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Assessing building performance in use 5: Conclusions and implications

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This final paper reviews the implications of the Probe post-occupancy survey project (methods and findings have been discussed in Papers 1 to 4). Recent pressures to improve the UK building industry and its products have so far focused on production and not performance in use. Feedback, however, reveals successes which are not immediately apparent even to experts (when newly completed, the best all-round performer in Probe did not make the shortlist for an environmental award), and that innovations can easily have unintended consequences. Meanwhile, persistent chronic low-level problems need to be tackled if we are move towards the triple bottom line of more sustainable practice and create a base of sound practice upon which innovations can flourish. Factors for success include

making sure essential features are in place; seeking simplicity, usability, manageability and responsiveness; identifying and managing downside risks; a culture of feedback with better benchmarking and constant review against client and design intentions; and more involvement of the supply side in improving and learning from the performance of buildings in use. Seven main themes are explored and initial actions suggested for the key industry players, clients and government.

Keywords: post-occupancy feedback, benchmarks, chronic problems, factors for success, continuous improvement, United Kingdom.

Introduction

The Probe project has shown that one can undertake and publish a series of post-occupancy surveys of named buildings. It has helped to increase the awareness of the building industry and its clients of factors for success in building performance, and to where things can go wrong. It has proved timely, as the UK building industry is now being asked to respond radically to pressures for improvement to product quality and delivery, sustainability, and business performance. The main drivers are sustainability and the Kyoto agreement; implementing the recommendations of "The Egan Report" [Construction Task Force 1998], and commercial competitiveness - seeking to reduce costs in use and add value through increased productivity.

Can Probe be reproduced? As described in Paper 1 [Cohen et al, 2000], its evolving techniques have become streamlined and standardised. However it still depends on a small team of highly experienced assessors. For Post-occupancy Evaluations (PoEs) to become more commonplace whilst maintaining their rigour and consistency, it will need commitment, effective training and accreditation programmes, with arrangements for collating high-quality survey information and maintaining benchmarks.

Figure 1 shows how PoE findings can be incorporated into strategies for procuring, occupying and managing buildings, helping to create virtuous circles of continuous improvement. Could clients, design and building teams do this routinely as a normal part of the follow-through on a project, so assisting rapid continuous improvement of building performance? So far there has been considerable interest but relatively little activity, for the following reasons:

- People can bite off more than they can chew, often asking for - and expecting to get - too much. Research can easily fail to deliver. Probe has been underpinned by three established methods - for occupant feedback, energy analysis and airtightness. So far it has not included, for example, space utilisation, costs-in-use, or aesthetics; all of which might be part of a fully-rounded PoE. Why? Because including them would have made the project unmanageable within the available resources; and because there were no tried-and-tested methods and benchmarks that we could rely upon.

- Professionals are wary of PoEs because they think that the findings - which inevitably bring both good and bad news - may not enhance their reputations. In fact, we usually find the reverse. Involvement in feedback can demonstrate to their own organisations, their peers and the outside world that they are seeking improvement by getting involved in understanding how the buildings they procure, design and manage really work for the users.

- Who pays for the survey? Probe has been paid for by the government and the publisher, with additional time given free by the occupiers of the buildings and the survey team. Similar - but unpublished - studies have been undertaken for owner clients and developers, but not in large numbers. Designers appear reluctant to fund PoEs.

- Who pays to implement the findings? The purpose of Probe has been to extract, through studies of specific buildings, findings that will interest the supply side of the industry - initially largely designers - and help them to build on successes and to address common shortcomings. Probes 1 and 2 had no funding to follow through into helping the occupiers to improve the performance of the buildings studied. In some the more intensively-managed buildings, they have done this themselves. In most of the others they have not, even though minor changes could sometimes have made significant improvements.

- Benchmarking. To be credible, PoEs need reasonably large samples of buildings, and yardsticks with which to compare them. This means a continuous programme of data gathering from the surveys and data management. It is easy to under-estimate the resources, ongoing diligence and quality control required to sustain such a programme of work.

There are major benefits in undertaking feedback routinely on every project, and ideally this would become commonplace. However, many generic issues have already emerged which can be tackled now. Papers 2 and 3 [Bordass et al 2000 a and b] on technical and energy performance, revealed that many buildings (even good ones) had recurrent problems - some relatively minor and correctable - which significantly increased energy consumption, or caused difficulties for management and occupants. Paper 4 [Leaman & Bordass, 2000] on the occupant surveys also revealed downward trends in thermal comfort, noise and perceived control; and misfits between the buildings now being produced and what occupants say they like. New techniques could have unintended consequences, and usability and manageability left much to be desired. Not only risks, but also success factors could easily be overlooked.

Many of Probe's findings support the results of earlier research, or ring true with anecdotal experience. Some say they reveal little new ... but if so, why have the earlier findings not led to improvement? Progress requires not just innovation (as some seem to think) but also steady consolidation and improvement: what is the point of "new" research findings if the old ones have not been acted upon? If we genuinely want better all-round performance, we must appreciate and tackle the chronic problems and create a base of sound practice. This paper identify some things which might be done in the way buildings are briefed, procured, designed, built, completed, operated and managed; to help overcome chronic problems and to exploit factors for success.

The positive messages from the buildings studied are that many solutions are not difficult to implement, and that improvements in occupant satisfaction, economic performance and sustainability do not have to conflict with each other, but can be mutually supportive contributors to the "triple bottom line", in virtuous circles of continuous improvement.

Factors for success

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

Seven unifying themes are examined below: things which have helped the buildings surveyed to be successful, and common pitfalls to be avoided. The evidence comes not only from the Probe buildings (for background and their three-letter codes see Table 1 of Paper 2 [Bordass et al 2000a]) but the authors' direct and indirect experience of other studies of buildings in use.

THEME 1. OCCUPANTS LIKE BUILDINGS THAT CAN RESPOND TO THEM

Figure 2 shows overall occupant survey scores for comfort by ventilation type in Probe and the reference database of Building Use Studies Ltd, who undertook the occupant surveys. The Probe buildings tend to be above average for comfort, health and productivity. The top 15% of the sample contains six Probes - two examples each each of air conditioning (AC), natural-ventilation (NV) and mixed-mode (MM) ventilation. This confirms that there is 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 (and the MM FRY) were relatively small, and their accommodation relatively simple; so containing many of the success factors discussed in Paper 4, in particular:

- 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
- largely self-managing, but with responsible management too.

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 of Probe's AC buildings were in the top 50% for occupant satisfaction; with the extremely deep-plan Tanfield House coming out best. Given the bad press that studies in the 1980s had given such buildings for health and comfort, this is a gratifying turnaround. It seems that good clients, designers and managers had become aware of the problems and striven to improve performance. In the best AC buildings studied in Probe, facilities and engineering management were also particularly well-resourced, knowledgeable and responsive to occupants' comments. However, most organisations did not regard such levels of support as affordable.

Mixed mode (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 [e.g. Rowe et al, 1997] 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, MM is no panacea either: effective integration of natural and mechanical systems needs care in both design and management.

The permanent occupants of Probe's advanced naturally-ventilated (ANV) buildings were generally less satisfied. Probe has been accused of casting a slur on these pioneers of a promising ventilation type, but the intention - as for all the buildings studied - has been to provide early feedback to the industry on successes, and on problems which need to be addressed. For ANV these include:

- Applying NV in intrinsically difficult situations, with fewer of the success factors identified three paragraphs above.
- Assuming that this new technology will be "right first time" and not making provision for fine tuning, which could sometimes be extensive and laborious.
- Little management attention devoted by the occupiers (mostly in the educational sector).
- Difficulties in getting controls to work well, or to suit the occupants.
- In addition, the ANV educational buildings had been designed to impress visitors. One consequence had been that the workstations of their permanent occupants tended not to be located in the most attractive and comfortable parts of the space. As in other buildings surveyed, the perceptions of students and visitors were usually more positive than those of permanent staff.

ANV 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.

A design often aspires to good conditions in which nothing will go wrong. However, complex situations in buildings make 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 out of trouble.

Occupant perceptions can be particularly influenced by annoying events they are able to do nothing about. No building should get occupants into trouble too often; but the best buildings also have the ability to respond quickly and reasonably well if problems arise. Ideally, the design should permit the individuals affected to take their own local action, but fast management response can also give good results. Complaints occur where a dependency culture is created, but in which management or system response is slow or non existent. Worse still, if automatic control action has itself created the problem (for example, if a motorised window with no local user over-ride facilities opens automatically to lower temperatures, but also causes a draught, or lets in noise, fumes or insects; or if lighting controls operate capriciously). Downside minimisation is also important for technical systems generally, see below.

THEME 2. DON'T PROCURE WHAT YOU CAN'T AFFORD TO MANAGE

Buildings can easily demand more than their occupants and management are prepared to supply. If management is overburdened, the symptoms of underperformance are very likely to come to the surface as occupant dissatisfaction and/or energy wastage. Designers will then say that occupiers do not devote enough time and skill to using, managing, operating and maintaining their building and systems. However, if a diagnosis by the lighting controls supplier costs as much as the annual spend on energy for lighting (as at MBO), what is an occupier to do?

An underlying cause of this mismatch is 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 can often be seen as the answer to a management problem, while its possible downsides and the vigilance and expenditure required to look after it are not discussed in depth. It can also be difficult for designers - who naturally have a great interest in and understanding of buildings - 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 3 illustrates this conclusion. 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 (e.g. TAN and C&G) - 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 (for example MBO and WMC) but it also has wider lessons in examining briefing requirements and design responses to see where simplification may be possible.

- Type C is the hole that many buildings fall into, e.g. the "sick" AC buildings of the 1980s. These often belonged to public sector organisations which could not provide the necessary levels of support; having budgets for maintenance and upkeep which could not be defended; and no ability as organisations to make value-added arguments for increased expenditure based on, say, increased staff productivity or better customer service. Probe's educational buildings - of which most also contained the innovative and unfamiliar ANV techniques - suffered similar under-resourcing; and indeed universities are constantly seeking to reduce labour-intensive support.

- Type D is rare, typified perhaps by designers in their own houses or offices, where high levels of insight and commitment can sometimes get systems which are thoughtful, imaginative, but not necessarily user-friendly to 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.

THEME 3. COMFORTABLE BUILDINGS CAN ALSO BE ENERGY EFFICIENT

There is little or no 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 bringing together comfort and energy efficiency in an intensively-managed head office, but even here senior management would not permit anything - e.g. the tighter levels of control which were technically possible - which might threaten the levels of service to occupants. C&G was also easier to run than the other, more innovative, AC offices; so used the least energy in spite of its more conventional specification: a lesson perhaps in avoiding complication. TAN was the most intensively managed, but when the Probe survey starter it regarded its energy costs as affordable, with efficiency low on its management agenda. However, the management - always seeking improvement - acted on the conclusions of the Probe report [Anon, 1997].

- Type B is epitomised by WMC, designed to be simple, and intrinsically low energy and low management. Interestingly, the only unusual piece of active technology here - the background mechanical ventilation heat recovery system - had fallen into disuse. WMC also demonstrated the difficulty of getting even the simplest alterations made after completion: in spite of overheating, nobody got round to adding remote controls (rods, cords or motors) to the roof windows. A “sea trials” period (see later) could have helped here and avoided the comfort cooling which the tenants had added in a few areas. Even the well-performing FRY could easily have become a Type C, but it was transformed into a Type B when management took account of the results of the independent monitoring, upgraded the controls, and spent the time to learn how to run the building; which then became almost self-managing after that.

- Most of the other buildings fell into the Type C category, and so tended to be either reasonably energy efficient and not very comfortable, or vice-versa.

- There were no Type Ds in Probe. Good examples of these might well deliver high levels of perceived comfort with very low energy use, but not be widely replicable to unskilled users.

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 or construction of the fabric, or supporting frequently uneconomical equipment which is left on too much. In moving towards sustainability, one should be seeking:

- reductions in loads - through more efficient and better-controlled fabric and equipment;
- gentle engineering, with improvements in effectiveness, efficiency and control; and
- closer matches between demand and supply, seeking where possible to use information and feedback rather than fossil 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 overlooking essential features; or getting 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 also, for example, by limiting their opportunities to alter their working positions - so increasing their dependency on the building's infrastructure and its management.

Minor shortcomings can lead to disproportionate reductions in performance. For good outcomes, it is often more important to minimise the downsides than to optimise the potential benefits, particularly where the optima are themselves 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.

For example, the design of RMC had been much concerned with effective use of passive solar heat gains to the sunspaces. In the event, the electricity used by the building's fans accounted for 20 times more carbon dioxide emissions than the design estimate of the solar heat to be recovered. In addition, recovering this heat almost certainly increased the fan power. Design attention to minimising annual energy use by the fans would have been more rewarding: a 50% reduction could well have been possible, at a similar or lower capital cost.

THEME 5. BUILDINGS ARE MORE LIKE SHIPS THAN CARS

It has often been said that the UK building industry should become more like the motor industry. Certainly the quality and initial reliability of cars has much improved and their supply chains have been streamlined. However, the analogy can only be taken so far, as Handy [1985] has discussed from the perspective of management style. Few buildings roll off the production line having been designed, prototyped, tested and refined over a substantial period. Most are responses to a site, context, design and specification which may be similar to previous buildings, but are seldom identical. The mix and match of design teams, procurement paths and contracts also varies. New techniques and technologies and more standardisation promise major benefits, but only after a period of development including post-occupancy feedback. People will need to get used to them, and there will always be "bugs", emergent properties, and unintended consequences - termed "revenge effects" by Tenner [1996]. In Probe this was particularly apparent with ANV, lighting controls, and the sensitivity of displacement ventilation to poor airtightness.

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; and distract and annoy people in the process.

Feedback of experience is therefore essential, particularly in buildings which are largely - and often necessarily - customised products of which the prototypes are built and occupied. To date the construction industry has been slow at learning from buildings in use because it does not get very close to its user clients. Indeed, the service normally stops at handover stage ("practical completion"), 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. With consumer products like cars, low-level chronic problems are much more likely to come to the attention of assiduous quality-control procedures ... though we are all personally aware of some persistent niggles. Research feedback in buildings 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 [1993], see figure 4.

For many products, technical innovations - although initially relatively expensive, unreliable , and difficult to use - 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 must 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 a range of products now do the job tolerably well); and more in solutions, convenience, appearance, and price. Figure 5, adapted from Norman [1998] illustrates the process.

Buildings are different. New techniques which improve the speed, cost or quality of construction are of interest to the supply-side; and clients may be happy if they help the supply side to give them a better, cheaper or faster building. However, few occupiers want to adopt a new building-related technology if in use they need to spend more time, money and effort to nurture it. Most seek instant, cost effective solutions and convenience. The difficulty of new ideas and products "crossing the chasm" - the gap in figure 5 which separates the very different early adopter and main market products and customers - is discussed by Moore [1998]. In buildings, however, the chasm is far to the left; particularly in speculative buildings for unknown users. 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, and should influence government attitudes to the need for public R&D expenditure in buildings in relation to many other industries.

More robust, more standardised, better-researched and more usable and manageable solutions are part of the answer. However, 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;
- better mutual understanding can develop 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.

THEME 6. PROMOTE VIRTUOUS CIRCLES

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? 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 6 for the situation at FRY.

Clear ends, means, and feedback and review systems help to establish virtuous circles of continuous improvement and to keep projects on track. Post-occupancy surveys are one part of this feedback. Monitoring, review and feedback also needs to take place during briefing, design and construction.

- The ends are about what buildings are for. In the broadest terms, social, cultural, economic and environmental benefits (both short and long term); to improve health, safety and comfort; and also to raise the spirits. Where possible, these benefits should be enjoyed by the wider community and not just the occupiers.

- The building itself is the means. Proposals for new buildings and refurbishments need to stand up to scrutiny as realistic and practical means and not as ends in themselves. 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 helps to keep things on target; or to modify the course or the target if necessary. It 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.

It is important that benchmark comparisons are used as means to review progress and plan improvements. If they benchmarks are treated as ends in themselves, they can easily become tyrannical, as discussed later.

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

Space, time and performance issues must be integrated to optimise usability and manageability and to make problem ownership clear. 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. This can lead to a loss of grip on overall mission. Expectations of buildings by clients, designers and occupants can easily become unrealistic, with with means and ends being confused, and unresolved problems “parked” in 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 the needs for fine-tuning once a building is occupied.

Figure 7 shows nine important principles - three each for defining ends, reviewing means, and undertaking feedback.

- To the left are the ends. This is where the commissioning client and user client usually stand. They need a clear strategy, to establish the essentials, and to review against moving targets.

- To the right are the means: the buildings and the designers, contractors, suppliers and others who provide and service them. In a design situation, focus can easily fall too quickly on the building as an end in itself, rather than the means to the occupier’s ends. Too much priority is then given to the spatial aspects with which designers are most comfortable, or to the use of a particular technology before its relevance and appropriateness has been fully examined. In other words, the solution becomes fixed in plans and diagrams which emphasise the tangible spatial attributes, but take attention away from the time dimension, or from basic performance attributes like comfort, health and safety. This is what the philosopher A N Whitehead called "the fallacy of misplaced concreteness". The process can be improved by clarity about context (how well does my solution really fit this client?); reviewing ownership of problems (however brilliant the building,what demands will it make on the client and the occupier); and recognising of the virtues of simplification.

- 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. These include reality-checking on the developing design; feedback from past and current projects; and a need for open-source data and benchmarks to allow experiences to be widely disseminated.

THEME 7. REVIEW EVERYTHING

Probe and its antecedents have shown how little can be taken for granted. It is important not to lose sight of strategic objectives, or of critical details. For example, UK buildings are not automatically airtight, plant efficient, or controls usable or effective: they have to be made that way. Eventually, of course, some of these will become industry-standard good practice; as indeed the current review of the Building Regulations for energy in England and Wales is proposing.

Too often, however, clients make what turn out to be unwarranted assumptions about the design team's approach, and designers may not understand the client's culture, resources and outlook (often they may not be asked, encouraged or paid to do so). 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.

The best results tend to be where monitoring and feedback forms part of the culture: this fuels the virtuous circles discussed above. 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 regard buildings as total systems. Many look (and indeed can be encouraged to look) through their own particular window and see only 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 outlined in Figure 7. 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.

The sad fact is that few 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 has found it difficult to escape from the focused agendas of industry (and indeed academe); and a pervading culture which is more concerned with cost than value. The current Egan initiative is 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.

A note on performance indicators

In recent years, and in many fields, there has been much interest in performance indicators. While such monitoring and benchmarking is important, sadly the indicators can too easily become ends in themselves, rather than aids to understanding and assessing what contributes 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 can be very much greater than the savings from the higher space efficiency.

AN EXAMPLE FOR ENERGY

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

- Few clients formulate their requirements in explicit terms.

- Where designers calculate and present energy figures, they are often aggregated, typically kWh (sometimes not even separated by fuel), £, or kg CO_2 per m^2 per year. They also tend to be used to differentiate between options; and not to predict what will actually happen.

- The input to the above calculations often contains implicit assumptions about usage and efficiency, to which most clients cannot easily relate; and interpret them as mostly gobbledegook.

- 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; and their effects 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)[1] 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 targets have not been set.

- An efficient light source or luminaire may too expensive, but what if the alternative did not meet the project's IPD target? At the very least one needs 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 and compared with benchmarks.

- 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.

As a general rule, throughout Probe we have tried to adopt the maxim used in the BUS occupant surveys: that there should be no begged questions resulting from the way data is collected, analysed and presented. For energy analyses, team members have found that the "tree diagram" approach, figure 8 [Field et al 1997, CIBSE, 1999] is a valuable survey aid in getting to the roots of energy use.

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1 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.

The same technique can be used in design. However sophisticated the approach, each end-use can be summarised in terms of:

E the standards to be adopted (e.g. litres/sec of ventilation per square metre);

F the efficiency of plant and equipment (e.g. J/litre for fans);

G the annual hours of operation (this can vary tremendously); and

H 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, helps to spell out assumptions and to nail the myth that energy statistics should be reported in aggregated form. The main benefit is that this approach helps all team members to understand means, ends, targets and consequences; and not to jumble them all up. Comparison of each component with typical, good practice and advanced practice benchmarks can be highly rewarding and contribute to better briefing, design, specification, installation, evaluation and management. Such an approach can potentially be used creatively in developing a language for briefing, design and performance evaluation and reporting; in tracking estimates and assumptions from briefing through design and construction into use; and in obtaining much better data for benchmarking purposes.

Suggested actions for the various players

At the end of Probe 2, the team listed all the generic opportunities and problems which had been identified, and how the various parties involved could participate in improvements. This led to some suggested initial actions for key players, as outlined below.

1. For clients who build. Establish clear ends and objectives, including the business mission for your buildings. If also the occupier, be clear about your organisational culture, changes affecting your business, and your attitudes to complexity and manageability. If not the occupier, make realistic assumptions about the priorities of potential occupiers, and the effect of social and technical change. Suggest quantitative benchmarks where possible, but do not let them become ends in themselves. Seek to obtain good value at reasonable cost. Manage the brief. Undertake reality checks on the developing design. Review the performance of the procurement process and the completed building. Promote responsible innovation, with provision 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 like 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 surveys to appreciate what adds real value for users. See that this 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 again do not let the benchmarks and the measures become ends in themselves.

5. For occupier clients. Be clear about your ends. Appraise premises and 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 what needs further improvement. If 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, for example in expressing user and management requirements and in becoming creatively involved in the briefing process.

7. For professional institutions. Improve collaboration and data sharing: use common definitions so problems get tackled collectively. Adopt cradle-to-grave benchmarking for closer comparison between design aspirations and performance in practice. Encourage post-occupancy feedback in practice, in standard contracts, and for a better service to customers. Use feedback information to target future practice, research and development. 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. Make assessing building performance an essential part of education.

8. For government. Encourage measures which lead to all-round improvements (e.g. triple bottom lines) not single issues (e.g. improved cost-effectiveness, energy saving). Expand the Egan agenda to deal with post-handover performance and feedback. Encourage transparent reporting and benchmarking, in order to assist improvement at all stages in a building's life cycle. Consider how open-source databases of results and benchmarks are best established and the role the public sector should have in maintaining them.

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

FIGURES

Figure 1 Feedback into the briefing process

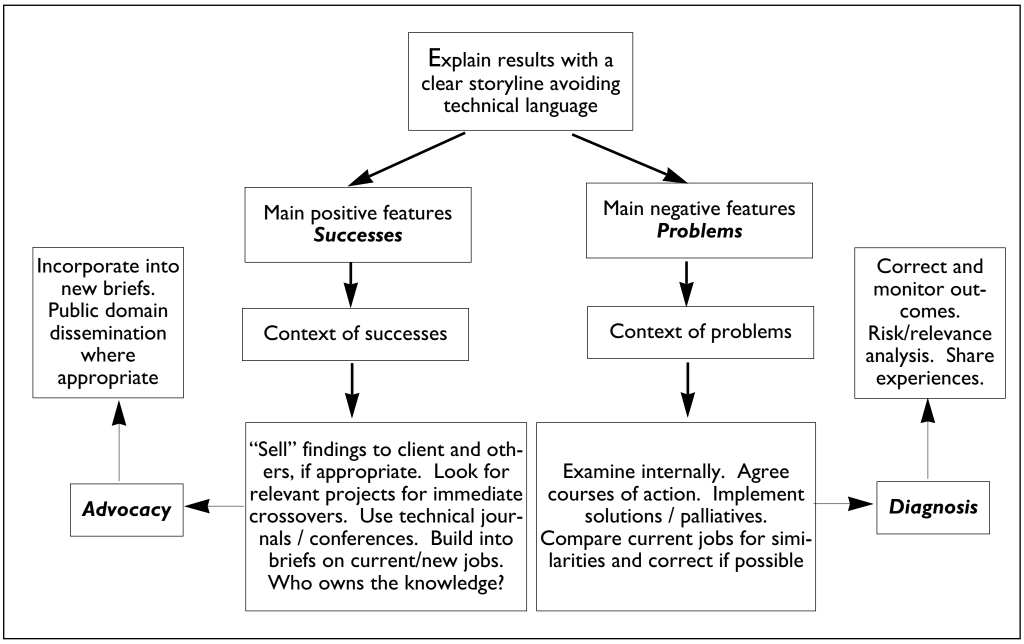
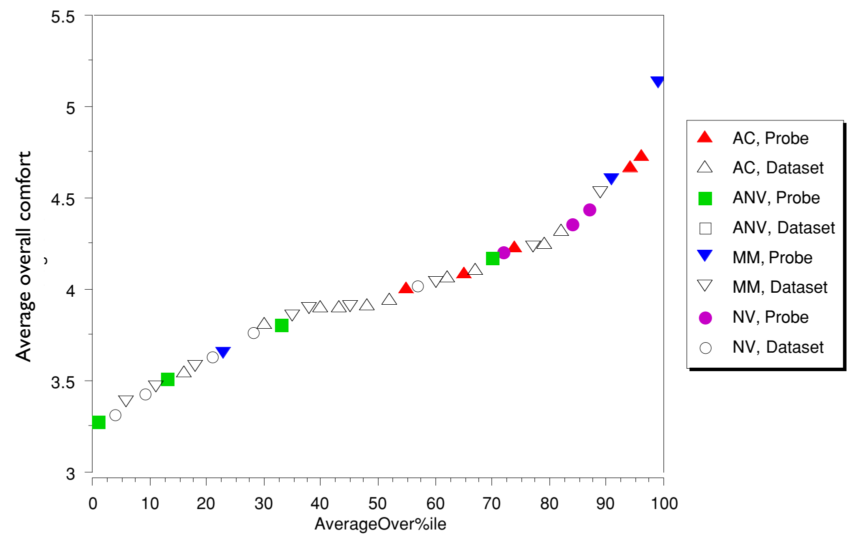


Figure 2 Overall occupant survey scores for comfort by ventilation type

Probe and BUS reference database



Notes

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.

Figure 3 Briefing strategies

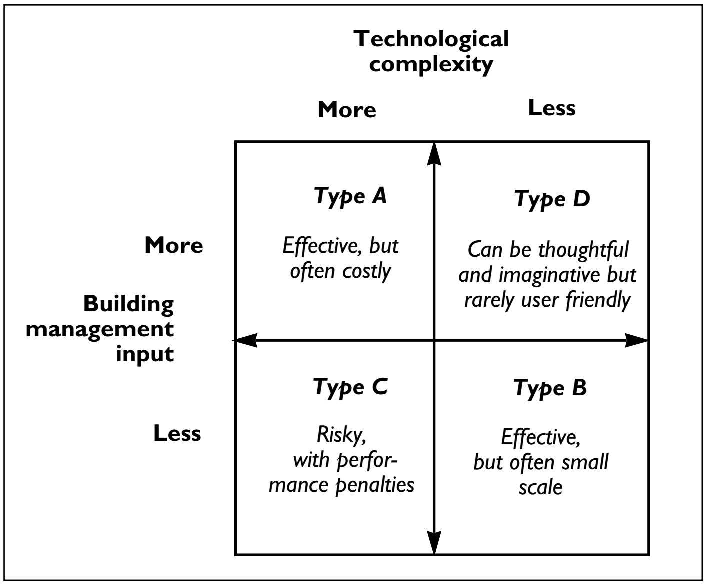
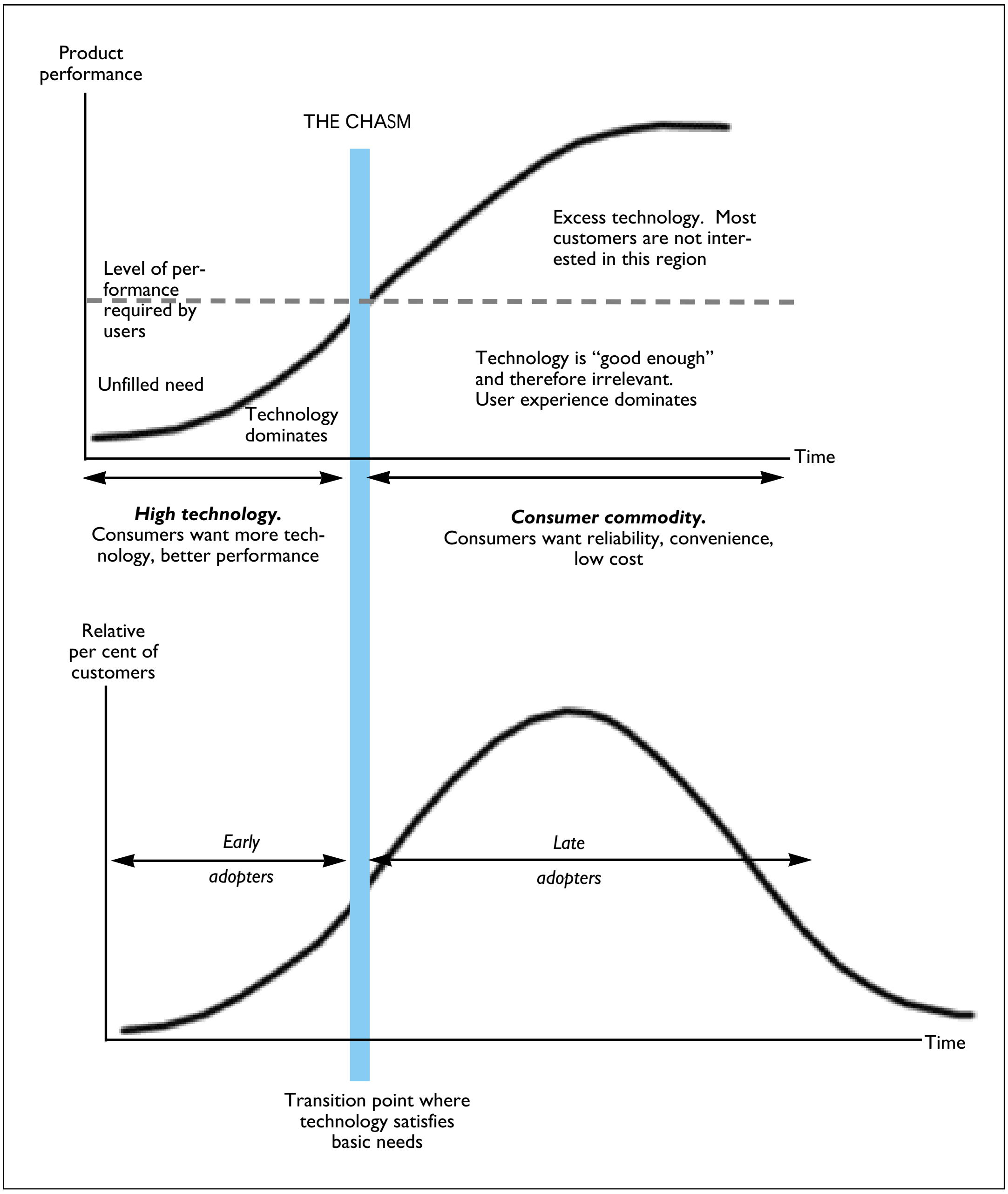


Figure 4 Real-world research

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.

Figure 5 The transition in technology take-up



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

Figure 6 Some factors for success at the Elizabeth Fry Building

1 A good client

2 A good brief

3 A good team (worked together before on the site)

4 Specialist support (e,g, on fabric insulation and airtightness)

5 A good, robust design (efficiently serviced)

6 Enough time and money (but to a normal budget)

7 An appropriate specification (and not too clever)

8 A good, interested contractor (and a traditional contract)

9 Well-built (attention to detail)

10 Well controlled (but only eventually, after monitoring)

11 Post-handover support (triggered by independent monitoring)

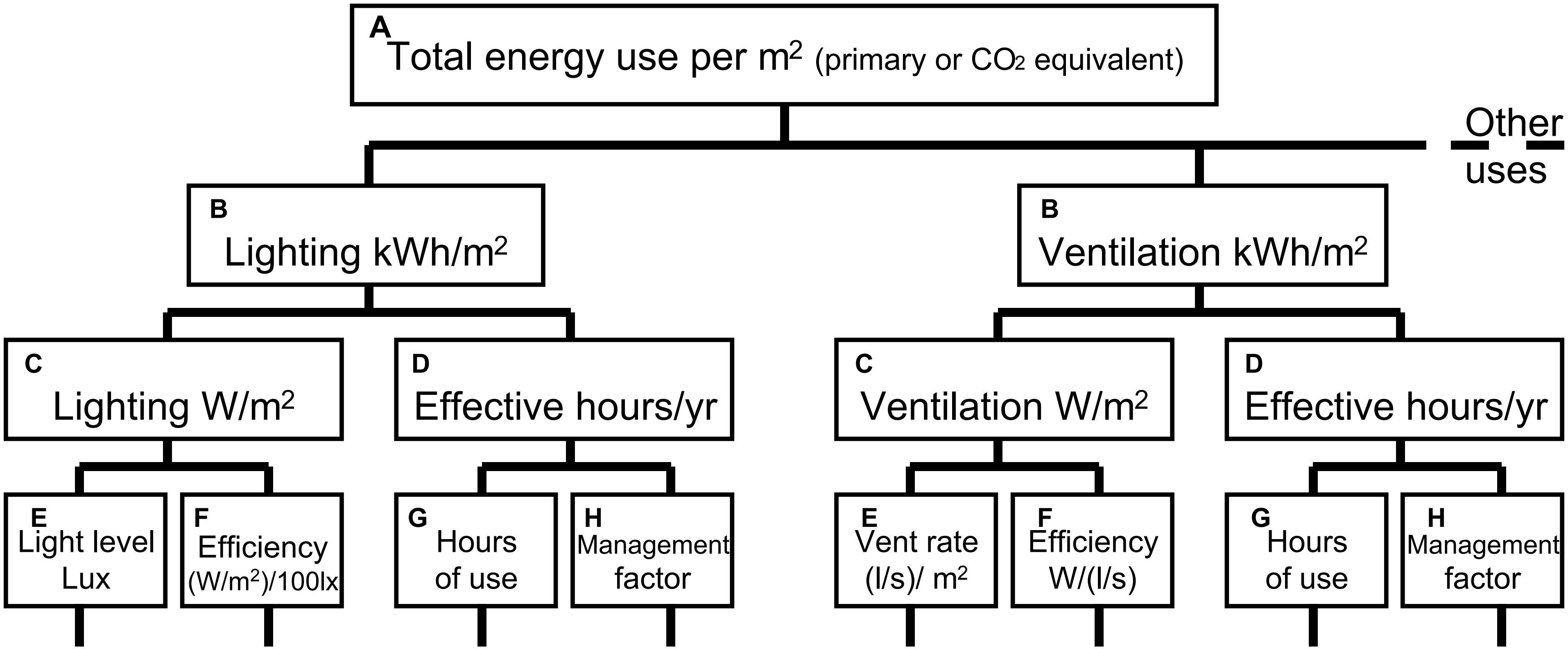
12 Management vigilance (but will it be sustained?)

Figure 7 Ends, means and feedback with nine Probe pointers

ENDS ← LINKING TOOLS → MEANS

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.

FIGURE 8 "Tree diagram" analysis of building energy consumption and service provision
Each box can be considered as a benchmark



Source: J Field, J Soper, P Jones, W Bordass & P Grigg, Energy performance of occupied non-domestic buildings: assessment by analysing end-use energy consumptions, Building Services Engineering Research and Technology 18(1) 39-46 (1997).