, with BSJ in partnership with government and the following research team:

- HG, Halcrow Gilbert, who also managed the investigations. Engineers, environmental and energy consultants, HG were heavily involved in applying advanced design tools to the design of low-energy buildings; including two series of design studies for passive solar buildings with leading designers and clients [1 to 3].
- BUS, Building Use Studies Ltd, who monitor customer satisfaction with buildings through questionnaire and interview techniques and feed the results back into briefing,project reviews, design, management and education. In the 1980s BUS undertook pioneering work on building-related ill-health and linking health with comfort, control and productivity [4 to 6]. In the 1990s they began to integrate this work more closely with technical investigations. BUS also has a unique database of occupant satisfaction statistics and benchmarks
- WBA, William Bordass Associates, who investigate technical and energy performance of buildings, and advise government, clients and design teams. Before Probe, WBA had monitored energy demonstration projects, undertaken case studies of energy efficient offices for BRECSU, collected and reviewed energy statistics, prepared performance benchmarks, and helped to develop a method to assess and report building energy use [7 to 9].

2.2 Probe 1 started in mid-1995; and re-visited selected buildings which had been reviewed in BSJ when first completed, between two and five years earlier. Eight buildings were investigated between then and early 1997: four AC offices, three educational buildings with ANV, and a low-energy medical centre. Each building was reviewed for technical performance, energy performance, and occupant and management satisfaction. The confidential technical report on each building was then converted by BSJ into an article of typically five or six pages.

2.3 The Probe process and its findings were discussed in some depth at the Probe conference in early 1997, and in subsequent articles. Funding was then obtained for Probe 2, which had a broader scope, including procurement issues, water economy, and a pressure test for airtightness by BRE or BSRIA. Following reader demands for faster feedback, Probe 2 aimed to look at all the buildings after two years of operation[7]. It included another eight buildings: three offices (one AC, one MM and one NV), a NV and two MM educational buildings (one with some ANV), a MM courthouse and a NV warehouse[8]. Probe 2 finished in early 1999. Figure 1.1 lists all the buildings studied in Probes 1 and 2, with their principal characteristics and the dates of the articles in BSJ. Appendix A gives a complete reference list of the BSJ articles.

2.4 THE BUILDINGS SURVEYED

The buildings reviewed in Probe 1 and 2 were well-designed, well-managed, and attractive workplaces (though sometimes with permanent staff located in the less attractive parts of buildings designed more to appeal to visitors). People often ask whether they are representative:

- In a statistical sense, no. They have been through three levels of selection: first by their interest to the editor of BSJ; secondly by the team’s perceptions of the potential value of a published Probe; and thirdly by the occupier’s assent to a Probe survey.
- As a result, they tend to represent leading-edge and better-managed buildings. However, and with some exceptions, architectural icons are few, partly because such buildings have proved more difficult to get into.
- There have also been few speculative and rented buildings: a large and growing part of the commercial market. These have been less widely covered in BSJ, and have also been more difficult to get into owing to the landlord/tenant split.
- On the occupant satisfaction side, and as discussed in Report 2, the Probe buildings are definitely better than average in the BUS’s dataset.
- Regarding energy consumption, the picture is less clear. All Probe buildings have claimed to be energy-efficient, but three major factors have worked against this:
  - i a general intensification of occupancy, use and service to occupants, leading to higher energy consumption, particularly in the office buildings;
  - ii more complicated and elaborate solutions than might normally be provided; and
  - iii innovations which will always prove difficult to get right initially.

While the Probe educational buildings were generally low in their energy consumption, the others - and particularly the AC offices - appear to be biased towards the high end.

7 Any earlier and the building might not have settled down and its patterns of use, performance and energy consumption not become clear.

8 This was on the same site and covered in the same article as the NV office.

3 CONCLUSIONS FROM REPORT 1: THE PROBE SURVEY PROCESS

3.1 Probe has shown that it is possible to undertake and publish a series of post-occupancy surveys of named buildings. This may be a world first, which we hope will help contribute to greater openness and better understanding of how buildings perform and how they can be improved.

3.2 In the process, the team were able to streamline survey techniques, including:

- A pre-visit questionnaire to collect initial data, to improve the effectiveness of the first visit, and to focus the host's mind on the Probe team's activities and information requirements.
- A two-page self-completion survey questionnaire, which was issued typically to a sample of 100-125 occupants; or to all occupants in the smaller buildings. Key questions were extracted from longer BUS/BRE questionnaires, for which benchmarks were available. High response rates (usually over 95% and only once below 90%) were obtained by the team issuing and collecting the forms on the same day.
- Energy data collection using a prototype version of the EARM™ office assessment method (with ad hoc modifications for other building types). This has recently been published in an updated form as CIBSE Technical Memorandum 22 [10]. Its main advantages are as an iterative technique (allowing one to get the best possible result for the time and information available); and instant reconciliation between survey estimates and metered data.

In spite of this, for the team the surveys became progressively more difficult, as items were added (e.g. pressure tests) and new results had to be reviewed against a growing database of reference material. Given the experience gained, further streamlining and standardisation is possible.

3.3 The surveys themselves usually consisted of:

- Occasionally an initial checking-out visit.
- An introductory fact-finding, contact-making and data-gathering visit by HG and/or WBA.
- Over the subsequent 3-4 weeks, preliminary analysis and request and receipt of more data. A major difficulty was getting good quality monthly fuel consumption data, particularly for gas, owing to widespread use of estimated readings. Occupiers also seldom read their meters.
- An occupant survey visit by BUS, including questionnaires, interviews and discussions.
- A detailed technical visit by HG and WBA to review initial findings and collect more detail.
- Occasionally another technical visit to clarify outstanding issues.
- Completion of the final report.

3.4 Can Probe be reproduced? For independent published surveys:

- Techniques and benchmarks are available, and largely published or available under licence.
- The team needs to be experienced, so that it both is not felt to be wasting the host's time; and is able to give back information at the same time as they are collecting it. Significant training would be required in order to reproduce this, including involvement in at least three surveys.
- The BSJ's high level of insight, commitment, support and objectivity was unusual.
- Without the rapport established between the occupier and the editor of BSJ at the time the initial descriptive articles were prepared, the success rate would have been much lower.

3.5 There is a big difference between reporting feedback in a journal; to the occupier or to a building team. For example, the world needs to know about factors for success (e.g. perhaps in the procurement system) in order to emulate them; and problems (e.g. unsuitable window opening mechanisms) to help avoid them. Occupiers will often take successes for granted (though benchmarked confirmation can be helpful); and are often well aware of the difficulties: they are more interested in priorities, low-cost solutions, and better coping strategies.

3.6 If the building team and their clients set out to undertake post-occupancy benchmarking as a normal part of the the follow-through on a project, procedures could be simplified and time saved. For example:

- Occupant surveys could become routine QA measures. In this case, industry-standard questions and published benchmarks would be particularly useful.
- The energy survey could be much quicker, as the designers would already have much of the relevant input information. For example, if EARM methods were used to summarise and benchmark energy consumption estimates at the design stage and to review them afterwards, feedback from operational experience into design estimation could be could greatly improved.

Systems should also be established to permit this and other feedback data (attributed or unattributed) to be widely available, so assisting rapid continuous improvement of building performance.

4 CONCLUSIONS FROM REPORT 2: TECHNICAL SURVEY FINDINGS

4.1 The buildings were successful in many ways but had problems - some relatively minor - which significantly degraded performance from the point of view of management, occupants, or energy efficiency. Many of the issues raised in Probe 1 cropped up again in Probe 2, confirming their pervasiveness. Detailed findings are given in the individual Probe surveys (see Appendix 1) and in Report 2 of the current series. Energy-related findings are covered in Section 5.

4.2 BUILDING ENVELOPE

Most of the buildings were well insulated, some exceptionally so. Unfortunately, ventilation losses were frequently high, increasing energy consumption and often discomfort. The main causes were:

- gaps in the fabric, particularly at eaves, cills and reveals of window and door frames, at junctions between structure and infill, and between light and heavyweight cladding: a chronic problem in UK buildings, as has been revealed in earlier work by BRE and BSRIA;
- motorised windows and particularly dampers intended for summer ventilation which did not seal well enough when shut - and were sometimes not built-in tightly; and
- unnecessarily high volumes and hours of mechanical ventilation, often without heat recovery.

Reception areas often suffered high infiltration (not only through the doors), inadequate heating and sometimes glare and solar gains. Remedial action had been required in most of the office buildings.

One reason for continued high air infiltration has been industry moves to prefabrication and subcontract packages. Neglected physical and organisational interfaces between work packages can lead to junctions not receiving sufficient design or management attention. In traditional construction, such gaps were often filled by formless materials: mortar, plaster, insitu concrete and mastics. Now well-designed, carefully-engineered and quality-assured techniques are necessary.

Triple glazing was used in TAN (a double-envelope design), APU and FRY (2+1 aluminium-clad timber windows) and CRS. At FRY this completed a high thermal mass/high insulation/ airtight package which allowed perimeter heating to be largely omitted, saving on capital and maintenance costs. In the other buildings, its advantages were more marginal. High standards of insulation should be the norm, with good airtightness particularly in MM, MV and AC buildings.

4.3 BUILDING STRUCTURE

Prevention is better than cure. Using thermal capacity to stabilise internal temperatures and avoid air conditioning was demonstrated most effectively in FRY. In other buildings with exposed ceilings, the cooling effect was often reduced by design, control and management difficulties in achieving the necessary night ventilation. These problems are not new [10,13], and need to be resolved. Exposed ceilings can also cause acoustic problems, as discussed in the occupant survey report.

4.4 WINDOW DESIGN

Of all the elements in a building, windows bring together the widest range of functions, providing views, daylight and sometimes ventilation, whilst avoiding glare, draughts, noise and unwanted solar radiation (and sometimes other things like dust, fumes, insects and small animals); and doing so in a secure and user-friendly way. Not surprisingly, there can be shortcomings, in particular:

- Ambitions to use daylight are often defeated by glare problems; or the lights stay on anyway.
- Poor usability. A common problem was openable windows with unreachable handles, insufficient fine control, or not enough friction so they fell or blew shut. Another was a lack of feedback from remote controls (manual or automatic) on the window position.
- Inappropriate automatic control of ventilation. In particular, no local over-rides (as at APU), so people could not shut the windows if there were draughts, noise, fumes or insects; or (as at POR) where the automatic system countermanded the manual over-ride just one minute later!
- Inappropriate control of blinds. The default setting of blinds (particularly in open plan spaces) tends to be the one which causes least trouble; which is often wholly or partially closed to avoid glare. Blinds often clash with ventilation, sometimes just blocking flow or rattling, and sometimes destructively, as initially at POR. Their automatic control suffers similar problems to automated natural ventilation. External blinds are often subject to local turbulence near corners, requiring them to be retracted at quite low windspeeds to avoid damage, as at POR.

Careful attention is required to windows and integrating them with other systems, particularly in the open-plan where adverse effects like glare and draughts are often worst for those some distance away. The interactive window system used at MBO tried to solve many of these problems but was found to need development: the motorised top window did not close tight; the lower one had too little friction; and glare caused the blinds and light shelf to be closed a lot, cutting out much light.

4.5 ADVANCED NATURAL VENTILATION (ANV)

Several buildings used natural ventilation in unusual ways, particularly the educational ones DMQ, APU, and CAB; plus C&W and MBO. Their designs had benefited from modelling, including CFD (computational fluid dynamics) and salt baths, and in use the NV was often automated. In practice, these promising developments were less satisfactory than had been hoped in terms of performance, reliability, and occupant satisfaction; for three main reasons:

1 Difficulty in getting controls to work as intended. Control problems are widespread, but as ANV is less well-known, there is more of a learning curve for designers, manufacturers, suppliers, and building managers. For example POR needed extra sensors and BMS control.
2 Poor reliability of components, with drive and connection failures and air leakage.
3 Insufficient understanding of occupant perceptions and provision for their requirements.

This approach needs consolidating, taking advantages of the lessons learned in these pioneering buildings. In particular, more time must be allowed to consider options and to get things right: in design, in construction and commissioning, and after handover.

4.6 HEATING

All heating was gas-fired, mostly with perimeter radiators or convectors, except ALD (heaters in ceiling-mounted terminals), FRY (highly insulated, with all heat provided from the supply air), and MBW (gas-fired warm air heater units). Disappointingly, none of the commercial buildings had condensing boilers, turning their backs on a simple way of significantly reducing consumption.

4.7 HOT WATER

Academic buildings and those with catering kitchens (except the speculative ALD) had LPHW calorifiers off gas-fired boilers (a gas-fired storage water-heater at FRY; and with an added condensing summer hot water boiler at C&G). Otherwise HWS was from local electric storage heaters which were on constantly, and would have benefited from more careful selection and use.

4.8 AIR CONDITIONING

Probe 1 included four AC offices, three with variable air volume (VAV) systems: C&G's a conventional ceiling installation with plenum return; ALD with fan assisted (FAT) terminals - also in the ceiling; and TAN a 100% fresh air system from the floor, with free return through the atria.

The fourth, HFS, was one of the first UK buildings with chilled beams and displacement ventilation. Sadly, the claimed energy savings from this approach had not yet materialised, for three main reasons: high preheating and humidification loads from a full-fresh-air system with no heat recovery; extended running owing to high air infiltration through the fabric; and no on-site engineers in this relatively small building. Probe 2 therefore visited CRS, a second building of this type which also had exposed ceilings and heat recovery. CRS had lower HVAC energy consumption, but operational and comfort problems and some air infiltration made overall success difficult to judge.

Chillers were all air-cooled reciprocating, except HFS's screw chillers, and ALD's evaporative condenser. ALD and CRS also included ice storage, to reduce chiller capacity and permit electricity cost savings. In both buildings, however, the systems had proved difficult to manage and suffered reliability problems, and the predicted energy cost savings had not yet materialised.

Humidification was gas-fired in TAN and C&G, and electric elsewhere. It was operating liberally in all the AC buildings except C&G. To what extent was it necessary?

4.9 MIXED MODE SYSTEMS

TAN and CRS were nominally mixed-mode, with openable windows at the perimeter. However, these deep-plan buildings essentially worked as fully AC, with the windows offering little benefit to anyone not immediately beside them; and their use being discouraged by the facilities managers.

Three other buildings had more closely integrated MM systems:

- RMC had displacement-ventilated courtrooms with cooling available, mechanical plus automated natural ventilation in public areas, NV in magistrates' rooms, and offices with openable windows, background mechanical ventilation, and added comfort cooling units.
- CAF had displacement ventilation with heat recovery and indirect evaporative cooling, plus openable windows and fanlights.
- FRY was designed as a highly insulated thermal flywheel, with trickle-charge ventilation through the hollow core floorslabs, and the windows openable, essentially as safety-valves.

WMC was predominantly NV. Initially it had a domestic mechanical ventilation heat recovery system which was no longer used; and in two rooms comfort cooling had been added. Occupant satisfaction in RMC and FRY was particularly good (see section 6). All MM buildings used significantly less energy than their AC counterparts (see section 5), but with scope for further improvement. MM looks a promising route for future developments, but needs careful integration.

4.10 ARTIFICIAL LIGHTING AND ITS CONTROL

Lighting was often over-supplied and over-used: in occupant surveys most people thought there was too much artificial lighting (but not in the low-energy naturally-ventilated buildings). Office lighting often defaulted to ON, while lighting in common and circulation areas was often excessive and also used wastefully. For example, in spite of its low-energy aspirations, all the corridor and stair lighting at FRY was key-operated, and was switched on first thing by security and stayed on until security shut the building down, regardless of the good daylight in the atrium and on the stairs.

Automatic controls were less of a solution than might have been hoped. In particular:

- Occupancy sensors in offices often switched lights on when they were not needed; in open areas this could distract staff, causing the sensors to be over-ridden or delay times extended.
- Photoelectric controls seldom took account of the effect of blinds; often requiring settings to be increased, making savings diminish.
- Integration with manual controls was often poor. Where local over-ride was fitted, it was seldom at the level of the individual workstation. The need for cleaners to interact with systems had often been ignored, so the management had to put all the lights on automatically.
- All circulation lighting (at TAN toilets and meeting rooms too) often came on if there was just one person in the building.
- The systems were often difficult for management to use and expensive to maintain.
- The long run-up and restrike times of high-intensity discharge lighting made responsive control difficult; as had been found in earlier studies [14].

4.11 CONTROLS AND OPERATION GENERALLY

The shortcomings in performance, operation and usability noted with control of windows, ANV and lighting also extended to other systems, particularly HVAC. Repeated problems included:

- Poor sequencing of boilers, with the load being juggled between them.
- Often non-existent sequencing of chillers, other than via their integral compressor controls.
- Wastefully extended hours of pump running, sometimes owing to overall system design.
- Heating and humidification running in warm weather.
- Poor user interfaces, both on computer screens and elsewhere, down to the light switches.
- Poor responsiveness to demand and to exceptional requirements, reinforcing the tendency for systems to default to ON.

If buildings are to deliver good performance efficiently and consistently, more detailed attention to the design, specification, usability, detailed development, documentation, commissioning, handover, and in-use checking of controls performance will be required.

4.11 INFORMATION AND COMMUNICATIONS TECHNOLOGY (ICT)

ICT is becoming increasingly important in buildings of all types, largely as PC and networks for the occupants, and as the building's own control, communications and security infrastructure. Much equipment is also left on constantly - if only on standby - and sometimes unnecessarily. Air-conditioned rooms containing file servers, electronic archives, communications equipment, printers etc. are proliferating, even in the smaller buildings. Their 24-hour use significantly affects annual energy consumption, see Section 5.

C&G and CRS had large computer air conditioning installations with close-control downblow room units on a cooling water ring main at C&G and a chilled water main at CRS. Although the designers had endeavoured to make the systems efficient, there appeared to considerable scope for further savings, but unfortunately this could not be quantified reliably in the time. Estimation was also complicated by the complete absence of electricity meters for computer rooms and their AC in all the buildings surveyed. Most of the other buildings had packaged AC, but again with no meters.

TAN had a communications room and several other equipment rooms connected to its chilled water system, and the main pumps had to be operated to service these small loads. C&G also had two small communications rooms connected to one of its four office VAV plants, which had to run all night. Both were installing stand-alone cooling systems so the main plant could be off at night.

4.12 GENERAL ISSUES

Across all Probe buildings, a number of issues recurred:

- Diversity of usage. Buildings today tend to be less routinely occupied - with out-of-hours use, flexible working hours, and so on; and contain a wider range of activities and equipment. Briefs and designs, however, often assume more routine operation. This tends to lead to services which are relatively unresponsive to changes in occupancy, use and load; and to default to ON. *Services must either become more accommodating and/or responsive to changing demands, or should operate much more efficiently, so that extended hours make little difference to the energy bottom line.*

- Manageability. The facilities and engineering staff at the larger financial services buildings, particularly TAN and C&G, were able to look after their buildings and equipment and respond rapidly and effectively to problems and occupant complaints. Most of the other buildings demanded more than their occupiers - or the contractors they employed - were able to provide, or regarded as affordable. *While there may be a misfit between occupant expectations and reality, designers must also strive to make buildings less complicated, easier to look after, with systems which are well-integrated but preferably non-interacting; and controls which are effective and easy to use.*

- Widespread shortcomings in controls and usability, leading to occupant dissatisfaction, management frustration, and often energy wastage: for example though unnecessary or wasteful operation and poor use of daylight. Recent buildings often seem to deprive occupants of choice, increasing dependence on management and technical systems. *Controls must be more usable and occupants more involved in choices where appropriate.*

- Access was sometimes poor, both to plant (e.g. in cramped rooms or crawl spaces and hidden behind fragile access panels), to luminaires, security and fire detectors, and particularly to motorised windows and dampers for ANV. This delayed and complicated maintenance and repairs, sometimes required special access equipment and safety precautions, and could increase the reluctance of managers to intervene. *Safe and adequate access is essential.*

- Innovation. New technologies often have unanticipated “revenge effects” [15] where a solution to one problem creates unexpected new problems. Themes include difficulties with lighting controls, automated natural ventilation, ice storage, and relatively unfriendly interfaces to BMS and controls systems. There often appears to be too much optimism about the good aspects of a new idea and less consideration of the possible downsides, not only the technical risk but acceptability to management and users. *Responsible innovation with more pilot projects, reality-checking and discussion with users should be undertaken. The simpler and more understandable solutions often give the better results.*

- Handover of buildings was often rushed. Although a fact of life, this eternally seems to come as a surprise. A frequent consequence is a curtailed commissioning period, because practical completion tends to be seen as a matter of physical rather than functional and operational completeness. *Designs should seek to minimise commissioning, for example with self-balancing, pre-calibrated, or readily-adjustable approaches. Controls and usability also need careful consideration.* See also below.

- Although more can and should be “right first time”, for some aspects - particularly operation and controls - it may be impossible to understand and fine-tune performance until the building is occupied and its management begins to take control. It is rather like getting software running smoothly on a computer. At present the industry is not good at dealing with problems after practical completion: this takes the edge of initial occupant enthusiasm and can lead to disillusionment. In part, the design and building team is not resourced to deal with problems (other than as defects). During the defects liability period, occupants, their contractors and designers are also loth to intervene for fear of ending up “owning” the whole of the problem. The result can be ineffective communications and meetings and little forward progress. *The contractual situation regarding practical completion and the defects liability period needs reviewing for today’s buildings which can be far from complete when they are physically complete, and will often require some fine tuning. For all but the simplest or most standardised buildings, a “sea trials” and feedback period should be undertaken in the first year, and be resourced appropriately.*

5 CONCLUSIONS FROM REPORT 2: ENERGY PERFORMANCE

5.1 INTRODUCTION

Assessing energy performance was an important part of Probe, as discussed in Report 2. Figure 5.1 is a bar chart of CO_2 emissions per unit treated floor area. It also includes (arrowed) some benchmark values from ECON 19 [16], and the unusually energy-efficient AC office One Bridewell Street [17]. The bars are sorted in order of increasing emissions from normal building services, the coloured bars: heating and hot water; refrigeration and heat rejection; fans pumps and controls; humidification and lighting Occupant equipment is in black-and-white: office equipment, catering gas and electricity (including vending); computer and communications rooms; and other items including external lighting, telecoms, security and lifts. The swimming pool and radio transmitter at C&W and the mechanical handling (including fork lift trucks) at MBW are shown separately. The underground car park at TAN is omitted, both its area and its energy consumption.

Nearly all Probe buildings claimed to be energy efficient, but the range of annual consumption and emissions was massive, with a factor of six between the highest and the lowest, and even greater variations in some individual end uses. For example, per unit floor area, fans and pumps alone in some of the AC buildings were responsible for more emissions than everything in a low-energy NV building! Some NV buildings had very good energy performance, but in spite of this still had significant opportunities for further improvement. Consumption was usually more than the designers expected. However, most design energy use estimates were patchy, frequently:

- omitting much of the black-and white area;
- assuming time schedules with fewer hours of operation than occur in practice;
- assuming lower levels of air infiltration than frequently occur in practice; and
- making optimistic assumptions about the efficiency of plant and effectiveness of control.

This gulf between expectation and reality needs closing. *This requires a common language for energy performance and influencing factors, usable at all stages in a building's life: briefing, design, modelling, specification, assessment, regulation, acceptance, management & research.*

If expressed per occupant, the variation is yet wider, as the two highest building services energy consumers (HFS and ALD) were relatively lightly-occupied; while the low-energy educational buildings had high peak occupation densities - though only sporadically; and with little weekend and vacation use. *Ideally, energy benchmarks would be separated into area-, occupancy- and production-related parts, and FMs would keep records of say person-hours occupancy to some agreed industry standard.* However, reliable figures of this kind are not available at present.

5.3 THE OVERALL PICTURE

As a general rule, the NV buildings have the lowest consumption and emissions, followed by ANV, MM and AC. This is effect as well as cause, as the intensity of use also tends to increase; e.g. with the black-and-white bars growing along with the coloured ones. However, the more highly-serviced buildings are more inclined to wastefulness. If heating in a NV building runs all the time, gas consumption will rise by perhaps 25%. In an AC building, not only does gas consumption rise much faster owing to the extra ventilation load; but fans, pumps, chillers and humidifiers run too.

5.4 ENERGY CONSUMPTION BY BUILDING SERVICES

- Heating energy use was often high, partly owing to high infiltration and ventilation rates, with full fresh-air and displacement systems also needing heating on summer mornings; and often relatively poor control and management. Major exceptions were the highly-insulated WMC and FRY, demonstrating the benefits of this approach and (at FRY) the importance of good control and management and the value of post-occupancy monitoring.
- Hot water. It was not usually possible to separate hot water consumption unambiguously. The trend to local electric storage systems with no associated time control or water economy measures was not good for CO_2 emissions. This was particularly noticeable at the otherwise low-energy WMC.
- Refrigeration. Consumption was relatively low, with widespread use of outside air for free cooling. High consumption arose at HFS (unstable control and unnecessarily long hours of use) and ALD (added demands from its ice storage and low temperature air systems).
- Fans, pumps and controls. Fan energy consumption usually dominates, owing to high air volumes, specific fan power, and hours of use. Pumps also ran 24-hours at TAN (tail-wags the dog to meet loads in equipment rooms which were in the process of being cooled independently) and for long periods together with the refrigeration at ALD and HFS.

- Significant refrigeration and fan energy consumption also occurred in some of the non-AC buildings, particularly:
  - C&W, where a local chilled water system ran constantly for a few classrooms which were expected to have high heat gains (in practice most did not owing to altered requirements). The system was also not interlocked with the heating or the natural ventilation.
  - The same applied in the conference room at CAB and the lecture rooms at POR.
  - RMC, with high ventilation rates in relation to its relatively low occupancy; partly to recover heat from the sunspaces which was much less valuable than the fan energy used.

  A focus on passive measures in these buildings seemed to have diverted attention from simple good practice elsewhere; in particular demand-responsiveness and air transport efficiency.
  - At CAF, the contractor had installed more powerful fans than the designer had anticipated.
  - At FRY - already the most efficient building in terms of specific fan power - the designers said that if they were to do it again they could have halved it.
  - At MBO/MBW, the shared toilet supply/extract ventilation plant ran for extended hours. Its air preheating was often the sole load on the boilers, significantly increasing gas consumption.
- Humidifier energy consumption was significant in all the AC buildings, which all used sterile steam systems. Humidifiers appeared to be wastefully operated except at C&G, one of the few Probe buildings to be undertaking any significant energy management!
- Lighting energy use tended to be lowest in the simpler buildings which had good, clear user control. While automatic systems did make some savings, most lacked compatibility with management and user requirements, brought lights on unnecessarily, and could annoy occupants. In the AC buildings, default to ON was the norm. The aspirations of MBO and DMQ to make good use of daylight were also frustrated by incompatible controls. Lighting energy use at the other ANV educational buildings: POR, CAB and APU was relatively low, owing to good daylight, low installed power density, and reasonable control; but even here considerable potential for further savings was found. WMC's consumption was also low, but similar to the ECON 19 good practice benchmark for a naturally-ventilated cellular office.

5.5 ENERGY CONSUMPTION BY OCCUPIER'S EQUIPMENT (AND DEDICATED SERVICES):

- Office equipment energy consumption was significant, but usually less than the lighting, partly because even in an office typically about half the floor area is devoted to other things: circulation, restaurant, toilets, meeting rooms and so on. The office areas of most buildings were compatible with BCO's typical equipment gain levels of 15 W/m^2 with local hot spots of 25 W/m^2, but with many lower-density buildings and areas, and occasional pockets of high density. A worrying trend, however, was for equipment to be left on permanently, even overnight: CRS - the last AC office to be surveyed - suffered particularly from this. Even when equipment is nominally off, "leaking electricity" often occurs, with power supplies and control circuits still live and using significant amounts of energy. Auto-slumber equipment is a mixed blessing: it reinforces people's habits of not turning things off and is often far from energy-efficient. EnergyStar's criterion of 30 Watts standby is liberal - less than 1 W would be more like it - and in practice the slumber facilities are often disabled (at CRS only 10 W were saved). Better national and international product legislation should be considered here.
- Catering and vending. Apart from APU, no installations were found that paid any particular attention to energy efficiency. Few kitchens were submetered (TAN, CAB and CRS were exceptions); and even here the meters were not generally read. In all the buildings, the catering contractors received all their energy "free" from their employer, so had no incentive to make either investment or management savings. Contract conditions need to be reviewed.
- Other. The biggest item here was usually external lighting, at least on the open sites. Provision and hours of use have been rising over recent years, owing to security concerns; and care is required in design, control and management to avoid waste. Lifts are another small item; and in these low-rise buildings architects increasingly prefer hydraulic designs, which are more attractive and flexible but much less energy efficient than traction ones.
- Computer and communications rooms. These air-conditioned rooms can use an important part of a building's electricity owing to their 24-hour operation, but are seldom taken account of in design estimates or statistical comparisons. The equipment and the AC plant is hardly ever submetered; though UPS displays can provide valuable information on VA output. As a rule of thumb, the ratio of annual energy consumption of AC to equipment is about 0.8, though this can vary from 0.5 to 1.5 or more (BT has reported 3 for some of its installations). Metering and management of these areas should be encouraged: any statutory restrictions on in-use building energy consumption will be difficult to implement without such information.

5.6 IMPROVING ENERGY PERFORMANCE

The energy expert Amory Lovins has said *"much energy consumption comes from compounding of unnecessary loads"*. Relatively inefficient services can operate for unnecessarily long hours to support unnecessarily high loads created by inefficient design, construction and use of the fabric or to support uneconomical equipment which is left on too much. In moving towards sustainability, services must work better with the building fabric to provide a safe, comfortable, healthy, productive and enjoyable environment to support the occupants' activities and equipment, through:

- Reductions in loads - through more efficient and better-controlled fabric and equipment.
- Gentle engineering, with improvements in effectiveness, efficiency and control.
- Closer matches between demand and supply, seeking where possible to use information rather than energy to achieve the required conditions with minimum waste.

. All need to be done in an effective and efficient manner, with attention given not only to the principal areas of the buildings, but to smaller areas and behind-the-scenes items.

Probe has helped to indicate trends, and illustrate where success is being achieved and problems to be addressed. Various issues have emerged:

- Intrinsically efficient technology (e.g. high frequency lighting, condensing boilers) should be more widely used. In the commercial buildings, no condensing boilers were found owing to their additional costs. HF lighting was more common, perhaps owing to its claimed health benefits. *Should not such items be considered to be essential baseline features, not added costs?*
- A tendency to full fresh-air ventilation, sometimes at high volumes and with no heat recovery; and leading to much increased demands for heating (even in summer) and humidification. *Should not heat recovery be mandatory for many systems, as it has been in Sweden?*[9]
- More humidification - usually with sterile steam for health reasons and often electrically-generated (with both a high energy costs and CO_2 overheads). In Probe (and other buildings known to the team), humidifiers - once present - also tended to be operated unnecessarily and wastefully. *Guidance is required on requirements for humidification, and its safe and energy-efficient provision and management.*
- Widespread use of electric water heating: often a convenient option, but frequently not the lowest in terms of running costs and CO_2 emissions, particularly - as in all the Probe buildings which had it - when it has no time control and few attempts at water saving. *Updated guidance on hot water systems should be considered.*
- A tendency for systems to default to ON, particularly if operating behind the scenes: fans, boilers, pumps and humidifiers and notoriously cooling systems. Lighting is also highly susceptible owing to unsuitable controls and interfaces, default inertia, and annoyance caused by inappropriate operation. This state is often the least troublesome for occupants and management; and sometimes the controls do not permit anything else. *There is a great need for systems to be designed, controlled and operated to be more demand-responsive.*
- High energy use in computer and communications rooms. The design and operation of the systems could be more energy efficient; and needs for close control can sometimes be questioned. Systems could also be more demand-responsive, with variable capacity operation, better sequencing, and fewer standby units left running. *Efficient use, servicing and monitoring of machine rooms is overdue for attention. For effective benchmarking, they and their air conditioning also need metering separately from the buildings.*

Although electrical consumption tends to dominate, good thermal performance and little need for heating will also be important to buildings of the 21st century. Unwanted air infiltration can cause disproportionate increases in energy use, not only to meet the extra losses, but because operating hours and heating seasons have to be extended to ensure adequate comfort, with increased pump, fan and sometimes humidifier use. In addition, plant design margins have to be larger to cope with the risk of high infiltration. FRY and to a lesser extent WMC demonstrate how things can be done very much better; and FRY also achieved good summertime comfort without refrigeration[10]. *Radical improvements in fabric insulation, airtightness, windows and use of thermal capacity are achievable and should be supported. Cost advisers often say that they can't be afforded: but if they are essential to sound performance, surely this is a false economy? And if done properly, other things can sometimes be omitted (like the perimeter heating at FRY).*

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9 However, heat recovery itself has to be done and controlled well to deliver good benefits.

10 Interestingly, the University of East Anglia reported that the maintenance cost of FRY's mechanical ventilation system (which also provided all its heating and cooling) was less than the annual maintenance contract for the external solar blinds alone in the same team's previous building on the site; also designed for low energy consumption, but which used considerably more energy than FRY.

5.7 CONCLUSIONS FOR ENERGY

In the buildings selected, Probe has found a less thoroughgoing approach to energy in briefing, design, construction and management than might have been expected The best all-round example was FRY, but even here the design, while strong on thermal aspects, was less good on lighting, control and air transport efficiency; and the need for better control and management of the H&V system was only identified and acted upon as a result of BRECSU's monitoring. In general:

- Energy was often poorly specified in briefing and design criteria. *Advice on qualitative and quantitative aspects of briefing and design brief management needs improving.*
- Standards may need to be considered more carefully. For example, several of the office lighting systems still adopted the 500-600 lux standard rather than the lower LG3 one for VDU use. The occupant surveys (Report 3 and section 6) however showed a general preference for offices with illuminance levels below 500 lux. If some individuals need extra light, this might be provided more effectively on an ad hoc basis. *Selecting appropriate standards should involve more of a dialogue, with greater consideration of individual requirements, environmental impact, and the specific features of the evolving design.*
- Designs were prone to focus on specific low-energy features, and could lose sight of overall performance and priorities. Buildings are both symbolic and functional, but sometimes (as in ANV), symbolism could get the upper hand. *Regular reviews of priorities are essential.*
- There was relatively little benchmarking of solutions (e.g. boiler capacity, chiller capacity, pump capacity and specific fan power) as projects proceed. *Regular comparisons with client requirements and industry benchmarks should be undertaken, with more emphasis on the roots of energy consumption (capacity, efficiency and hours of utilisation).*
- There was very little energy management in these leading buildings - even those which had low-energy briefs - so measures requiring management input were fragile. While their management might well swing into action if energy were to become a real priority, management time is an important design constraint. Simple, robust, "fit and forget" measures are preferable, with emphasis on reducing loads, efficient plant, effective controls, and waste avoidance. Energy management must be seen as an essential component of good management. *Designers must also try deliver systems which are intrinsically-efficient and user-friendly. Systems should not demand more from management than is likely to be available; adopt simple default operation; and if necessary warn of potential problems.*
- In some buildings - particularly in Probe 1 - very high allowances for internal gains from office equipment had led to oversized AC systems. In Probe 2, this had quietened-down. However, energy use by office equipment had continued to rise, owing to longer hours of operation. Management should encourage people to turn equipment off when not in use: unfortunately some IT managers do the opposite! It should also be easier to select energy-efficient equipment, through labelling and accreditation schemes. *Government should also seek to encourage manufacturers to produce and customers to choose equipment which uses the absolute minimum amount of electricity when "off" or on standby.*
- Most of the AC buildings in Probe used large amounts of energy, particularly electricity. Some was an inevitable consequence of their intensity of use and equipment levels, but there were avoidable shortfalls in performance, efficiency, control and responsiveness. Heating, cooling, pumps, fans and lighting ran for much longer than designers had anticipated, owing to technical, management and control-related tendencies to default to ON. *An initiative is required to improve performance, efficiency, control and management, particularly in mechanically-conditioned buildings. AC should not be demonised: there is much scope for better energy performance; as seen in good examples such as One Bridewell Street.*
- There were few submeters in Probe buildings. Where installed, they were seldom read - owing to the limited amount of energy management. Utility meter readings were patchy, particularly for gas. An initiative on better energy metering and reporting would help to foster better understanding and energy management, with routine sub-metering of main plant items and areas of high energy intensity such as kitchens; and computer rooms and their air conditioning. *The Regulator could consider requiring fuel suppliers to make fewer estimated readings, and to report consumption and trends to their customers.*
- Innovations are difficult, particularly in buildings where the prototype is often the end product. Inevitably, not everything will be right first time, as in the ANV buildings. The MM buildings also had shortcomings, particularly high fan energy consumption at RMC and CAF, but in spite of this CAF used about half as much as the similarly sized, occupied and sited AC HFS; and MM appears a promising alternative to AC for both energy and comfort (see section 6). *There is a lot more to learn about getting the best performance from innovative approaches such as ANV and MM. Possible downsides must not be overlooked.*

6 CONCLUSIONS FROM REPORT 3: OCCUPANT SURVEYS

6.1 THE SURVEYS UNDERTAKEN

Probe collects information from occupants[11] for 49 variables, and falling into twelve groups:

- background (age, sex etc);
- the building overall (its design and how well it meets perceived needs);
- personal control (over heating, cooling, lighting etc and speed of response in meeting needs);
- speed and effectiveness of response after complaints have been made to the management;
- temperature;
- air movement;
- air quality (in both summer and winter for the last three);
- lighting;
- noise;
- overall comfort;
- health;
- productivity at work.

A standard two-page, tick-box questionnaire is licensed from Building Use Studies (BUS). This has evolved from a twelve-page version first used in 1985 and now includes what experience has shown to be the most significant questions. For a few buildings, extra questions were added on special topics of interest to the study team (e.g. perceptions of floor supply ventilation at TAN) or to the managers of the visited building (e.g. journey to work data at C&G). Sometimes a shorter secondary questionnaire was also given to specialist user groups (e.g. school pupils at CAB, students at APU and magistrates at RMC). When opportunities arose, meetings with management were also held, and occasionally staff focus groups.

6.2 DATA MANAGEMENT AND BENCHMARKING

Probe uses a relatively small core set of key performance indicators (KPIs), which remain essentially the same across all building types studied. Many surveys end up with too much data and not enough time to consolidate and analyse the results. A smaller core data set avoids this “data bloat” problem, and also releases time for managing the wider data set. This makes benchmarking achievable, using average scores from the last fifty buildings surveyed by BUS. To maintain these benchmarks, questions are changed as little as possible; and then by omitting those found to convey little information and adding ones on issues found to be important or interesting. For example:

- About two years before Probe started, questions had been added on system and management response, as a study on controls had found that these were important to user satisfaction.
- Questions on spring & autumn comfort were omitted, being less reliable than summer/winter.
- Late in Probe 1, questions on satisfaction with the design of the building and the degree to which the facilities met occupant needs were trialled. These were included in Probe 2.

As more buildings are added to the dataset, the burden of data management and quality control increases. However, the larger knowledge base makes the information gained more valuable, and the early trade-offs between "must have" and "nice to know" questions particularly important. An important aspect of Probe, especially in benchmarking all-round performance, was its early decision to use tried-and-tested methods to collect both energy and occupant data, and to alter these techniques only incrementally. More details of the techniques are in Reports 1, 3 and [PC1].

6.3 DATA PRESENTATION

In spite of frugal data gathering, there is still a prodigious amount of potential information[12]. To provide overall statistical snapshots of occupant responses, Probe uses two summary indexes:

- One based on comfort, see figure 6.1, based on scores for summer and winter temperature and air quality, lighting noise and overall comfort.
- One on satisfaction, figure 6.2, based on scores for design, needs, productivity and health.

These indexes are usually the first step in presenting results on a particular building. For example, buildings may score highly for satisfaction but less well for comfort (e.g. MBO); or well on both (e.g. permanent staff at FRY).

11 Normally, questionnaires are issued to a sample of 125 permanent staff per building - or of all staff if the building is smaller than this. With the BUS technique used, response rates are typically 90% or more.

12 49 variables; Fifteen Probe buildings nested with 35 others in the benchmark dataset; and typically 100 completed questionnaires per building! To be credible, the results must demonstrate that they have statistical validity and are reasonably comprehensive, so you need large samples and plenty of data. Given this, however, most people only are interested in a few things (e.g. how do the best buildings compare with the worst; is noise a serious problem?) so one must be concise and not overwhelm with statistics. To help overcome this, we plan to make the Probe occupant survey results available in an internet format so people can select items that interest them, and use the data at the level with which they are comfortable.

Percentile presentation. Figure 6.1 shows how the comfort indexes for all the Probe buildings (red) relate both to each other and to the other (anonymous) buildings which make up the benchmark data set of 50 buildings altogether[13]. Occupants' rating scores on the 7-point questionnaire scales (1=Uncomfortable; 7=Comfortable)[14] are averaged for each building, and the values plotted at their positions on the vertical overall comfort scale. On the horizontal scale, buildings are in their rank order with the first-ranked (i.e. the best) placed at the 99th percentile, and the lowest-ranked at the 1st percentile. Using the percentile scale, it is then possible to say where the index for a building lies with respect to whole the dataset (e.g. is it in the top 20 per cent or the bottom 25 per cent?). This type of diagram thus combines absolute (i.e. real) scores on the vertical scale and relative (i.e. derived) scores on the horizontal scale. Figure 6.2 does the same thing for the satisfaction index.

Presentation of study scores with statistics. Scores based on the averages of occupant responses to a particular question in each building can also be presented in rank order on graphs, together with their benchmarks. These graphs can also include confidence intervals, to emphasise that they are based on sample statistics, and so subject to variations owing to sample size, variability of responses and random fluctuations. This permits rapid visual checks to see whether buildings differ significantly (in a statistical sense) from the benchmark, the scale midpoint or another building. For example, Figure 6.3 shows ratings for glare from sun and sky for each of the Probe buildings, together with the benchmarks from the BUS dataset:

- If the range shown for a particular building is intersected by the line for the benchmark mean, then that building is not significantly different from the benchmark (e.g. #10 POR).
- If the scale midpoint intersects the range, then the building is not significantly different from the scale midpoint (e.g. #8 RMC). This is of particular interest in scales which run from "too little" at one end to "too much" at the other, making 4 the point of balance.
- If a mean for a particular building intersects the range for another, then the buildings are not significantly different from each other (e.g. #4 (HFS) and #7 (FRY)).

In these comparisons, we are usually interested in the buildings significantly above benchmark (e.g. with too much glare from sun and sky, here APU, C&W, CAB, CAF and MBO); and those significantly below (here CRS, ALD, HFS and TAN); and to consider the reasons why. In this instance, all the low-glare buildings were AC ones with tinted glass, good provision of blinds, and limited use of daylight. The high-glare ones were shallower-planned and had all attempted to make good use of daylight; and the survey shows that this was not entirely successful for the occupants.

Scores for an individual building. For a single building, scores (along with the details for statistical tests) can be shown alongside the benchmark, as in Figure 6.4.

6.4 INTERPRETING THE RESULTS

Probe buildings are not a random statistical sample. Nor is the BUS sample, which is based on buildings in which post-occupancy evaluations have been commissioned. All will be self-selecting to some extent: managers who are prepared to commit resources to post-occupancy evaluations will also be interested in improvement, so they are already likely to have better buildings.

In buildings, obtaining statistically structured samples with requisite "random" elements of choice is almost impossible, owing to the difficulty of defining the sampling frame. Physical design and human and management issues are also inextricably linked. The questionnaire seeks responses on building-related issues, but a complete separation of influencing factors is not possible. For example, if occupants are not happy with their work, managers and colleagues, they may project their dissatisfaction onto the environment and facilities[15]. People can also use their physical environment as a risk-free way of protesting about poor management.

Interpretation also requires readers to consider particular contextual factors. High levels of occupant satisfaction are easier to achieve when the following features are present:

- shallower plan forms and depths of space (workstations typically 6m or less from a window);
- cellularisation;
- thermal mass (provided the acoustics are satisfactory);
- stable and comfortable thermal conditions;
- air infiltration under control;
- openable windows close to the users;
- views out;
- effective controls with clear, usable interfaces;
- a non-sedentary workforce (including relatively low VDU usage);

13 For some variables, there are fewer than 50 data points, because the question concerned may have been omitted from some of the benchmark surveys for some reason, for example for confidentiality, in a short survey, or if newly-introduced.
14 Most of the scales used in the BUS questionaires are 7-point tick-boxes. For more details see Report 3.
15 Even the best buildings (e.g. TAN) still have 65 per cent of their staff pointing out that something is not right!

- predictable occupancy patterns;
- well-informed, responsive and diligent management;
- places to go at break times inside or away from the building.

All these features tend to give individual occupants some autonomy, and to reduce their reliance upon management. For example, occupants of FRY like many aspects of the building very much. However, this building has features that most occupants like anyway, which adds leverage to the scores: stable, comfortable conditions winter and summer; individual offices with openable windows for most staff; reasonably effective acoustic separation; and excellent controllability over ventilation, noise, and to some extent lighting. FRY also has work-related features which are associated with higher scores, in particular:

- many staff use the building fewer than five days a week;
- when there, they also move around more, e.g. teaching and doing surveys; and so
- they spend less time at their desks and VDUs.

Features which make occupant satisfaction harder to achieve include:

- deeper plan forms;
- open work areas;
- larger workgroups, sometimes split between different locations;
- greater mixes of activities;
- higher densities;
- longer working hours, but with main support services active only during core time;
- presence of complex technology, particularly if unfamiliar.

These tend to make individual occupants more dependent on the systems and management in the building. If management is inadequate or unresponsive (or bossy and intrusive), or finds it difficult coping with the building and the technology, occupants will be dissatisfied and vicious circles of decline can easily develop. On the other hand (but on fairly rare occasions) excellent management can look after complex buildings, satisfy staff, and engage in virtuous circles of continuous improvement. For example, the deep-plan AC TAN has many of the physical (e.g. very deep plan) and usage (e.g. predominantly clerical staff) factors which are often associated with poor occupant satisfaction. The fact that TAN’s occupant scores are good is a great credit to the designers and the management - not only of the building, its furnishings and equipment, but also of its briefing and procurement.

6.5 COMFORT IN GENERAL

Occupants tend to rate buildings as most comfortable when:

- conditions are stable (and reasonably predictable so that people know what to wear); and fall for most of the time within acceptable (not necessarily ideal) comfort thresholds; but
- if necessary, conditions can be quickly altered in response to perceived fluctuations (like the weather) or unpredictable events (like glare, draughts, or noises outside); and
- if conflicts or unsatisfactory conditions occur, occupants can decide for themselves how to resolve them, by over-riding default settings rather than having conditions chosen for them.

For a control action to be perceived as effective, occupants must experience a rapid improvement. Conditions must no longer be beyond their threshold of discomfort, but do not have to be ideal.

The best buildings for comfort often also have:

- ratings for summer which are better than or equal to winter, as at FRY and RMC (in NV buildings, summer ratings are nearly always worse than winter - a problem unless a MM emergency cooling approach can be adopted);
- a perception of slight coolness, as at FRY; cooler buildings often also have higher health ratings (FRY is rated as healthiest), while many buildings are now perceived as too hot;
- lower variances, so that there is either less disagreement about the conditions; and people are more readily able to resolve any differences that do exist; and
- high levels of perceived control, especially over heating, cooling and ventilation. Control over noise is also becoming more important with trends to more open buildings, and sometimes also with exposed surfaces to increase their thermal inertia.

6.6 COMFORT, PRODUCTIVITY AND RESPONSIVENESS

Occupants who perceive that they are comfortable also tend to say that they are healthy and productive at work, so responses to health, comfort and productivity questions can often be surrogates for each other. As an illustration of this, we split respondents' scores in each building into those who are uncomfortable (i.e. they rate the overall comfort variable as 1, 2 or 3 on the scale) and neutral or comfortable (4, 5, 6 or 7). In the Probe buildings, uncomfortable staff overall report productivity losses of minus 8.8% and comfortable staff productivity gains of plus 4.0%, a difference of 12.8 percentage points.

The implication of the above is that there is more is to be gained not by aiming for better and better levels of comfort (as defined perhaps by engineering design criteria), but by strategies which seek to understand and eradicate factors that lead to perceived discomfort, ill health and low productivity (c.f. section 6.5). Productivity ratings for the Probe buildings are shown in Figure 6.5.

Probe has confirmed that respondents' perceptions of performance are linked to how rapidly they think the buildings' systems respond to their needs. The faster the better, as the two graphs in Figure 6.6 show. The top left graph has ratings of quickness of system response (bottom axis) with overall comfort (vertical axis). The R^2 value of 0.41 (correlation coefficient 0.64) indicates a significant positive relationship: the faster the perception of response, the better the comfort scores[16]. The bottom right graph has ratings of effectiveness of response once a complaint has been made to management. The association is similar (though with a lower correlation coefficient of 0.54): the more effective people perceive the response is, the more comfortable they say they are. In other words, demand-responsive buildings work better in the eyes of their occupants. The implication for design is that greater usability at interfaces perceived as critical by occupants (e.g. controls for heating, cooling, ventilation and glare) pay dividends, and that better management and manageability also helps to improve the overall responsiveness of the system.

6.7 PERCEIVED CONTROL

Building designers are now well aware of the importance of control to building occupants. However, the move towards open planning, linked furniture, and more automated control is causing occupants' ratings of perceived control to decline! In the BUS dataset the average control rating[17] for all buildings is 2.69, split by AC 2.13, ANV 2.90, NV 2.92 and MM 3.10. The Probe buildings with highest control ratings are WMC 4.4, RMC 3.9 and POR 3.4 (see Figure 6.7). Unusually low perceived control scores were found at HFS (1.3) and ALD (1.6).

High perceived control is frequently associated with better comfort, health and productivity, but not invariably so. Low perceived control may not matter much if conditions are good, management is good, and problems seldom occur, as at TAN. Control is particularly valued when it provides practical and effective means of mitigating discomfort without adversely affecting others and where it does not need to be exercised too frequently.

6.8 LIGHTING

One emerging finding from Probe (yet to be tested more fully) is that lighting tends to influence overall ratings of comfort only when it is either very good or very poor. In figure 6.8 the relationship is driven by the buildings at the top right and bottom left extremes, the rest of the scatter is virtually random.

Overall ratings of lighting in Probe are in Figure 6.9. Interestingly, the two buildings judged best for both had indirect systems (cornice lighting at FRY and metal halide uplighting at TAN). FRY's top score is probably related to the simple usability and responsiveness of an individual room with a light switch. In some buildings, problems with controls had forced the score down, most notably at MBO, where occupants were disproportionately affected by an unfriendly automatic control system and some difficulties with the window blinds.

Occupants are asked to rate whether they have too much (=1 on the scale) or too little (=7) natural and artificial light. Occupants often say that they have too little natural and too much artificial. If the scores are subtracted (i.e. natural minus artificial) the Probe buildings come out with AC showing the highest differences, partly owing to their deep plan forms (see Figure 6.10). However TAN, the deepest in plan form, shows the least difference amongst the AC buildings, illustrating how thoughtful design can compensate to some extent even in the most challenging circumstances.

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16 Note that the observations are not split by ventilation type owing to the small samples for ANV and MM.

17 On a 7-point scale from 1=no control to 7=full control.

6.9 NOISE

Next to thermal comfort and personal control, occupants usually complain most about noise and its consequences, especially random disturbances which affect concentration. Noise is particularly difficult to deal with because relevant noise (e.g. workgroup colleagues' conversations) is acceptable to many, while irrelevant but intrusive noise (e.g. conversations of others) is not. Not surprisingly, buildings with the greatest degree of cellularisation (WMC and FRY) score best on noise ratings (see Figure 6.11).

Figure 6.12 gives percentages of staff who say they were dissatisfied or satisfied/neutral with noise. For the Probe buildings overall, 42 per cent of staff are dissatisfied. Dissatisfaction was lowest in HFS (high absorption, low density, some cellular) and WMC (cellular), highest in DMQ (dense, reverberant, open plan offices for some staff). In their written comments, occupants also draw attention to particular areas of dissatisfaction with noise. These include:

- the normal factors of open plan offices and insufficient acoustic treatment;
- layout, in particular poorly integrated workgroups, circulation routes cutting through clusters of workstations, adjacent kitchens, meeting areas and vending points, and banging doors;
- external noise including loading bays and car parks;
- noisy colleagues, particularly if not in the same workgroup;
- telephone ringers and computer feedback noises.

Figure 6.12 also shows differences in perceived productivity between staff who are dissatisfied with noise and those who are satisfied or neutral. Productivity differences of 15 percentage points are reported at POR, C&W and ALD. At POR, satisfied/neutral staff make the most difference - reporting high productivity gains; at C&W and ALD, the dissatisfied staff make the difference, reporting losses. Only two buildings, HFS and APU have negligible differences in productivity: HFS is lightly-occupied and quiet, but at APU, although occupancy levels were also low, noise was more of a reported problem. The differences at the well-managed TAN are also small; but here the large open-plan spaces are very uniform in character, and the ceilings unusually high.

6.10 IMPROVING CONDITIONS FOR OCCUPANTS

Concern about occupant satisfaction came to the fore in the 1980s with the discovery that chronic ill-health was often building-related (that is, reported symptoms like lethargy, headaches, dry eyes and dry throat appeared during the day and went away again after people left in the evening). These clusters of symptoms tended to be most common in deep-plan, air-conditioned offices, so it was naturally, but rather prematurely, concluded that AC was the cause.

Things are no longer so cut-and-dried, partly owing to developing survey techniques and partly to improvements in the design, maintenance and management of AC buildings; and more complication in NV ones. For instance, TAN has many of the risk factors associated with chronic ill-health (very deep plan form, AC, open office layout) but staff perceive it as comfortable, healthy, and improving their productivity at work. FRY also scores very well on occupant comfort, but has many physical and work-related characteristics which one would expect to create good scores, see Section 6.4.

It is tempting to focus on design and technical features to explain good occupant satisfaction, but the real reasons may be more to do with how design and management come together to create a total system. Buildings which the occupants perceive as best tend to have good ratings for perceived quickness of response (Figure 6.13); which is itself associated with comfort and productivity. Responsiveness is related to:

- usable controls which are easy for occupants to understand, deliver acceptable performance and can be seen to be obviously working;
- comfortable conditions for the majority of the year, with the ability for occupants to trim and fine tune if things alter for the worse;
- a space plan which accommodates workgroups properly to maximise within-group requirements and minimise between-group conflicts (for example, people within a group can decide for themselves how the window blinds can be set, without affecting the preferences of the adjacent group);
- a diligent facilities management team backed up by a proactive help desk which deals with complaints sensitively and rapidly;
- 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. Amongst the Probe buildings it is well illustrated by MBO, which scores reasonably on the comfort index (fifth in Figure 6.1), but comes first (just) in the summary index of satisfaction (Figure 6.2)[18]. MBO is instructive not just for its design philosophy and its pioneer window system [18] but because all levels of staff were involved at most phases in the design, development and handover processes, albeit at modest level. For example, when MBO was being fitted out prior to occupancy, the architect and senior management hosted staff meetings in the new building to explain what things were for and how they worked. The occupier's senior management were also committed to the Investors in People programme, and proud of their achievements in it. The developer, Lansdown Estates Group (now Milton Park Ltd), encouraged independent post-occupancy feedback on its buildings, and has striven to ensure that its clients obtained value in the buildings it supplied.

MBO itself had flaws and disappointments - particularly lighting control, together with glare and air leakage, but the total package as a working building pleased both management and staff. Its energy performance is also reasonable, with prospects of further improvement. While FRY was best on most performance indicators and has received most of the plaudits, MBO is an instructive all-round example of how developer, client, architect, management and staff - working within modest budgets and the added constraints of large warehousing requirements alongside - create value and performance in a building which has exceeded most expectations.

6.11 CONCLUSIONS FOR OCCUPANTS

Many things occupants want in buildings are clear: comfort, health and safety are prominent at the strategic level; and functionality, airtightness and usability at the technical. Most clients will not even think of asking for these in a project brief, because they will assume that they come as part of the service. However, while the good buildings are getting better, Probe and other studies indicate that chronic problems are still rife, and affect occupants' perceptions and performance. Many of these never come high enough on anyone's priority list to receive the attention they require, so slamming doors, glare, overheating, unresponsive or intrusive control systems and random disturbances are widespread. Even the best-laid plans can be undermined by a leaky fabric (as at HFS and CAF); a rogue lighting system (MBO); too much noise (POR or APU); or too few usable controls (ALD).

In the buildings occupants like most (FRY, MBO, RMC, TAN, C&G, WMC and to some extent CAB, POR and CRS), what are the factors for success? Best results tend to occur when:

- Features like shallow plan depths, openable windows, comfortable thermal conditions (especially in hot summer periods), acoustic separation and good views out are all present. Ideally, as at FRY and WMC, there should also be no need for high management intervention to achieve an acceptable working environment.
- If some or all of these features are absent for any reason (e.g. if the building is large, complex and deep-plan), they are compensated for by all-round excellence in facilities services such as cleaning and a responsive help desk (e.g. TAN, C&G, and to some extent CRS).
- These need to be additionally underpinned by a stream of managed feedback about performance, not just relating to occupants' main preoccupations like comfort, but also data on areas such as cost-in-use, space utilisation, 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 improved its - already excellent - response rate and revised its energy management strategy after Probe).

However, contexts and circumstances change from case to case, making buildings different from consumer products like cars. Success often emerges from a combination of clear-minded foresight and a happenchance of factors, many of which will not be repeatable on the next job[19]. 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 benefits. This why the last of the points above is the most critical: monitoring gives advance warning of unusual contextual factors which may threaten or undermine performance, and highlight areas of risk more successfully.

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18 The "design" and "needs" components of this index were introduced halfway through Probe, so the earlier buildings are not included.
19 As the architects and engineers of FRY reported at a Probe seminar in 1998.

Improving conditions for occupants requires not only:
- better tactics which take account of risk factors in design (e.g. deep plan, lack of control etc.);
- more enlightened design (e.g. more humane workgroup layouts or space plans); and
- better environmental performance (because the associated design and monitoring activities have carry-over effects on occupants' comfort, health and productivity).

It also needs to embed design issues in a much broader picture of technological and management consequences, with:
- strategic foresight in perceiving the right links between ends (such as business goals, staff satisfaction and energy efficiency) with the available means to meet those ends (e.g budget, cost, quality, and perceived constraints); and
- putting emphasis in the right places (on both ends and means, rather than just means as is often the case, or confusing the two by treating means as ends).

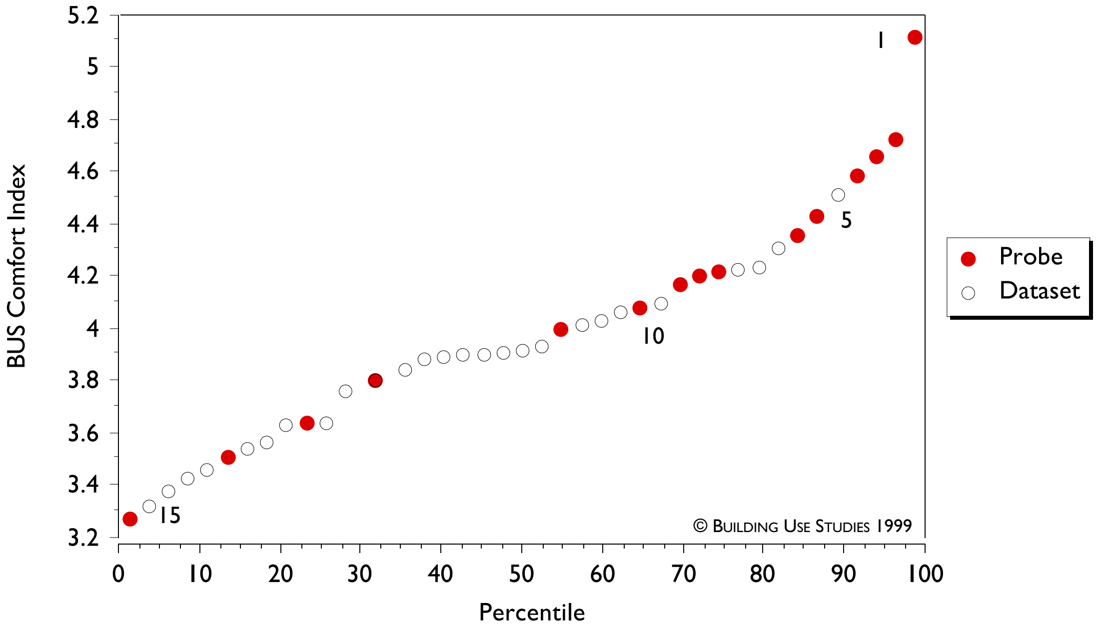
Because of volatility and the difficulty of predicting outcomes, strategic thinking in the early stages is particularly important, and especially
- a targeted strategy, preferably expressed in a well-structured, jargon-free brief; together with
- constant evaluation and re-evaluation of performance outcomes against objectives during design, handover and occupation; and, most vital of all
- a programme of reality checks throughout the design process protects the occupants' interests, by keeping ends in view.

If buildings put means (e.g. higher space densities; natural ventilation; or open planning) before broader ends and performance criteria (e.g, productivity; energy efficiency, adaptive comfort, or a more open culture); there can be revengeful problems later on. Difficulties often arise not so much from 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.

Noise is an important illustration of this in action. Only in Probe's cellular buildings (FRY and WMC) was it under good control from the occupants' point of view. Cellularisation delivers privacy and freedom from distraction, but cuts people off from each other. Increasingly, clients and designers perceive that the benefits of greater communication (and associated higher occupant densities) can be traded off against lack of privacy. In some cases the risk is low - as at MBO and HFS; in others very much higher - as at DMQ, where academic staff were moved from cellular offices into crowded, insecure and poorly-furnished open areas. Although outcomes are mostly predictable, lack of foresight at the briefing stage, and poor evaluation procedures, mean that solutions are seldom checked against likely outcomes.

Designers and clients also tend to assume that technology will take care of the basics, whilst imposing little or no burden on facilities management. Our experience is the opposite: added technology requires increased management vigilance; and if not properly managed can reduce a building's overall effectiveness. Probe's findings suggest that thoughtful simplification could make many buildings more appropriate for a wide range of uses; and deliver all-round benefits in occupant satisfaction, environmental efficiency, productivity and cost-effectiveness. On the other hand, complex, but very well managed buildings will be the appropriate solution for other needs: in practice, however, we have found that only a small proportion of occupiers find themselves able to afford and to justify the levels of management that such buildings demand.

Figure 6.1 Comfort index showing Probe buildings and BUS dataset

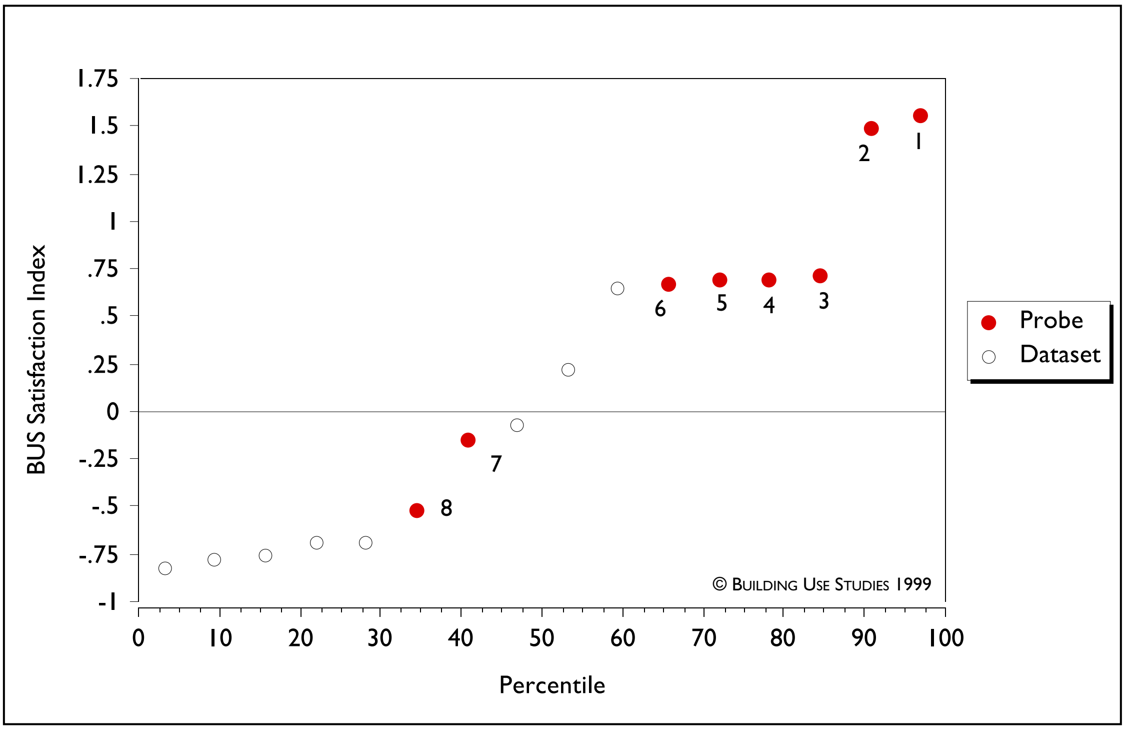


Comfort index score

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 6.2 Satisfaction index showing Probe buildings and BUS dataset

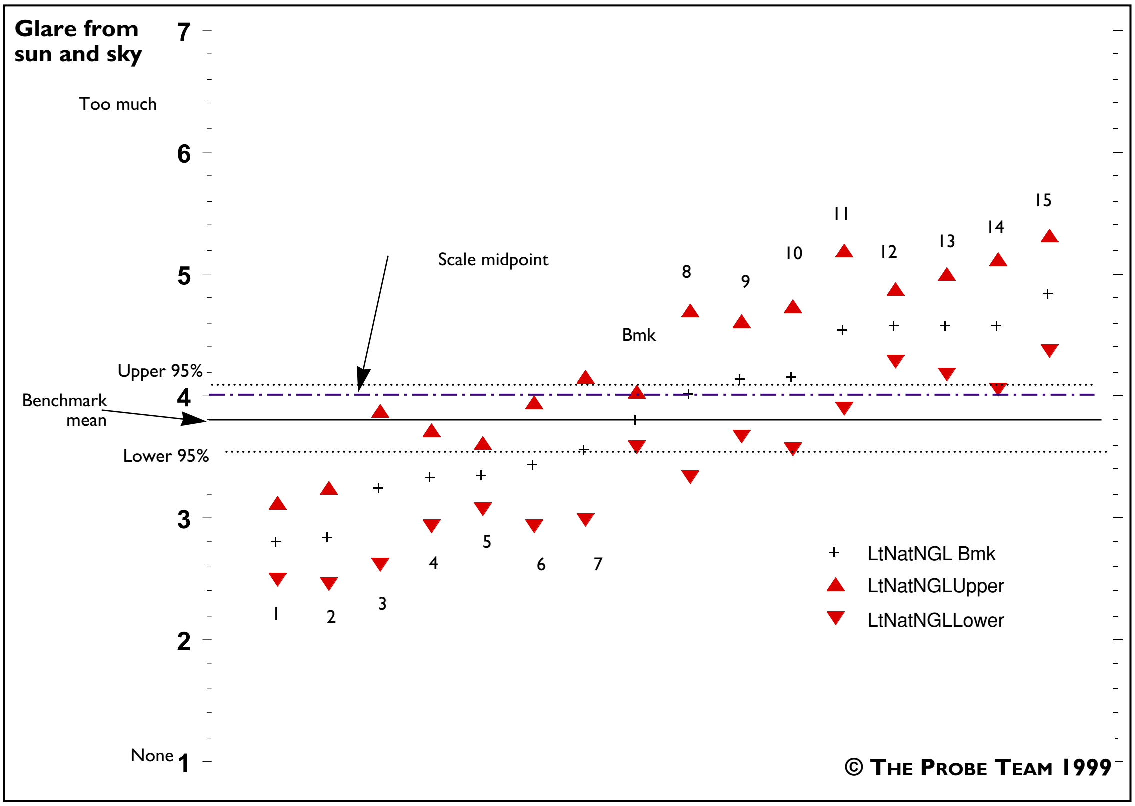


Satisfaction index score

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 6.3 Benchmark example for glare from sun and sky



Key to buildings

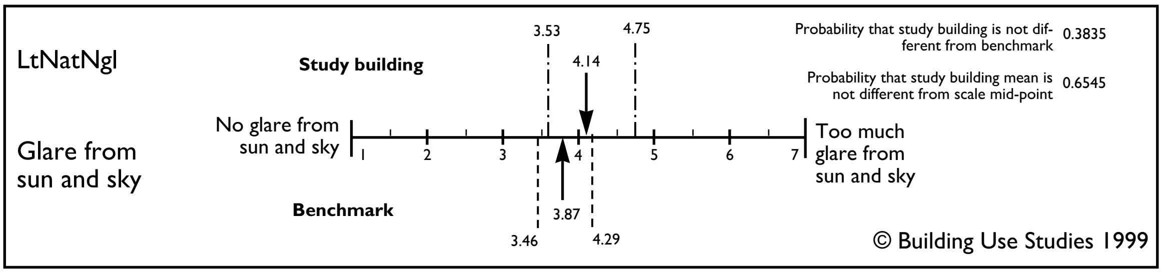
1.	CRS	8.	RMC
2.	ALD	9.	DMQ
3.	WMC	10.	POR
4.	HFS	11.	MBO
5.	TAN	12	CAF
6.	C&G	13.	CAB
7.	FRY	14.	C&W
	Benchmark	15.	APU

Notes

Upper and lower ninety-five per cent confidence intervals are shown for 1) individual building means; 2) Building Use Studies dataset benchmark for 50 buildings.

A building mean is significantly different from the benchmark mean if the mean value falls outside the interval range for the benchmark mean. A building mean is significantly different from another building if its mean value falls outside the interval range for that building.

Figure 6.4 Benchmark example for glare from sun and sky (top) and overall comfort (bottom) showing single study building and benchmarks



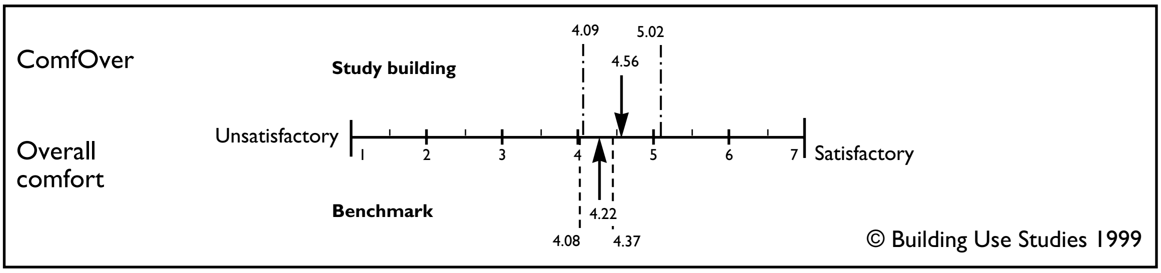


Figure 6.5 **Perceived productivity ratings: Probe buildings**

	Productivity ratings
WMC	10.9
TAN	8.0
MBO	7.1
CAB	6.3
FRY	6.2
POR	4.8
HFS	2.1
RMC	1.8
CRS	1.1
Scale midpoint	0.0
Benchmark	-2.6
CAF	-3.5
ALD	-4.2
APU	-5.6
C&W	-8.1
DMQ	-10.0
C&G	No data
	Plus or minus %

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Figure 6.6 Quickness and comfort: BUS dataset

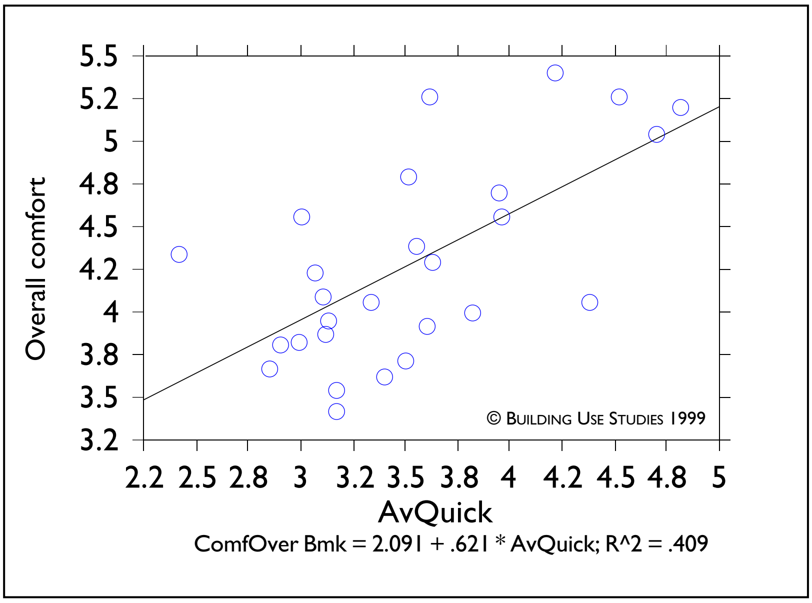

Figure 6.6 Speed of response and comfort: BUS dataset

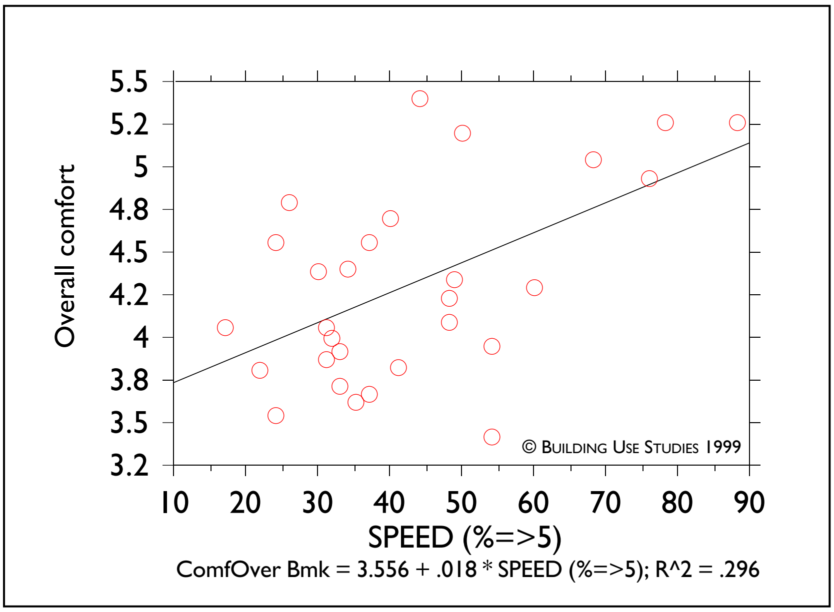

Figure 6.7 **Perceived control ratings: Probe buildings**

	Control ratings
WMC	4.4
Scale mid point	4.0
RMC	3.9
FRY	3.4
POR	3.4
CAB	3.2
C&W	3.0
DMQ	2.9
CAF	2.9
MBO	2.7
Benchmark	2.6
APU	2.3
CRS	1.7
TAN	1.7
ALD	1.6
HFS	1.3
© Building Use Studies 1999	Average based on 5 rating scores: Scale 1=No control; 7=Full

Figure 6.8 **: Lighting and overall comfort: BUS dataset and Probe buildings**

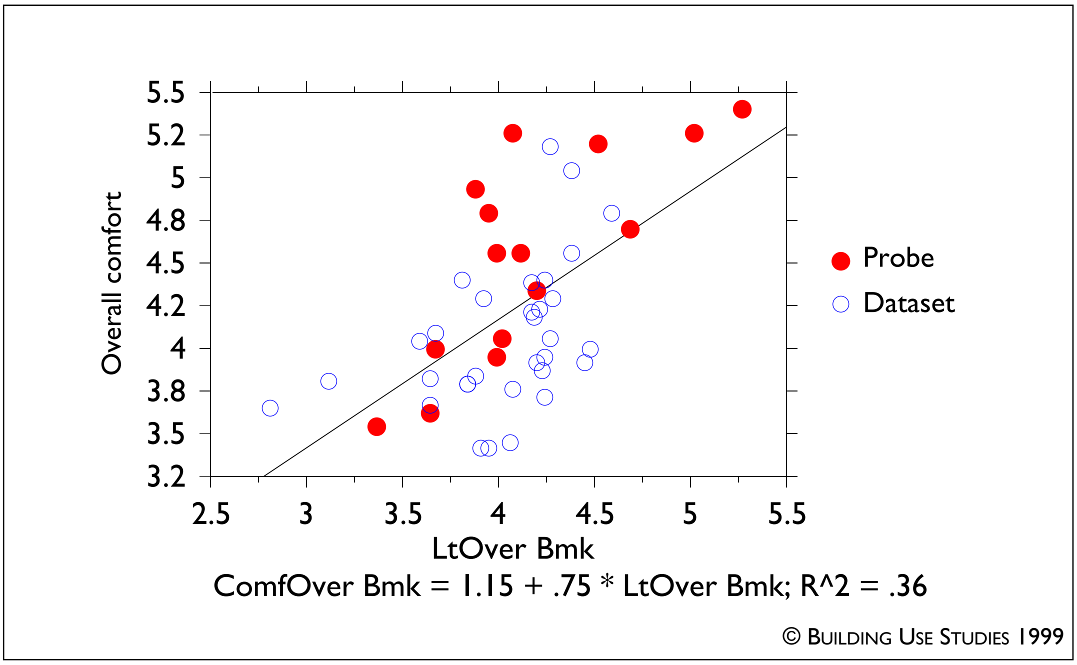

Figure 6.9 **Perceived lighting ratings: Probe buildings**

	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 6.10 **Differences in ratings of natural and artificial light: 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 6.11 **Perceived noise 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 6.12 **Staff satisfaction and noise: 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 6.13 **Noise and perceived productivity: 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 6.14 Perceived quickness of response: Probe buildings

	Average quickness
RMC	4.8
WMC	4.5
FRY	4.2
Scale midpoint	4.0
POR	4.0
CAB	3.9
CAF	3.8
TAN	3.6
MBO	3.5
Benchmark	3.5
C&W	3.4
DMQ	3.3
APU	3.2
ALD	3.1
CRS	3.0
HFS	2.4
C&G	No data

Average based on 5 rating scores: Scale 1=No response 7=Very quick response

7 OVERALL CONCLUSIONS 1: FACTORS FOR SUCCESS

7.0 This section outlines some unifying strategic messages from Probe: things which have helped to buildings to be all-round successes, and pitfalls to be avoided. The main themes are:

1 *Occupants like buildings that can respond to them.* Robust solutions in which people can get themselves out of trouble can work better than optimum - but more fragile - ones.
2 *Don't procure what you can't manage.* Buildings which overtax their management tend to have shortcomings in technical performance and occupant satisfaction.
3 *Comfortable buildings can be energy-efficient.* The two can go together, but not automatically: they have to be made to do so. Good briefing, good design, careful execution with attention to detail, and good management produces good results.
4 *Get the essentials right.* Innovations need to be built on firm foundations. Seemingly minor aspects can have major effects - for good or ill - on final outcomes. Things need to be kept simple and intrinsically efficient; and done well, with potential downsides minimised.
5 *Buildings are more like ships than cars.* While as much as possible should be got right first time, some things will need fine-tuning. A "sea trials" period will often be necessary.
6 *Promote virtuous circles.* Otherwise buildings will go into circles of decline.
7 *Review everything.* Don't lose sight of strategic objectives, or critical details. Use feedback to learn from your own experiences and from the pioneers of new techniques[20].

7.1 THEME 1. OCCUPANTS LIKE BUILDINGS THAT CAN RESPOND TO THEM

Figure 7.1 shows overall occupant survey scores for comfort by ventilation type in Probe and the BUS reference database[21]. The Probe buildings tend to be above average for comfort; and hence health & productivity - see Section 6 and Report 3. The top 15% of the sample contains six Probes and one other building. The four highest-scoring buildings were all Probes: two MM (FRY and RMC), two AC (TAN and C&G), followed by one MM reference and two NV buildings (MBO and WMC). With the top 15% containing two Probe examples of each HVAC type, there is clearly no technical panacea: good outcomes result where the building, its systems and its management are well-matched to the requirements of the occupants, the brief and the site.

The NV Probe buildings, MBO (with some ANV features in its manually-operated motorised windows) and WMC (with some MM features with its abandoned background mechanical ventilation and two added comfort cooling units) were relatively small and simple, as indeed was the MM FRY. These buildings contained many of the success factors discussed in Report 3:

- shallower plan forms
- cellular offices (in MBO and FRY)
- thermal mass (particularly in FRY, but all had solid walls with modest window areas)
- openable windows
- non-sedentary workforce (in WMC; and many in FRY going out teaching and on fieldwork)
- low VDU usage (particularly in WMC)
- usable controls and interfaces (with some limitations, in particular lighting controls at MBO)
- clearly defined occupancy patterns
- responsive management (but these buildings were also largely self-managing).

To some extent they were therefore pushing at an open door.

Deeper plan buildings, with larger workgroups, higher densities, greater mixes of activities, and complex technologies pose more problems for their occupiers, designers, managers and users. In spite of this, all Probe's AC buildings were in the top half of the distribution; with the very deep-plan TAN coming out best. This is a surprising turnaround, given the bad press that studies in the 1980s gave such buildings for health and comfort. This trend was identified in Probe 1: it seemed that clients, designers and managers had become aware of the problems and striven to improve performance. Most importantly, facilities and engineering management in the best AC buildings (TAN and C&G) was particularly well-resourced, knowledgeable and responsive. However, most organisations would not regard such high levels of support as affordable.

MM can sometimes bring the best of both worlds, more modestly serviced than AC; more responsive to occupant needs without depending upon management; and lower in energy use. Surveys [19] also indicate that occupants prefer buildings in which they can open windows if they feel they need to, but which have mechanical cooling available for extreme conditions. However, close integration of natural and mechanical systems needs care in both design and management.

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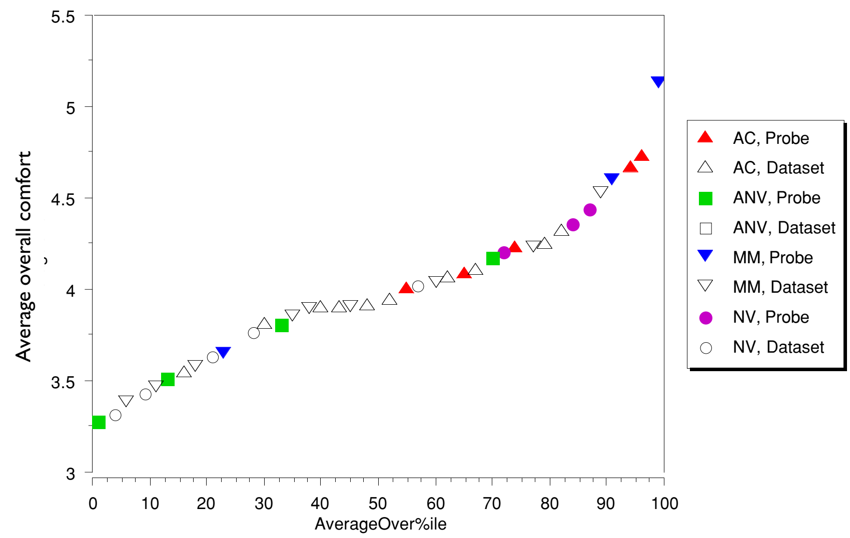
20 *Fools say they learn by experience. I prefer to profit by others' experience.* Bismarck.
21 The fifty most recently surveyed buildings, including Probe, covering the past 4-5 years of BUS surveys.

Figure 7.1 **Overall occupant survey scores for comfort by ventilation type**
Probe and BUS reference database



Notes to Figure 7.1

Average Overall score
A score based on the average scores of the following seven summary variables.

TSOver	Summer temperature
TWOver	Winter temperature
AirSOver	Summer air quality
AirWOver	Winter air quality
LtOver	Lighting
NseOver	Noise
ComfOver	Overall comfort

Average Overall percentile
A percentile based on the Average Overall score.

Example
TAN scores an average of 4.73 on the seven summary variables. When converted to a percentile this evaluates to 97. Thus TAN is in the top 5% of the dataset by this criterion.

Scales
Type A. Best on right

Ventilation types

NV	Natural
ANV	Advanced natural
MM	Mixed mode
AC	Air conditioned

Interpretation
For the average percentile variable, all dataset buildings have been a) ranked into order from worse to best (left to right on bottom axis); b) split into four ventilation types c) plotted showing rank against average percentile. The buildings in the top right of the graph are "best" by these criteria.

Probe's ANV buildings (there are none in the reference dataset) were not as good at satisfying their permanent occupants. Probe has been accused of casting a slur on these pioneers of a promising ventilation type, while Probe's intention - as for all the buildings studied - has been to provide early feedback on successes, and on problems which need to be addressed[22]. For ANV these include:

- Applying NV in intrinsically difficult situations, as identified three paragraphs above.
- Assuming that this new technology will be "right first time" and not allowing for fine tuning.
- Little management attention devoted by the occupiers (often in the educational sector).
- Difficulties in getting controls to work well, or to suit the occupants, see also below.
- Sometimes locating permanent occupants in the less attractive parts of buildings which had been designed with an eye to impressing visitors.

These buildings are innovative, and need care. Being closer to the edge of the performance envelope, they are more critically dependent upon the correct functioning of all their components, and in particular the controls. Consequently their occupants are more sensitive to shortcomings.

Occupant responses can be particularly influenced by annoying events: things that goes wrong which they can do nothing about. The design aspiration is often to seek good conditions in which nothing will go wrong. However, complex situations in buildings make some local clashes virtually inevitable, e.g. between noise and ventilation; or daylight and glare. The unexpected can also happen (e.g light reflected off a glass partition onto a computer screen). Occupants then need to get themselves out of trouble. The best buildings avoid getting into trouble too often, but also have abilities to respond quickly and reasonably well when they do. This response is often best left to individual action: if this is not possible, fast management response can also give good results. Complaints occur where a dependency culture is created, but management or system response is slow or non existent. Worse still, if automatic control action has itself created the problem[23]. Downside minimisation is also important for technical systems generally, see section 7.4.

7.2 THEME 2. DON'T PROCURE WHAT YOU CAN'T MANAGE

Probe and other studies have found that buildings can easily demand more than their occupants and management are prepared to give. If the management is overburdened, there will inevitably be shortcomings in performance, which tend to surface as reduced occupant satisfaction and/or energy wastage. Designers will respond that occupants do not devote enough time and skill to using, managing, operating and maintaining their building and systems. However, if a visit by the lighting controls supplier costs as much as the annual energy spend on lighting, what is an occupier to do?

An underlying cause of this mismatch is often poor communication and false expectations: the occupier has not defined the level of management they regard as reasonable; and the designers have not made clear the level of support the building is likely to demand. For example, technology is often proposed to answer a management problem, while the possible downsides and the vigilance and expenditure required to look after it are not discussed in depth. Designers - who naturally have a lot of interest in and understanding of buildings - also find it difficult to appreciate that occupiers may quite reasonably lack that insight and commitment. Indeed, most occupiers want to take their buildings for granted so that they can get on with their lives and their businesses.

Figure 7.2 summarises the situation. Buildings can be more or less demanding (usually through technological complexity) and have more or less management.

- Type A - a demanding building with well-resourced management - can be an excellent solution for organisations for which this enhances their corporate image; and which regard the extra management as an investment in their staff and their business. These are however rare.
- Type B suits most occupiers better: simpler, less demanding buildings which don't get in the way. This is easiest to do at a more domestic scale - as at WMC, MBO and the offices in FRY - but it also has wider lessons in examining briefing requirements and design responses.
- Type C is the hole that many buildings fall into, e.g. the "sick" AC buildings of the 1980s, often belonging to public sector organisations which could not provide the necessary levels of support within their budget allocations; and were organisationally unable to increase budgets by making value-added arguments based on, say, increased staff productivity. Probe's ANV educational buildings suffered similar under-resourcing. Even the now-excellent FRY did not perform optimally until after independent monitoring had identified the need for attention.

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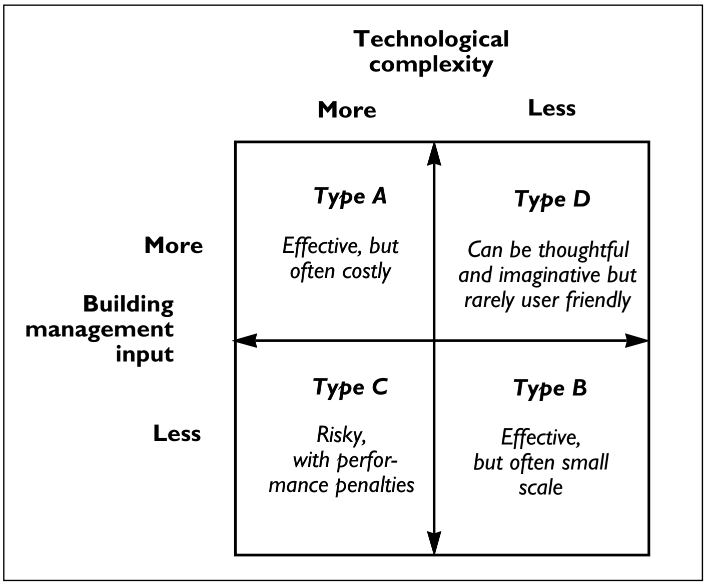
22 "Direct experience is inherently too limited to form an adequate foundation either for theory or for application. ... The greater value of indirect experience lies in its greater variety and extent." B H Liddell Hart, Strategy, London: Faber & Faber (1954), reprinted New York: Meridian (1991), page 3.

23 For example, if a motorised window which has no local user over-ride facilities opens automatically to lower temperatures but also causes a draught, or lets in noise and fumes (as at APU); or if lighting controls operate capriciously.

Figure 7.2 Briefing strategies



- Type D is rare, typified perhaps by designers in their own houses or offices, where high levels of insight and commitment can sometimes make systems which are thoughtful, imaginative, but not necessarily user-friendly perform extremely well - but only in the hands of their originators or similar enthusiasts.

Clients and their design teams must take account of manageability: the occupiers' capabilities to manage a building and its engineering systems; and provide solutions to suit. They should also seek to limit the adverse consequences if the management is not up to the standard anticipated.

7.3 THEME 3. COMFORTABLE BUILDINGS CAN BE ENERGY EFFICIENT

There is little direct relationship between comfort and energy efficiency, but an important indirect one, in that good management of the procurement of a building and its subsequent operation can help to deliver simultaneous comfort, energy and organisational benefits. In Probe:

- Type A. C&G had got closest to combining comfort and energy efficiency in an intensively-managed building, but even they were wary of anything which might threaten the levels of service to occupants. C&G was also easier to run than the other, more innovative, AC buildings; so used the least energy in spite of its less advanced specification: a lesson perhaps in avoiding complication. TAN was the most intensively managed, but at the time of Probe it regarded its energy costs as reasonable, so energy efficiency was low on the management agenda. However, after the Probe report, TAN's management's devotion to monitoring and improvement (Themes 7 and 6) picked up on the issues raised, see reference [22].
- Type B is epitomised by WMC, designed to be intrinsically low energy and low management. Interestingly, the only unusual piece of active technology here - the background mechanical ventilation heat recovery system - had defeated the occupants and fallen into disuse. WMC also demonstrated the great difficulty of undertaking even the simplest alterations after completion: here by nobody getting round to adding remote controls (rods, cords or motors) to the roof windows. FRY could easily have become a Type C, but was transformed into a Type B after management had taken account of the results of the monitoring, had been prepared to upgrade the controls, and had taken the time to learn how to run the building.
- Most of the other buildings fell more squarely into the Type C category, and so were unable to achieve high levels of comfort and energy efficiency at the same time.
- There were no Type Ds in Probe. Good examples of these might well deliver the highest levels of perceived comfort for the least energy, but would be unlikely to be widely replicable.

7.4 THEME 4. GET THE ESSENTIALS RIGHT

In the past, relatively inefficient services have often operated for unnecessarily long hours to support unnecessarily high loads created by thoughtless or inefficient design and use of the fabric or supporting unnecessarily uneconomical equipment which is left on too much. In moving towards sustainability, we need to seek:

- reductions in loads - through more efficient and better-controlled fabric and equipment;
- gentle engineering, with improvements in effectiveness, efficiency and control; and
- close matches between demand and supply, seeking where possible to use information rather than energy to achieve the required conditions with minimum waste.

Several Probe buildings appeared to have over-reached themselves in seeking excellent performance in some respects while at the same time having overlooked essential features, or becoming too complicated for their management and occupants. Repeated problems included:

- unwanted air infiltration undermining both comfort and energy efficiency;
- inappropriate control interfaces, for example for windows, lighting and ANV;
- high costs of looking after unfamiliar technologies, e.g. ice storage; and
- depriving occupants of opportunities for personal control, not only over environmental systems but often also over fine-tuning their working positions, so increasing their dependency on the building's infrastructure and its management.

Often minor shortcomings led to disproportionate reductions in performance. In hindsight, minimising the downsides often seemed to be more important to good outcomes than optimising the potential benefits, particularly where the optimum was itself fragile. "Keep it simple and do it well" is a good initial message, seeking robust solutions which do not require too much vigilance, and getting the basics right. A thermally good, airtight fabric, high efficiency plant and usable controls should be regarded as essential items, not dispensable options.

Figure 7.3 Real-world research

Solving problems	… *rather than* …	Just gaining knowledge
Predicting effects	… *rather than* …	Finding causes
Looking for robust results and concern for actionable factors	… *rather than* …	Statistical relationships between variables
Developing and testing services	… *rather than* …	Developing and testing theories
Field	… *rather than* …	Laboratory
Outside organisation (eg business)	… *rather than* …	Research institution
Strict time and cost constraints	… *rather than* …	R&D environment
Researchers with wide-ranging skills	… *rather than* …	Highly specific skills
Multiple method	… *rather than* …	Single method
Oriented to client	… *rather than* …	Oriented to academic peers
Viewed as dubious by some academics	… *rather than* …	High academic prestige

Source: Adapted from Box 1.2 of Robson R., Real-world Research London, Blackwell, 1993.

7.5 THEME 5. BUILDINGS ARE MORE LIKE SHIPS THAN CARS

Few buildings roll off the production line having been designed, prototyped, tested and refined over a substantial period. Most are built individually to a site, context, design and specification which may be similar to previous buildings, but is seldom identical. New techniques and technologies promise major benefits, but in practice seldom immediately. People will need to get used to them, and there will always be "bugs", emergent properties, and unintended consequences - termed "revenge effects" by Tenner [15]. This was particularly apparent with ANV and with lighting controls. The sensitivity of displacement ventilation to poor airtightness was also exposed at HFS. Concentration on the upsides can also hide the downsides: for instance displacement ventilation can reduce cooling requirements, but the air needs more preheating; and occupancy sensors, which turn lights off when they are not needed, can easily turn them on when they are not wanted!

Feedback is therefore essential, particularly in buildings which are largely - and often necessarily - customised products for which the prototypes are built and occupied. To date the industry has been slow at learning from experiences of buildings in use because it does not get very close to its user clients. Indeed, the service normally stops at the practical completion stage, apart from attendance to "defects", which themselves can be difficult to get remedied where causes are unclear, because anyone who attempts to tackle a problem is likely to end up being blamed for it!

As a result, while major and minor defects will eventually be identified and dealt with, low-level chronic problems seldom receive the attention they deserve, unless they are pursued by an enthusiastic individual; an influential repeat client; or are revealed in research. Research feedback can be very slow in relation to the rate of change: there is relatively little of it; it takes a long time; and it is often more concerned with finding single-issue causes rather than seeking factors for success in complex dynamic situations. Buildings in use are prime candidates for "real world research", as discussed by Robson [20], see figure 7.3.

For many products, technical innovations - although relatively expensive and unreliable - are seized upon by early adopters, either as trendsetters or because the new technology and performance offers them real rewards in relation to the high levels of expense and effort they devote to using, supporting and upgrading them. Once the technology becomes more mature, it attracts later adopters, who are less interested in the technology itself, or in its performance (if any alternative now does the job tolerably well); and more in solutions, convenience, appearance, and price. Figure 7.4, from [21] illustrates the process.

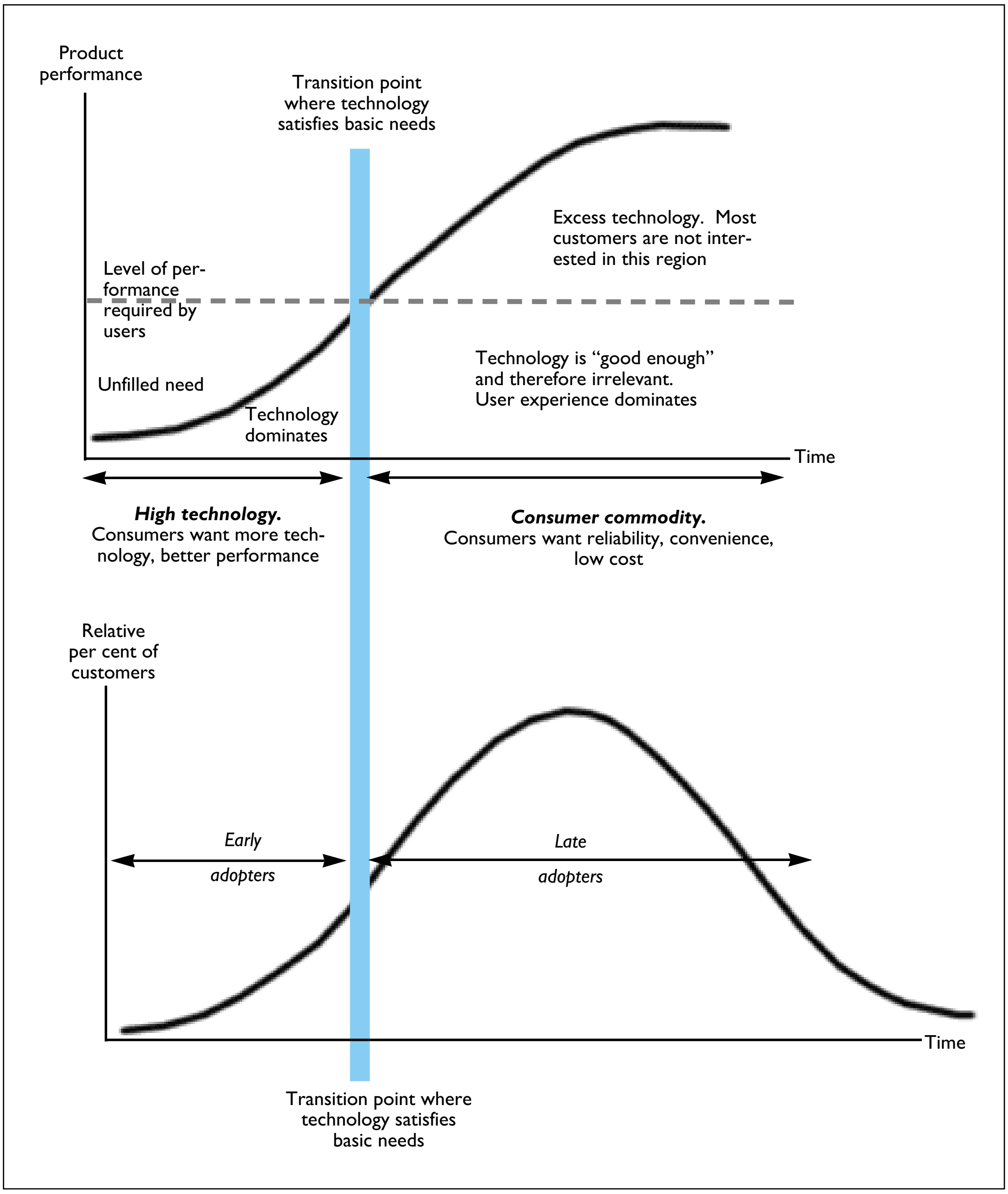
Buildings are different. Very few occupiers want to adopt a new building-related technology and then to dedicate extra time, money and effort to nurture it. Most seek instant, cost effective solutions and convenience, for buildings making the gap in figure 7.4 very far to the left; particularly in the speculative market where the user is unknown This characteristic is important to grasp if one is to bring the benefits of innovation in buildings rapidly to the market in a usable form. More robust, more standardised, better-researched and more usable and manageable solutions are part of the answer.

While as much as possible should be got "right first time", for many buildings - and particularly for elements such as their services which respond dynamically - it is entirely reasonable to expect a period of "sea trials" following initial commissioning and beyond practical completion so that:

- systems can be fine-tuned (as at FRY);
- problems can be identified and tackled more quickly;
- there is better mutual understanding between the providers and users of buildings;
- rapid feedback is obtained, both for the parties involved and for more general benefit.

This will all contribute to virtuous circles of continuous improvement.

Figure 7.4 The transition in technology take-up



Source: D Norman, The Invisible Computer, p35, MIT Press (1999)

7.6 THEME 6. PROMOTE VIRTUOUS CIRCLES

Good buildings are made by processes which work well, with effective relationships between the design and building teams and the commissioning and user clients, as illustrated by figure 7.5 for the situation in FRY. This will include clear strategies for:

- the ends (what the building does for the end user);
- the means (the building itself, and the way in which it is finally operated and managed); and
- monitoring and feedback, to keep on target; or to modify the course or the target if necessary.

Clear ends, means, benchmarks and feedback and review systems will help to establish and keep projects in virtuous circles of continuous improvement. Post-occupancy surveys such as Probe are of course part of this feedback. Careful review and feedback must also occur during briefing, design and construction. These topics are discussed further in Section 8.

Sometimes, of course, the user client will not come onto the scene until the building is completed. However, the same process still applies: the commissioning client and the design and building team should anticipate the needs of the users and the likely capabilities of their management to the maximum extent possible. An incoming tenant should also apply the same kind of thinking when considering how suitable a building is likely to be to their requirements, and what may need to be done operationally as well as physically in order to adapt themselves to it.

7.7 THEME 7. REVIEW EVERYTHING

Probe and its antecedents have shown that little can be taken for granted. It is important not to lose sight of strategic objectives, or of critical details. For example, buildings are not necessarily airtight, plant efficient, or controls usable or effective: these features may mistakenly be taken for granted, but they have to be made that way. Too often, clients make what turn out to be unwarranted assumptions about the design team's approach, and designers may not try hard enough to understand the client's culture, resources and outlook (often they may not be asked, encouraged or paid to). The result can be black holes in the brief, with little attention given to what turn out to be crucial dysfunctions (like noisiness or poor airtightness). In use too, few things are completely "fit and forget"; they also need to be operated, maintained, reviewed and checked, see Section 8.3.

The best results tend to be where monitoring and feedback forms part of the culture: this fuels the virtuous circles discussed in Section 7.6. However, feedback is not always well-embedded in many processes affecting the procurement and use of buildings, hence the relative novelty of an exercise like Probe. Missing feedback is also widespread at other levels, from strategic reviews and usability checks of briefs, through to contractual requirements for outsourced services, which - for example - seldom include energy-related criteria, be it for running a kitchen or maintaining plant.

Why is feedback so often absent? Because only exceptional clients and design practices conceive of buildings as total systems; many just look through their own particular window, seeing only a part of the total picture. As a result few take ownership of quality control, and all the consequential responsibilities such as defects databases, good practice feedback and benchmark data management[24].

The sad fact is that hardly any architectural or engineering design practices consistently collect information on whether or not their buildings work, and none make the information available in the public domain. All this despite clear evidence that managed feedback produces better buildings. Many argue that current fee arrangements, conditions of appointment, forms of contract, and professional indemnity insurance requirements do not allow this to happen.

"Who pays?" is usually the first question posed, and in this respect - as for many systemic problems in the building industry - there has been poor support by tightly-focused commercial interests and professional institutions. While government has recognised the problems, it too has found it difficult to escape from the focused agendas of industry (and indeed academics) and a pervading culture which is more concerned with cost than value. The current Egan initiative provides an opportunity to change the process and to add better all-round value; but to do so it will need to become well-informed on how buildings really work and where true value needs to be added.

24 Inappropriate outsourcing of support services may also sever feedback loops and divorce occupiers from valuable information which could help them to improve performance and satisfaction in their existing and future buildings.

In recent years, and in many fields, there has been considerable interest in performance indicators. While monitoring and benchmarking is important, sadly the indicators can too easily become ends in themselves, rather than aids to understanding and assessment of contributors to performance in different contexts. For example, designers are often asked to achieve certain nett:gross floor area ratios, even though (for instance) this may make the plant inappropriate or difficult to maintain. Similarly, a quest for increased occupancy densities may occur with little regard to assessing the satisfaction of the occupants; even though the costs of dissatisfaction or operational inefficiency could be very much higher than the savings from the higher space efficiency.

On the energy side, performance indicators do not yet seem to be acting as very efficient engines for improvement. It is perfectly normal for UK buildings to use much more energy than their designers predicted. In most cases very little then happens. Partly this is because energy is not a high priority at today's low fuel costs. There are also problems of communication between briefing, design, modelling, construction and operation; but without such a vocabulary it is not easy to have a productive dialogue about energy use and its root causes between all parties involved. For example:

- Few clients formulate their requirements in explicit terms.
- Where designers calculate and present energy figures for options, these are normally in an aggregated form, typically kWh (sometimes not even by each separate fuel), £, or kg CO_2 per square metre per year; and tend to be most often used to differentiate between options.
- The input parameters to the above calculations are normally based on usage and efficiency assumptions which are seldom made explicit and to which the client cannot easily relate.
- Much modelling and prediction takes little account of true plant and control performance; or of occupant and management behaviour.
- Frequently modelling reports energy use by HVAC only, or HVAC and lighting, perhaps with a rule-of-thumb allowance for equipment and appliances. Many other things which use energy in a building - from control systems to kitchens and computer rooms - are simply not counted; but this may not become clear until the building is in use.

Consequently, not only are many assumptions not checked; but in the process of design and client dialogue many issues can easily be overlooked; or battles lost. For example:

- Depending on a building's geometry, the installed power density (IPD)[25] of the lighting may need to be increased significantly to meet a designated illuminance standard at all points. A small relaxation in standard or area covered could permit significant cost and energy savings. The option is not volunteered because IPD standards have not previously been discussed, or targets set.
- An efficient light source or luminaire may be rejected as too expensive, but what if the alternative did not meet the project's IPD target? At the very least there should be a discussion of the trade-offs between luminaire performance, costs, and lighting standards. Usually there is none.
- Air transport is frequently a high energy user, but specific fan power is seldom discussed; or even estimated.
- Hours of operation assumptions often take no account of, say, cleaning or night working; or electricity use by equipment left overnight, legitimately or otherwise; or of the tendencies of central systems to default to ON in support of small local demands.

Probe team members have found the "tree diagram" approach [11, 12 and figure 7.6] to be a valuable aid to getting to the roots of energy use in undertaking surveys. We think that this approach could also be used creatively in developing a language for briefing, design and performance evaluation and reporting. However simple or sophisticated the energy calculation, each end-use can be summarised in terms of:

- the standards to be adopted (e.g. litres/sec of ventilation per square metre);
- the efficiency of plant and equipment (e.g. J/litre for fans);
- the annual hours of operation (this can vary tremendously); and
- the means and effectiveness of control and management, which can also vary greatly.

Explicit discussion for each of these variables for each system or subsystem; and comparison with typical, good practice and advanced practice benchmarks could be highly rewarding and contribute to better briefing, design, specification, installation, evaluation and management. The values could also be used to provide input values for regulatory procedures such as the proposed EPIM.

25 The installed power density (IPD) of a service, in Watts per square metre, is the total electrical load in the area concerned, divided by the floor area. It can be a useful guide, and can be applied to end-uses other than lighting. For instance the electrical demands (and heat output from office equipment is usually stated this way.

8 OVERALL CONCLUSIONS 2: ENDS, MEANS AND FEEDBACK

8.1 INTRODUCTION

How can the results and strategic findings of Probe be used in practical ways to help improve buildings and their performance and help to avoid the oversights, vicious circles, and unintended consequences which commonly occur? In three words, ends, means and feedback:

- The ends are about what buildings are for. In the broadest terms, social, cultural, economic and environmental benefits (and preferably long term ones); improve health, safety and comfort; and also raise the spirits. Where possible, these benefits should be enjoyed by the wider community and not just their occupiers.
- Proposals for new buildings and refurbishments need to stand up to scrutiny as realistic and practical means and not as ends. What they are like (not just physically but operationally); what they give to and demand from their occupiers and the wider environment; and what support services they require.
- Feedback, review and benchmarking monitors the appropriateness of the ends and the effectiveness of the means; and allows them to be constantly evaluated and readjusted in the light of experience, to suit changing circumstances, minimise risk, and permit continuous improvement. Yet again, benchmark comparisons must be regarded as a means of reviewing progress and planning improvements, and not as ends in themselves.

It is vital to integrate space, time and performance issues, to design for usability and manageability, and to know who owns which problems. Often one finds too much concentration on the means (the building) than on the benefits it will bring to the occupiers; and what it will demand of them. Consequently there can be a loss of grip on overall mission. Expectations of buildings by clients, designers and occupants can easily be unrealistic, with unresolved problems “parked” in the areas of greatest ignorance. Examples are enthusiasm about the promises of new technology, but not assessing possible downside risks; relying too much on management without considering the effort and costs involved; and not addressing possible needs for fine-tune once a building is occupied.

This chapter runs through “The Probe Nine”: three aspects each aimed at clarifying the ends; examining the means; and setting up feedback mechanisms to review and link between the two. The points are summarised in Figure 8.1.

- On the left are the ends. This is where the commissioning client and user client usually stand.
- On the right are the means: the buildings and the designers, contractors, suppliers and others who provide and service them. In a design situation, often the focus falls too rapidly on the building as an end in itself, rather than the means to the occupier’s ends. For instance, the solution may go spatial too early, or seek to adopt a particular technology before its relevance and appropriateness has been fully examined.
- In the middle are linking tools based on feedback, helping to build bridges between the ends and the means; the demand-side and the supply-side.

8.2 Ends: the client agenda

1. STRATEGY FIRST

Obvious, but easily forgotten. In wishing to procure, alter or select a building, clients must concentrate on what they want of it, and what it can deliver for them. A building can bring business benefits in many ways, for example:

- in a better location for staff, logistics or communications;
- as a more efficient, productive, or inspiring facility;
- in demonstrating the values of the organisation to its staff, its customers, and the public.

Frequently, however, ends get confused with means. Client requirements get expressed almost entirely in property market terms: sizes, occupation densities, technical systems, cost levels. While these values are useful indicators of the building’s characteristics and the client’s expectations, they are not the ends themselves; and their relevance and importance will vary with context. For example too stern a requirement to achieve a certain occupation density or nett:gross ratio - or to adopt a particular form of servicing - can easily get in the way of a good building or an effective alteration.

Today’s occupiers also often hope to change their culture by occupying a new building. However, they can trust too much in the building doing this for them, while it has to be carefully planned. Organisations today often have mission statements for themselves, but seldom for their buildings.

Figure 8.1 Ends, means and feedback and means with nine Probe pointers.

ENDS ←	LINKING TOOLS	→ MEANS
What are buildings for?	***How can feedback make things better?***	***Is the response realistic and practical?***
The public interest: health, safety, social benefits. *The triple bottom line: people, business, environment.* *Added value: joy, humanity, delight.*	*Methods of linking clients, service providers and regulation to improve understanding, products and performance in an environment of socio-technical change.*	*Agendas for:* *- designers and providers of buildings and components;* *- providers of outsourced services*
STRATEGY FIRST Don't confuse means and ends. Define what you are about as an organisation. Be clear in the brief about objectives, performance and risk levels. Beware of property criteria dominating too much.	**KEEP HOLD OF REALITY** Manage the brief. Prescription should not trump performance. Identify and minimise downsides. Question everything, undertake: reviews and reality checks.	**GET REAL ABOUT CONTEXT** Identify constraints (site, budget, culture …). Consider requirements, risk, relevance. Work to the occupiers' true capacities.
ESTABLISH THE ESSENTIALS What do you want to forget about? Seek good quality baseline requirements - essentials not just desirables. Don't procure what you can't manage.	**SHARE YOUR EXPERIENCES** Essential to learn on the job. Feedback internally and more widely. Mechanisms for disseminating attributable and unattributable items.	**OWN PROBLEMS, DON'T HIDE THEM** Tasks for the professionals. Tasks for the occupier's management. What can be reasonably left to individual occupants?
TARGETS ARE ALWAYS MOVING Constantly review objectives and solutions. Consider change, volatility, and risk, and seek robust solutions. Avoid vicious circles: seek continuous improvement. Beware that the cure may be worse than the disease.	**ADOPT OPEN SOURCE DATA** Benchmarking: start with basics. Measurement is key to effective results, but must be sensitive to context. Tag data with likely status. Cradle to grave monitoring and reporting.	**LESS CAN BE MORE** Make essential features of intrinsically efficient options. Seek simplicity. Beware of unnecessary technological complexity creating unwanted management burdens.

2. ESTABLISH THE ESSENTIALS

Part of the mission statement is to help occupiers to procure what they are prepared to manage. In Figure 7.2, is the occupier in the market for a Type A building, and prepared to work hard on looking after it for the potential rewards it will bring? Or would they prefer a Type B, which can be forgotten about as much as possible (though it may require some fine tuning and management education first)? Designers can easily both underestimate the effort actually required and overestimate the amount an occupier would be reasonably prepared to put in. Building briefs also need to set out the baseline requirements to achieve good environmental and energy performance. Qualities such as an airtight fabric, high standards of insulation, usable controls and high efficiency plant should be essential items, not desirable options.

3. TARGETS ARE ALWAYS MOVING

Hence the importance of flexibility and adaptability; together with monitoring to review where you are and what you want. Might the cure be worse than the disease? For example, flexible design solutions which appear to remove obstacles to change may exact revenge in the form of technical and management vigilance which is out of proportion to the benefits gained; or with the very features that provide the flexibility actually obstructing more radical change. “If in doubt leave it out (but provide elbow room in case you need to put it or something else back)” can be a useful maxim.

8.3 Means: the industry agenda

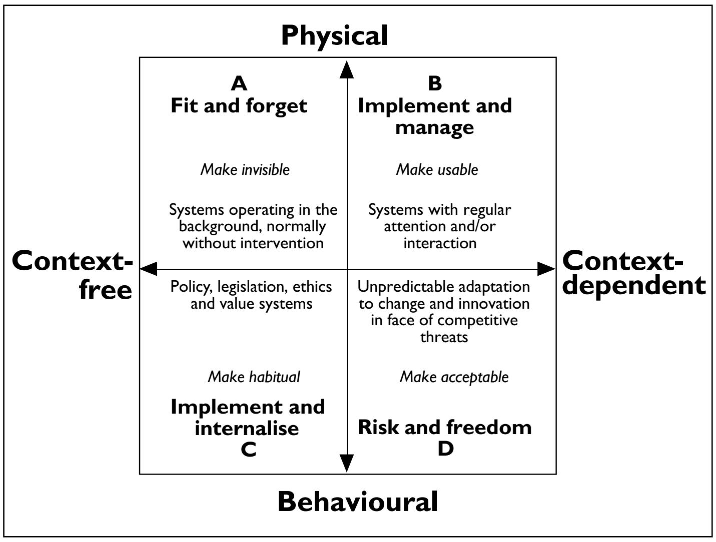
4. GET REAL ABOUT CONTEXT

Buildings, and particularly sustainable buildings, are about creating and responding to context: they provide an appropriate context for their occupants; they relate to their site and to their neighbours; and they make use of and modify the physical, business and social infrastructure. Providers of buildings need to respond to this and to the needs and requirements of the occupiers.

Figure 8.2 has proved useful in diagnosis. Its vertical axis Physical - Behavioural, and the horizontal axis Context-free - Context-sensitive divide the diagram into four quadrants.

- Top left is physical and context-free. This is where aspects of buildings can really be put into the “fit and forget” background. This can of course be constraining (e.g. columns in the wrong place); but well-done, it can be liberating if it provides an unobtrusive framework which helps to support and discipline everything that goes on inside the building. A design aim should be to put as much as reasonable into this category. For example, in improving energy efficiency, one should aim to do the load-avoiding (e.g. controlling air infiltration, not over-specifying) and intrinsic efficiency (e.g. condensing boilers, HF ballasts, low specific fan power) measures first. In reference [22], the client representative for (and subsequently premises manger of) the first Probe (Tanfield House), said; *“overall down-sizing of equipment which could be achieved with minimal risk to all concerned could have a dramatic effect on the build cost and running costs of any building”*.
- Top right is physical and context-dependent, i.e. it needs management to match provision with requirements. This includes operating plant, programming controls, or moving furniture around. The maxim here is to *make usable*. Unfortunately, here there are often shortcomings which are not exposed until the building is in operation, by which time - as Probe has shown - it can prove difficult to get even the trivial things done, let alone the fundamental ones. Hence the importance of considering the need for “sea trials”.
- Bottom left is behavioural and context-free, where people interact with each other and the building. Buildings tend to be most successful where they fit in with and support normal habitual behaviour. Unfamiliarity can lead to difficulties, particularly if how a system (or even one device) works is neither well-explained, nor intuitively obvious, nor readily explicable; not applied consistently. More discussion is required of the likely acceptability of novel features and, if appropriate, the ways in which they can be made clear to users. Ideally, they should be designed to be obvious, if not at first sight, then at least after they have been explained once [21]. If this is difficult, then standardisation should be considered.
- Bottom right is behavioural and context-dependent. Nobody can be sure exactly what is going to happen here, but the design and management should seek to make the outcomes acceptable. Clearly risks must be minimised, for example by combinations of fit and forget, fit and manage, and implement and internalise measures to assist safe escape in a fire. However, freedoms should not be ignored, for example, by seeking to give occupants opportunities to fine-tune their environment to avoid discomfort, rather than designing on the assumption that it will always be comfortable; and they will always be happy!

Figure 8.2: Four strategic requirements for excellence in building performance



Source: BORDASS, W. & LEAMAN, A, Design for Manageability, Building Research and Information Journal, May, 1997, No. 3

5. OWN PROBLEMS, DON'T HIDE THEM

Frequently difficulties arise because discussion between occupiers, providers, designers and builders has not been sufficiently clear about where the problems lie and whose problems they are. This can occur either during the procurement of a new building or major alterations, or when choosing and occupying space on the market. It can particularly affect assignment of problems between the building, its services, its occupants and its management. Use of benchmarks as ends can also create problems for the occupier, for example if one result of striving for an 80% nett:gross ratio is making the plant inaccessible and difficult to maintain (it may add to its installation costs too!).

While clients, reasonably enough, want the building team to solve building-related problems for them, there can be false expectations on both sides. Figure 8.2 can help in diagnosis: in short, the building team should aim to put as much as possible in the "fit and forget" box at the top left, while making clear to the client what their expectations of management and users are. At the same time, the client may be concerned with the bottom right hand corner: the robustness of the proposal and how the risks can be made acceptable. Chronic problems tend to occur when things which were expected to have been in the "fit and forget" box leak out, and there are no clear strategies in place to avoid or to deal with their effects. However, a certain amount of leakage will be inevitable, as social and technical change alters requirements and perspectives.

6 LESS CAN BE MORE

Probe indicates that unmanaged complexity (or certainly complication) can cause much dissatisfaction in buildings. Complex technology is often promoted as a means to reduce management costs, but is it a solution, or will it add yet more complication to a situation caused by unmanageable complexity in the first place? Similarly, sophisticated space plans and furniture systems may look good and fit extra people in, but they can also trap them and increase dependencies upon management.

We see four main ways in which complication can be dealt with:

- Avoidance. Is the complication really necessary? Will the extra feature really add value? Or is it nuisance technology, e.g. the ice storage at ALD and CRS; the BMS control at CAB; and the automatic lighting control at MBO?
- Resolution. Can the complication be limited to the physical and operational areas in which it is really needed, rather than being spread too widely about the building as, for example, when lights in individual WCs were switched on automatically at TAN - with no means of manual over-ride, and therefore defaulted to ON (not only wasting energy but also causing overheating).
- Packaging. Locking the complication up in a box, so to speak. This was clearest at FRY, where the complexity of the Termodeck system was largely locked-up physically in the plant rooms and operationally (after sea trials) in a well-understood BMS. The client was delighted with how little there was that needed attention in the rooms themselves.
- Management. Often seen as the first, but preferably the final port of call.

Usability and manageability can be the antidotes to complexity; but to achieve good, clear solutions can require a lot of thought, insight and discussion - which can mistakenly be regarded as unaffordable. One should try to put complication in the background where one can; and focus on occupant requirements without introducing unnecessary management-dependency. Building occupants are typically more comfortable and potentially more productive in environments which provide adaptive opportunities and rapid response. If they can be given the ability to do this by themselves, so much the better.

What makes for responsible innovation: innovation as a response to reality, not an escape from it? Innovations do not have to be technical: technology is the means, not the end. Innovations can also be about:

- Strategy. Helping to improve clarity of purpose.
- Process. Improving effective action.
- Product. Often seeking more robust, forgiving, gentle solutions, for example with power assistance, not dependence.
- Improving usability and manageability.

8.4 Linking tools

Linking tools can build bridges between commissioning and user clients, service providers, research and government in helping to improve understanding, service, products and performance in an environment of technical and social change. They can relate means better to ends, in particular by helping to keep schemes on target; and progress and success under constant review.

7. KEEP HOLD OF REALITY
It is no longer sufficient for most buildings to be precise responses to measured briefs: margins are required to adapt to uncertain change. The evolving solutions can in turn affect the brief. Design Brief Management therefore becomes necessary in order to keep the dialogue going: to test the developing solution against the requirements and vice-versa; taking proper account of the contextual factors which again can be influenced by the solutions which are under consideration.

An important aspect is reality-checking, for the client and the team to go through the proposals and to review whether they will deliver the benefits requested or offered, identifying and minimising the possible downsides, and determining the best means of delivering an effective solution. A useful tool to check any particular measure (or group of measures) is to use figure 8.2 in diagnosis: how much will they be fit-and-forget; and what are the likely implications for management and users?

8. SHARE YOUR EXPERIENCES
Feedback is key to learning faster. With today's rapidly-changing requirements, techniques and technologies, it is vital to learn on the job. The traditional research routes tend to be too slow. Experiences must be shared not only amongst the members of the team directly concerned, but with the wider community. Means of disseminating the good and the bad news may need to be somewhat different. People are usually happy to broadcast their successes (except where they are seen as trade secrets). However, failures and disappointments may require more discreet routes; though the Probe experience has shown that - at least in favourable circumstances - it is possible to publish studies which cover both the good and the bad points.

9. ADOPT OPEN SOURCE DATA
Measurement is the key to effective results, but frequently benchmarks are not well characterised (or responsive to changes in context). Different people also use different methods - with different levels of skill, accuracy and resolution - so it is important to tag data with its likely status, e.g. from rough estimate to audited result using an accredited standard techniques and definitions.

It can also be difficult to relate design predictions to briefing requirements and in-use data. For example, energy use and environmental performance is crucial to demonstrate success, identify shortcomings and facilitate control, but global energy targets in terms of kWh/m^2 per annum can be difficult concepts for clients and design teams, in which assumptions are too intermingled. Breaking these down into their constituent components - as in the tree diagrams of figure 7.5 - can provide a rapid and effective means by which the elements of energy use can be examined and communicated.

9 OVERALL CONCLUSIONS 3: WHAT NEXT?

9.1 INTRODUCTION

Probe has aimed to provide feedback to make buildings better: for people, for the environment, for business, and as good investments. It has revealed relatively straightforward things that can be done to improve value rapidly by using strategy, feedback, management and benchmarking to achieve better performance. It has also shown that some aspects of performance improvement which look simple in principle will require careful attention to be resolved successfully in practice.

These messages are particularly relevant to initiatives currently underway to improve the performance of buildings, and in particular:

- The Egan report, of which the recommendations are now being expanded and implemented through the Movement for Innovation and the Construction Best Practice Programme.
- The Kyoto protocol, with legally binding treaty agreements upon governments to reduce their greenhouse gas emissions.
- An increasing concern by industry and government about human productivity in buildings, which is also linked to occupant satisfaction, health and well-being.
- A sharper focus by occupiers on cost and value in buildings.

If feedback is not properly developed, ends and means may continue to be confused; features promoted which do not necessarily add value (and certainly not unless they are better supported and their performance better understood); and the industry and its clients will be unnecessarily slow to exploit and build upon successes, while chronic problems will persist uncorrected.

There are good reasons for tackling the chronic low-level problems - in particular the improvements to occupant satisfaction and business and environmental performance - but the "real"market drivers of time, money and business and property market agendas have tended to ignore them:

- Energy has been cheap, so not really worth worrying about.
- The effect of occupants' gripes on efficiency and productivity have not been appreciated.
- Adverse environmental impacts could be exported onto others with impunity.
- The costs of management have not been factored into the argument.
- An obsession with cost rather than value has meant that essential but invisible features have been ignored - or not regarded as affordable, while expensive (and often marginal) but visible features have sometimes been incorporated.
- The increasing pressures on businesses to deliver results quickly, with resultant short-termism, often amplified politically.

It can also take a long time for occupiers to discover whether a building is delivering good value.

There has also been a tendency to divide and rule amongst professions (and indeed academics), helping to support their individual interests and topic areas, rather than pursuing approaches based on improving overall social, environmental and economic need, and how buildings and their use can best help to bring this about. This has been reinforced by woeful underfunding of trans-disciplinary research which crosses the boundaries between subject areas, professional interests, and the different parties involved in creating, altering and using buildings; and which connects with real-world outcomes and decisions, rather than theories and models. The increasing influence of management theorists and design gurus, who offer quick and simple solutions but may not be alert to contexts or outcomes, can also make things worse.

Given this background, it is understandable that the property industry and its advisers have been more concerned with immediate returns and rental levels, rather than longer term value. This behaviour has been reinforced by customers - often also advised by the property industry - who have not been able to find effective ways of identifying the attributes of buildings which deliver genuine improvements. Features which add (or subtract) value have therefore not been valued properly in the marketplace, and customers often pay for (or think they can't afford) features rather than better functionality. It is therefore important to make achieved performance more visible.

Solving the chronic problems also requires changes in practice, which often affect several different players. If they cannot agree on common goals, problems will tend to occur. In addition, and especially before an approach or technique has become standard, there will be added costs - in thinking time if not in later expenditure - for example in making the building airtight, the plant intrinsically efficient, the controls usable and manageable, and undertaking the necessary sea trials. So what should be essential features end up being regarded as too difficult and not affordable!

This uncomfortable message from a price-driven system can no longer be ignored. We cannot afford to continue offloading such inefficiencies onto people and the environment. The Egan/Kyoto focus on improving the efficiency of the building industry and the economic and environmental performance of its products will need to include technical and process improvement and innovation to tackle the chronic problems. This will then feed through to better value on the triple bottom line, with positive benefits for business efficiency, occupant satisfaction, & environmental performance.

Our tasks therefore lie in:
- Clear understanding of ends and objectives.
- Tuning the means to suit the ends.
- Better methods of using and sharing data, including feedback and benchmarking.
- An open approach of the building team and its clients in helping to do this.
- Encouragement and support by government in achieving socially responsible buildings.

9.2 FUTURE ACTIONS BY THE PROBE TEAM

While this report was being written, the Probe team was advised that their application for funding for Probe 3 under DETR's Partners in Innovation programme had been successful, subject to amendments to bring it more into line with policy objectives. In additional to four more Probe surveys, Probe 3 will include up to four "intervention studies", in which the Probe team will provide advice to buildings at various stages in their life cycles. The resulting effect (if any) will be evaluated and commented upon. Intervention studies may include:
- Commenting on the brief and initial proposals for a building which is about to be designed, and a review of any effects this had on the subsequent design.
- Commenting on the scheme design for a building which is about to move into the production information stage, and a review of the extent to which this affected the subsequent development of the detailed design and specification.
- A study of an existing building for a client planning a similar new building or major alteration, and a review of the effect of this feedback on the brief and the outline proposals.
- A re-visit to a building surveyed in Probe 1 or 2, a review of any alterations and improvements made to the building, its use and its management since then; an action plan for further improvements; and a revisit to assess the consequences of the actions taken.

In addition, DETR has asked the Probe team to seek opportunities to disseminate the results of the Probe studies and this review more widely, in order to deliver "real improvements". In preparation for this, meetings are currently being held with a variety of organisations and professional bodies to establish agenda items for future activities either with - or with the benefit of material produced by - the Probe team. More detailed dissemination activities are proposed in Appendix C.

9.3 FUTURE ACTIONS BY OTHERS

We are often asked to summarise the findings of Probe and to tell people what they should be doing ... and all in a few bullet points! This is an impossible task, owing to the amount of information produced, and the wide variety of perspectives on it. However:
- Section 7 has identified seven ways in which buildings could be made more successful.
- Section 8 suggested nine ways to clarify ends and means and make effective use of feedback.
- Figure 9.1 attempts to extract the key points from Sections 4 to 6, which in turn have been extracted and developed from the survey results in Reports 2 and 3. This gives an idea of how the implications can ripple out to affect all the parties involved.

We finish with a summary of what we see to be key early actions by these nine players, both individually and in collaboration.
1 Clients for development: developers, investors, owner occupiers and government.
2 All members of the design team.
3 Builders, general and specialist contractors and suppliers[26].
4 Property advisers, particularly when acting in the interests of the building occupier.
5 Occupier and user clients.
6 Facilities managers, both in-house and outsourced services.
7 Institutions for the building and design professions.
8 Government.
9 All stakeholders in meeting the UK'S Commitment to the Kyoto agreement to reduce greenhouse gas emissions.

26 Note, Probe has not investigated the construction process itself.

9.4 ACTIONS FOR THE VARIOUS PLAYERS

1. For clients who build. Establish clear ends and objectives, including about the business mission for your buildings. If also the occupier, be clear about your organisational culture, the constraints and changes affecting your business, and your attitudes to complexity and manageability. If not the occupier, make realistic assumptions about the likely priorities of potential occupiers, and the effects of social and technical change. Suggest quantitative benchmarks where possible, but take care that these are not slavishly used as ends in themselves. Seek to obtain good value at reasonable cost. Manage the brief and undertake reality checks on the developing design. Promote responsible innovation but be sure to allow appropriate resources for fine tuning.

2. For members of the design team. Don't turn means into ends: be sure that the characteristics of the building suit the requirements of commissioning and user clients. Set the right expectation levels and identify who owns what problems. Do not impose high risks and management burdens. Seek to understand more about how buildings and new ideas perform in use through feedback systems and involvement in sea trials and post-occupancy surveys. Seek intrinsic efficiency, and use fit-and-forget measures where practicable. Pay attention to usability and adaptive opportunities for occupants. Identify risks, and seek to minimise possible downsides and knock-on problems.

3. For builders, specialist contractors and suppliers. Establish "no surprises" industry standards which seek to avoid widespread problems such as unwanted air infiltration, poor access to services, and substitution of less efficient components and plant. Develop techniques and assured quality standards for functionality, usability and intrinsic efficiency. Provide effective after-sales support beyond handover, for example with provision for sea trials periods in standard contracts.

4. For property advisers. Learn from post-occupancy survey results to appreciate what adds real value for users. Promote this so that it is reflected in the relative commercial values of buildings, so encouraging people to feel it is worth investing in these measures. Develop benchmarks and review buildings against them, but don't let the benchmarks and the measures become ends in themselves.

5. For occupier clients. Be clear about your ends. Appraise premises fitout proposals for, usability, manageability, and appropriateness for your real needs. Seek estimates of energy use in a form that simplifies comparison with real performance. Undertake occupant surveys before and after occupying new space to identify the issues to be addressed, the success achieved, and items requiring further improvement. If also building or undertaking major alterations, see item 1 above. Set up suitable arrangements for facilities and energy management and support fine tuning and sea trial exercises. Avoid excessive dependency on professionals and service providers. If outsourcing services, make sure that you do not lose control of the feedback which can be the engine of continuous improvement. Make sure that suitable energy metering is present ... and monitored.

6. For facilities management. Appreciate the importance of rapid and effective response to occupant problems and complaints. Set up and manage feedback streams - both individually and as a profession - to help understand, compare and improve elements of building performance. Represent the client side more strongly in dialogues with the supply side of the industry.

7. For professional institutions. Improve collaboration and data sharing with common definitions so problems get tackled collectively[27]. Encourage post-occupancy feedback in normal professional practice and standard contracts, to give better service to its customers, and provide the necessary information on progress and performance to target future practice, research and development[28]. Develop cradle-to-grave benchmarking procedures which permit closer comparison between design estimation and performance in practice. Make real performance an essential part of education. Encourage rapid improvements in environmental performance through integrated policy statements, professional guidance, and good practice standards. Encourage competitions etc., to reward improvements in achieved performance and help to set new standards.

8. For government. Encourage measures which lead to all-round improvements (e.g. triple bottom lines) rather than single issues (e.g. improved cost-effectiveness; or energy saving). Expand the Egan agenda to deal with post-handover performance and feedback. Encourage transparent energy reporting and benchmarking and databasing of results, in order to assist improvement at all stages in a building's life cycle. Further energy issues are included in Appendix B.

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27 For example, problems of airtightness (which are now well known to services engineers) and the Egan agenda have so far made only a relatively small impact on architectural practice.

28 Support this real world information in your professional journals, as CIBSE has through Probe in its magazine.

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Mixed mode thermal control: high score for comfort, low energy consumption,
University of Sydney, Australia (1997).

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APPENDIX A
COMPLETE LIST OF PROBE POST-OCCUPANCY STUDY SERIES PAPERS IN BUILDING SERVICES JOURNAL (BSJ) & THE PROBE 1 CONFERENCE[29]

PROBE 1 BUILDING SURVEYS

P0 P Ruyssevelt, W Bordass and R Bunn
Probe - Post-occupancy review of building engineering, BSJ 14-16 (July 1995).
P1 W Bordass and A Leaman, *Probe 1: Tanfield House,* BSJ 38-41 (September 1995)
P2 M Standeven, R Cohen and W Bordass
Probe 2: 1 Aldermanbury Square, BSJ 29-33 (December 1995)
P3 M Standeven, R Cohen and W Bordass,
Probe 3: Cheltenham & Gloucester Chief Office, BSJ 31-34 (February 1996).
P4 R Asbridge and R Cohen
Probe 4: Queens Building, de Montfort University, BSJ 35-41 (April 1996).
P5 M Standeven and R Cohen, *Probe 5: Cable & Wireless College,* BSJ 35-39 (June 1996).
P6 M Standeven, R Cohen and A Leaman
Probe 6: Woodhouse Medical Centre, BSJ 35-39 (August 1996)
P7 W Bordass, A Leaman and J Field
Probe 7: Homeowners Friendly Society, BSJ 39-43 (October 1996).
P8 R Cohen, A Leaman, D Robinson and M Standeven
Probe 8: Queens Building, Anglia Polytechnic University, BSJ, 27-31 (December 1996).

PROBE 1 FINAL CONFERENCE
(Buildings in Use 1997, February 1997, papers available from CIBSE)

PC1 R Cohen, P Ruyssevelt, M Standeven, W Bordass and A Leaman
The Probe Method of Investigation.
PC2 W Bordass, R Cohen and M Standeven, *Technical Review: Probe Office Buildings.*
PC3 R Cohen, M Standeven and W Bordass, *Technical Review: Probe Non-office Buildings.*
PC4 A Leaman, W Bordass, R Cohen and M Standeven, *The Probe Occupant Surveys.*
PC5 W Bordass and A Leaman, *From Feedback to Strategy.*
PC6 R Bunn, *Real World Solutions*, BSJ 27-32 (April 1997).

PROBE 2 BUILDING SURVEYS

P11 M Standeven, R Cohen, W Bordass and A Leaman
Probe 11: John Cabot City Technology College, BSJ 37-42 (October 1997).
P12 M Standeven, R Cohen, W Bordass and A Leaman
Probe 12: Rotherham Magistrates Court, BSJ 25-30 (Dec 1997).
P13 M Standeven, R Cohen, W Bordass and A Leaman
Probe 13: Charities Aid Foundation, BSJ 33-39 (February 1998).
P14 M Standeven, R Cohen, W Bordass and A Leaman
Probe 14: Elizabeth Fry Building, BSJ 37-41 (April 1998).
P16 W Bordass, R Cohen, A Leaman and M Standeven
Probe 16: Marston Book Services, BSJ 27-32 (August 1998).
P17 W Bordass, R Cohen, A Leaman and M Standeven
Probe 17: Co-operative Retail Services HQ, BSJ 37-42 (Oct 1998).
P18 W Bordass, R Cohen, A Leaman and M Standeven
Probe 18: Portland Building, BSJ 35-40 (January 1999).

PROBE REVIEW ARTICLES IN BUILDING SERVICES JOURNAL (BSJ)

P9 W Bordass, R Cohen and M Standeven
Probe 9: Energy and Engineering Technical Review, BSJ, 37-41 (April 1997).
P10 A Leaman, *Probe 10: Occupancy Survey Analysis,* BSJ, 37-41 (May 1997).
P15 A Leaman and W Bordass
Probe 15: Productivity in buildings: The Killer Variables, BSJ, 41-43 (June 1998).
P15AR Bunn, *Probe feedback,* BSJ 44 (June 1998).
P19 Probe 19: *Designer feedback,* BSJ 35-38 (March 1999).

29 Many more review papers which have drawn upon this material have appeared in other national and international conferences, courses and publications. See also **www.usablebuildings.co.uk/Publications.html**

APPENDIX B - POSSIBLE NEW INITIATIVES TO REDUCE CARBON DIOXIDE EMISSIONS FROM PUBLIC AND COMMERCIAL BUILDINGS

While this report was being completed, the project officer asked for a list of possible new initiatives to reduce CO_2 emissions. The Probe Team's suggestions are reproduced below.

1 Integrated approach to energy awareness and management
Good energy performance and low CO_2 emissions should be sold not as ends in themselves but as essential attributes of responsible and well-managed organisations which meet business, social and environmental objectives. Tie into company reporting, environmental assessment and professional standards for managers, building professionals and outsourced services.

2 Cradle to grave benchmarking
Readily-understandable context-aware quantification of energy performance to help establish and communicate requirements, discuss options and review outcomes between all players: in briefing, design, modelling, regulation, specification, acceptance, tenant evaluation, in use and in research. Establishment of default values and advisory minimum, good practice and advanced practice standards. Tap into data streams of design and in-use information to certified quality standards and including contextual data. Track ownership of problems: context, requirements, design, construction, equipment, control, usage, management, maintenance?

3 Promoting essential features
A programme ("Have you got what it takes?") to encourage getting the simple things right,e.g:
Fabric: Getting the loads down: importance of integration and things other than insulation, viz glazing, thermal capacity and particularly air infiltration control.
Standards: Well-structured briefs. Seek efficiency and appropriateness without extravagance.
Services: Intrinsic efficiency, e.g. condensing boilers, HF lighting, low specific fan power.
Systems: Improving demand-responsiveness. Avoiding defaults-to-on and tail-wags-dog.
Controls: Designed for performance,usability and manageability, with good feedback.
Sea Trials: To get things working properly and to educate occupiers and the building industry.
Management:. For continuous improvement; plus requirements for outsourced services.
Properly integrated packages of measures,
aimed at stable, robust solutions which minimise unnecessary loads.
Seek endorsement from building professional institutions. Take programme to designers, builders, developers, occupiers, agents, investors and outsourced service providers.

4 Promoting efficiency in air conditioned buildings
Really a subset of the above, but may be worth pursuing separately because the more highly-serviced buildings tend to be the most energy-wasteful, but they often also have more capability of mobilising the management skills to sort things out. Include mixed mode alternatives to AC.

5 More effective metering (and meter reading)
- Possible requirement for registration of key data (viz: occupancy type, levels, floor area, exceptional end-uses).
- Regulator to require fuel suppliers to report annual consumption to all customers, possibly together with performance indicators (but this would need extra input data)..
- Above requirement to be based on true, not estimated readings.
- Promote sub-metering of high-intensity uses, viz: computer and communications rooms and (independently) their air-conditioning, catering kitchens, major process/plant items..

6 Office equipment energy efficiency
- Improve understanding of equipment energy use. Labelling and benchmarking.
- Encourage innovation and market awareness of equipment efficiency. Consider public sector competitive bulk procurement programme (viz NUTEK in Sweden).
- Avoiding "leaking electricity".

7 Responsible innovation programme
Keeping careful track on innovations in order to sort our problems, identify unintended consequences, minimise the downsides, and develop preliminary codes of practice (viz Agrement certificates?). Avoiding technical mirages and unmanageable complexity. Improving the functionality and usability of controls, especially lighting controls.

APPENDIX C: DISSEMINATION

This appendix discusses the dissemination of the results of Probe, including this review, and possible implications for the client for this review, DETR.

APPENDIX C
DISSEMINATION

CONTENTS

C1 Summary

Dissemination of research results is key to any initiative aimed at improving products and processes. The best media to use depends on the nature of the material, the target audience, and purpose of the information. The main recommendations for disseminating Probe material are as follows:

- DETR should give strong consideration to the publication of a Probe book or books, perhaps together with a searchable resource on CD.

- Careful thought should be given to packaging Probe Review material into workshops and seminars.

- DETR is strongly advised to consider how Probe could be reversed into the Egan initiative. Probe material could form the basis of at least two Key Performance Indicators: energy and occupant satisfaction.

- Messages from the Probe Review could be used to inform a series of best practice reports; and in the sponsorship of new or updated professional guidance.

- DETR should consider ways in which the main findings of the Probe review can be communicated to relevant Government departments, to assist in their procurement, occupation and management of buildings.

- DETR already publishes building performance material in various energy and environmental publications. It should consider combining these outputs into a single publication on building performance issues, closely linked to forms of electronic dissemination.

- Electronic publishing is very suitable for disseminating Probe material. A website with appropriate links to other construction and non-construction websites could be a cost effective method of disseminating Probe guidance across industry professions. DETR is urged to consider sponsorship of websites tailored to the target audience, perhaps produced in collaboration with industry bodies.

C2 Probe dissemination to date

C2.1 INTRODUCTION

Since 1995, Probe's findings of have been delivered, primarily to practising building services engineers via comprehensive articles in BSJ: Building Services Journal, the magazine of the Chartered Institution of Building Services Engineers. BSJ took the view that that a building's ultimate performance (and particularly occupant satisfaction and energy consumption) was critically dependent upon its building services, especially HVAC and lighting. Services engineers are also closely concerned with the design of the building envelope in terms of controlling solar gains, limiting heat losses and air infiltration. They also need products which are key to the correct operation of the services (e.g. ventilation openings) to be correctly detailed, specified and installed.

As CIBSE's official magazine, BSJ has a remit to inform, educate, and to provoke professional building services engineers to deliver of their best. Industry practitioners trust the magazine to deliver robust, honest and objective guidance. However, like other professional construction magazines, BSJ is forced to rely on information provided by architects and engineers. While this information may be honest and objective, it can rarely be verified owing to the lack of feedback in the construction industry, together with the lack of diagnostic tools and funding. In a construction culture which denies itself feedback, it is axiomatic that performance myths can be perpetuated over many project cycles before problems are identified.

Journalists are also limited to reporting catastrophic failures, whilst chronic under-performance goes unreported. BSJ recognised that this cycle needed to be broken. It must be recorded that the Probe initiative started out with a very modest objective - to identify the actual performance of building services installations and compare them with the claims made by the supply side at the point of building completion. However, the impact among construction professionals has been profound. The Probe project has spawned many seminars, conference papers, articles in other construction media, mentions in submissions to regulatory authorities, and latterly an industry-sponsored award for the best managed Probe building. After four years and sixteen building studies, the Probe acronym has now become a pan-institution expression of real-world research.

C2.2 FACTORS FOR SUCCESS

BSJ makes strenuous efforts to study a wide range of building types, from offices to schools to medical surgeries. The published Probe reports were kept as close as possible to the content of the technical reports produced by the investigative team. The use of emotive language was restrained, as was the urge to "dumb down" the data. The six pages of dense copy was not always an easy read, but BSJ's readers clearly persevered. Indeed, the breadth and depth of the articles engendered considerable trust in the veracity of the reporting. Value judgments were not totally absent, and readers were conditioned by the editor to expect slightly more anecdotal views in the box headed "design lessons". A succession of editorial leaders, plus one notable front cover, made it clear what the magazine thought of the results of particular Probe investigations. In spite of this, or perhaps because of the clear demarcation between straight reporting and editorial bias, the building owners and the original designers were not offended, and readers did not complain of being misled.

C2.3 OTHER OUTPUTS

By virtue of the 50% Contribution in Kind provided by BSJ, Probe output in other construction media has been limited. However, strong efforts have been made to publish material in non-competitive media, and many conference and seminar papers have been delivered by the Probe investigation team, largely at their own cost. BSJ's publisher, the Builder Group, also produces magazines for other sectors of the construction industry, notably Property Week (developers, property surveyors, letting agents), Building magazine (builders, construction firms, main contractors) and the RIBA Journal (registered architects). However, these magazines work to their own independent editorial agendas. A limited amount of Probe information has appeared in their pages; but - here as elsewhere - where Probe is reported by others, there has been a tendency to sensationalise, distort or "dumb down" the information. This has proved harmful to the investigative team and the building designers, and placed at risk client willingness to become involved with the Probe initiative.

On the other hand, the magazine of the British Institute of Facilities Management was invited to share the Probe findings with the proviso that the reports should be free from journalistic spin. The two resulting articles were factual, relevant and valuable in getting the key messages from Probe over to the facilities profession. However, two articles are hardly enough to raise high awareness of Probe amongst facilities managers.

C2.4 USE OF GRAPHIC MATERIAL

The graphics in BSJ were designed to meet the needs of both the casual reader while also providing enough detail for the specialist. Considerable effort was made to present the energy and occupancy data in an accessible form, and the graphics were revised for Probe 2 to improve the balance between statistical rigour and ease of understanding. The importance of good graphics to drive home Probe messages cannot be overstated. A single photograph of billowing smoke showing excessive building air leakage propelled the issue of uncontrolled infiltration to the top of the professional agenda and caused pressure testing to be added to the Probe 2 contract. The resulting clear and easily understood graphics played a key role in raising awareness and placing the Probe results immediately in context.

Each Probe article finishes off with a list of key design lessons, illustrated by photographs. These were distilled from the main report as a series of short, punchy statements, sometimes carefully infected with modest hyperbole and a little ironic humour as a slight antidote to the serious issues raised by the building investigation. The readership appreciated the effort, and people have said that they turn to this section first when reading the articles.

C3 Lessons for the future

C3.1 INTRODUCTION

The seminal and hitherto unique nature of Probe has been a great learning experience for all those involved. Courage was required by DETR, the sponsoring government department, in awarding a contract to a commercial magazine. The Probe investigation team, widely respected for their rigour, objectivity and professional standing, also placed a lot of faith in the magazine. In short, the Probe project proved the value of:

1 A public feedback process in construction

2 The creation of a tightly knit, professional and compact team with internal refereeing

3 Regular and rapid reporting

4 Identification of the buildings concerned

5 High public visibility of the research team

6. The Probe team's close proximity to industry

7 Flexibility of the Probe agenda, by all involved

8 Editorial freedom

9 Exemption from Crown Copyright

10 Truthful reporting. No injuries reported.

Some of these issues are discussed in more detail below.

C3.2 PUBLIC FEEDBACK

The Probe reports have been unique in that the buildings investigated were identified by name, as were the occupying organisations and the professional design team. Most research seeks to protect its sources of data: a laudable objective, but one which dissociates the results from their contexts. In buildings, however, context is often vital to engage the audience and to understand why certain events occur in complex situations with uncertain causal chains. In one context a technology or technique may be viable, in another it may not. For example, the more able the facilities management, the greater the chance that a complex system - such as ice storage - will function in line with the design intent.

Probe has also popularised feedback in construction. However, it is important that feedback processes in future are as public as possible, and that the contexts of any results are recognised. Sponsors of feedback should insist on open and interoperable datasets, including those generated by Probe. This inevitably tends towards a publicly accessible database where the contexts are properly described; the tools used to access the information clearly identified and detailed; data quality and reliability identified; and the boundary conditions of the research explained. Ideally, such a database should only receive data from accredited tools, for example EARM-OAM; the occupancy survey methods used by BUS and BRE; and other established conventions to present energy data, such as those used in ECON 19.

C3.3 REGULAR AND RAPID REPORTING

Research conducted by agencies, universities and institutions tends to rely on peer group review and rigorous control of the output in an attempt to preserve objectivity and eliminate inaccuracies. While this can make for a robust message, the penalties are sanitisation, delay in publication, and limited distribution of results. In today's rapidly-changing world, it is essential that feedback information is disseminated as rapidly as possible. Probe has demonstrated that commercial publishing can drive high quality research with rapid reporting. This has major implications for the ways in which DETR funded research could be disseminated in future.

Properly configured, the various media options open to government-funded research can help to drive research rather than be a passive recipient of it. What appears at first glance to be an illogical assertion does in fact make much sense, viz:

1 The success of the media depends on the level of engagement by the target audience, hence:

2 the disseminating mechanism is often closer to the practitioner than those involved in research.

3 The expert disseminator knows which information to present to the target audience, and how it should be presented.

4 Communication is a skill in short supply in research circles, particularly construction research.

5 In research circles, publication is often a surrogate for real communication - a confusion of ends and means. Indeed, funding usually stops at or before this stage. Hence many reports go unread and unused.

However, the legal aspects of open publication of attributable research results are delicate.

Dissemination of information generated by feedback needs to be tailored for the chosen media and target audiences. At the same time it must have strategic coherence, so that all parties involved in the production, use and operation of buildings can communicate effectively and move forward together. As has been demonstrated, the body or bodies responsible for presenting the information can successfully influence how the work is carried out. As feedback information is provided, the dissemination specialist(s) could repackage the information for paper and electronic dissemination, in a form appropriate to the target audience, without loss of credibility or accuracy. The DETR already publishes building performance material through various publications. It is suggested that it considers combining these outputs into a single publication covering building performance issues, which itself should be closely linked to forms of electronic dissemination.

C3.4 COPYRIGHT ISSUES

The waiver on Crown Copyright for the Probe project was a very important decision for the DETR, the magazine and the Probe team. Where challenges to publication arose (and there were fewer than might have been expected), the DETR was free from liability, so precious time was saved having to go through the formalities of legal checks, which otherwise might have ground the project to a halt. Similarly, the Probe investigation team were shielded by the magazine's libel insurance. That said the team's professional pride and internal checking systems played a great part in making sure the reports were defensible, and that any conclusions drawn were underpinned by additional information in the technical report.

The entire Probe Team recognise that editorial freedom played a major part in Probe's success, but it is a freedom to be bestowed with care. The technical team commented vigorously on the draft articles - in particular if any points were not fully supported by the facts - and the editor took these inputs very seriously. One might argue that a less professional magazine might take liberties with the release of Crown Copyright, and DETR should weigh up the pros and cons very carefully in any future collaboration with a commercial publisher. This is a further reason why DETR should reconsider its own routes to disseminating building performance and energy related information.

C4 Dissemination of findings from the strategic review

C4.1 DISSEMINATION OPTIONS

A variety of dissemination options for material Probe and the Strategic Review are open to DETR. All are mutually supportive:

1 Publication by the Builder Group

2 Publication directly by DETR

3 Publication of a series of best practice reports

4 Sponsorship of seminars and conferences (see C7)

5 Publication of a Probe textbook (see C8)

6 Promotion through construction and non-construction media

7 Sponsorship of pan-industry professional guidance (see C9)

8 Sponsorship of electronic or web-based information (see C11).

The Probe Strategic Review contract stipulates that The Builder Group, publishers of BSJ, should be given first option on publishing the results of the strategic review. The precise nature of publication is a matter for future discussion between The Builder Group and DETR. The following options are therefore expressed without prejudice to that contractual arrangement.

C4.2 DETR PUBLICATION

As DETR is client for the Probe strategic review, the reports are by definition public documents. However, it has been agreed that the interim technical reports will remain confidential, and the final reports will be available for release to named individuals at DETR's discretion. The main public domain outputs from the current project will be the refereed papers at the CIBSE conference and in the Building Research and Information Journal. Further options following completion of the project are outlined below.

C4.3 BEST PRACTICE REPORTS

There is strong justification for the Probe strategic findings being used to inform a series of best practice reports. These need not necessarily be targeted at construction professionals, indeed greater impact might well be achieved by targeting customers such as developers, surveyors, investors, occupiers and facilities managers. Strong consideration should be given to co-sponsorship with the relevant professional and representative bodies. The Probe Strategic Alliances project will generate more detailed advice to DETR on potential partnerships for such dissemination.

C4.5 ELECTRONIC PUBLISHING

The growth area of electronic publishing is very suitable for disseminating Probe material. The impact of a website with appropriate links to other construction and non-construction websites will depend strongly on the way the information is structured to suit specific audiences. The cost of tailoring the Probe information for electronic dissemination will inevitably be front-loaded, but it could be very cost effective over a long term, with good searching capabilities low capital costs for adding and updating information. The material can also be delivered on CD.

C4.6 PROMOTION THROUGH OTHER MEDIA

There is strong justification for disseminating information through other construction and non-construction media. For the supply side of the industry, this would cover textbooks, papers in refereed and industry journals, and seminars and conferences. For the demand side - client bodies, property developers, surveyors, local authorities etc. - it may be better to consider non-construction media . This could include newspaper and consumer magazine articles, slots in relevant television and radio programmes, and various forms of direct mailing.

Other mechanisms are also open to government to influence the use of Probe material. For instance, many building projects are funded by national lottery grants, which come with written conditions on how funds should be spent. This is also true of standard public sector contracts and PFI contracts. For example, the grant system operated by the Lottery Commission could be modified to disseminate Probe advice on achieving better building performance in use. The mandatory use of occupancy and energy surveys, the use of CIBSE TM22 techniques for reviewing both design and achieved energy performance, and fabric airtightness measures would all be appropriate. This would fit with the current initiative of joined-up government.

Dissemination through other construction and non-construction media (excluding web-based media) might include:

1 Advice on CD ROM with word search and context search functions leading to passages in the Strategic Review reports and related data items.

2 Sponsorship of revisions to professional guidance (e.g. CIBSE and RIBA and BIFM)

3 Sponsorship of revisions guidance by other bodies (e.g. BCO Specification for Offices, British Property Federation)

4 Import of Strategic Review lessons into the Key Performance Indicators, and perhaps a KPI based on occupant satisfaction, comfort and perceived productivity.

5 Co-sponsorship with industry bodies of a series of seminars and workshops.

These issues are dealt with separately below.

C4.7 SEMINARS, WORKSHOPS AND CONFERENCES

Probe has spawned a great many conference papers since its inception in 1995. BRECSU co-sponsored a Builder Group conference "Buildings in Use 1997", attended by 130 delegates, together with follow-up seminars at CIBSE . The seminars were successfully repeated in Scotland. Since then the Probe Team has been much in demand at conferences held by CIBSE, BIFM and the British Council for Offices, at University postgraduate courses, and overseas in Norway, Sweden, Holland and North America. This latter dissemination has been carried out at no extra cost to DETR; though some invitations have had to be declined for lack of funds, notably an invited keynote paper to the Green Building Challenge conference in Vancouver in October 1998. The inability to obtain additional funding for such items is one of the shortcomings of the current PII process. Careful thought needs to be given to packaging Probe Strategic Review material into workshops and seminars. Properly promoted, these events might even become self supporting.

Interest in hosting such events has been expressed by CIBSE, the Building Environmental Performance Analysis Club (BEPAC), and the Workplace Comfort Forum. DETR should consider a "Buildings in Use 2000" conference, perhaps a two-day event in collaboration with other Construction Best Practice initiatives. The Builder Group and Probe team members are currently considering how such conferences might be organised.

C4.8 PROBE BOOKS

The Probe Team consider that DETR give strong consideration to the publication of one or more Probe books or compilations. We see a market for two distinct and complementary publications:

1 A reprint of the first 16 Probe reports as published in BSJ, with an introductory section and some updated information. This would be a valuable sourcebook for professionals and for students of engineering, architecture, building and facilities management. The material could perhaps also be included in a searchable form on CD.

2 A second volume developed from material and conclusions in the strategic review. This would put across the strategic issues and detailed lessons in a crisp, clear and insightful form, and aimed as much at clients, developers and investors as at designers, builders and students.

C4.9 RESEARCH JOURNALS

As part of the Probe Strategic Review Project, papers on the Probe techniques and findings have already been submitted to the CIBSE National Conference 1999 and to Building Research and Information journal (BR&I). This more archival material, aimed at more international and academic audiences, will help to underpin the findings in the first two publications. The editor of BR&I has also offered to publish further papers.

C4.10 INFORMING PROFESSIONAL GUIDANCE

The Probe review has generated material of considerable value in professional design guidance. Mechanisms and agreements are needed with the construction institutions to export Probe findings into professional practice and best practice guidance material. The Probe Strategic Alliances initiative is currently working to solicit support from a number of professional bodies from which a selected few will be targeted for closer collaboration. These bodies include:

1. The British Council for Offices
2. The British Property Federation
3. The Chartered Institution of Building Services Engineers
4. The British Institute of Facilities Management
5. The Royal Institute of British Architects
6. The Construction Round Table
7. The Briefing Forum
8. The Workplace Comfort Forum
9. The Institution of Civil Engineers
10. The Energy Saving Trust
11. The Movement for Innovation.

These meetings are likely to generate ideas for further dissemination.

C4.11 INFORMING GOVERNMENT POLICY

DETR is strongly advised to consider how Probe could be reversed into the Egan initiative, so helping to joint it up with the Government's sustainability agenda. Probe material might easily form the basis of KPIs for property owners and estate managers, particularly those who have environmental obligations, e.g. under Agenda 21. Two KPIs would be possible in the short term: one for energy use and carbon emissions; and one for occupant satisfaction, comfort and perceived productivity. It will be important to separate the contributions to these KPIs from the building itself and from its management. The KPIs could have strong links with a graded building performance award scheme, not dissimilar to the BREEAM certification levels. Currently, BSJ runs an annual Probe Award as part of the prestigious Building Services Awards: this award could be raised in profile if government sponsored, and possibly part of the larger benchmarking scheme. The Probe Strategic Review findings also have strong relevance to the Building Regulations. DETR is advised to consider which of the Probe findings might be reflected in future regulation.