CLOSING THE LOOP
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Probe: How it happened, what it found, and did it get us anywhere?

Bill Bordass
William Bordass Associates, 10 Princess Road, London NW1 8JJ, England
bilbordass@aol.com

Adrian Leaman
Building Use Studies Ltd, 4/90 Bootham, York YO3 7DG, England

ABSTRACT

Between 1995 and 2002, twenty post-occupancy surveys of recently-completed buildings of technical interest were published in the journal of CIBSE – the UK's Chartered Institution of Building Services Engineers. The surveys covered both "hard" issues (e.g. energy performance and envelope airtightness) and "soft" ones (e.g. occupant satisfaction). How was this possible? Why did it stop? Has it changed anything? The studies concluded that, although the buildings were good examples of their kind, similar problems also cropped up time and again; and there was often considerable scope for all-round improvement, sometimes by making things simpler. A case is made for designers and builders to work closely with the occupier in the early life of a building to review what they have done, fine-tune the systems, and learn from the experience.

KEYWORDS

Energy performance, fine tuning, occupant satisfaction, post-occupancy surveys, Probe.

Background to Probe

WHAT WAS PROBE?

Between 1995 and 2002, *Building Services Journal (BSJ)*[1] published the PROBE (Post-occupancy Review Of Buildings and their Engineering) series of articles[2].

- Most of these (20 articles of typically six pages each) were post-occupancy evaluations (POEs) of the performance in use of interesting buildings that had been featured in *Building Services* when newly-completed, typically between two and five years beforehand.
- A few, in 2000-2001, were *Interventions,* in which Probe team members applied their insights to reviews (with clients, designers, users and managers) of buildings during the processes of briefing, design and early operation.
- Others, at intervals throughout the series, introduced Probe and its research methods; drew conclusions on issues including technical and environmental performance, occupant satisfaction and productivity; and reviewed responses to the series and to the findings by the designers of the buildings concerned.

HOW DID PROBE START?

The idea for Probe emerged from a discussion at the *BSJ's* editorial board, at which members expressed interest in finding out how the innovative buildings and systems featured in BSJ really functioned when in use. This information would be of great interest to readers wishing to learn from the experience of others in order to fine-tune their solutions to meet the growing expectations of:

- clients for flexibility, predictability, service, performance and cost-effectiveness;
- occupiers for better health, comfort and productivity; and
- all with greater energy efficiency and less environmental impact.

But who would do it and how would the research be paid for?

WHO WOULD DO THE WORK?

BSJ's Editor, with support of editorial board members, put together a team that they felt had the experience and techniques to undertake the work. It consisted of:

- Principal investigators and project managers HGA Ltd (and subsequently ESD Ltd), which had been involved in managing investigations of low-energy buildings, including PSDS - the government-supported *Passive Solar Design Studies,* in which design advisors and computer modellers worked with design teams and their clients to improve the energy efficiency of selected projects, primarily by planning to avoid unnecessary loads and to exploit solar gains, solar shading, fabric heat storage, passive cooling, natural ventilation and natural lighting. HGA had also written protocols for monitoring performance of passive solar buildings across Europe, and undertaken monitoring themselves.
- Building performance consultants WBA, who undertake monitoring and troubleshooting of energy and environmental performance of buildings in use and take the messages back to clients, designers and researchers. In the 1980s, WBA had undertaken energy-saving projects in universities, developed concepts for

[1] The monthly journal of CIBSE, the UK's Chartered Institution of Building Services Engineers.

[2] The Probe material including reviews is available for download from www.usablebuildings.co.uk . The Probe articles themselves can also be found on the BSJ website and on the CD issued annually by CIBSE to its members.

low-energy office and educational buildings, reviewed monitoring results from energy demonstration projects and done case studies of energy use in offices. To support this, WBA developed an energy assessment spreadsheet, which had proved powerful in undertaking surveys, reviewing results from detailed monitoring, and preparing benchmarks (e.g. Energy Consumption Guide 19 for Offices (EEO, 1991)). WBA also assisted HGA in reviewing PSDSs in offices.

- Human factors consultants Building Use Studies (BUS), which had undertaken the first major study of building-related ill-health (known at the time as "sick building syndrome") in the UK and had more recently worked with WBA on occupant use of manual and automated controls in both conventional and low-energy buildings.

The research team would provide the technical material on the performance of the buildings for the editor to put into a form that would appeal to *BSJ's* readers.

The team was later joined by:

- Target Energy Services Ltd (TES) for support with the energy surveys. TES had developed the energy assessment procedure initiated by WBA into a codified method which was tested on the early Probes and elsewhere. Following these trials, TES developed it further into the CIBSE TM22 Energy Survey Method (CIBSE, 1998) and associated software, which was used on the later Probes.
- The Building Research Establishment (BRE) and the Building Services Research and Information Association (BSRIA) for support with envelope pressure tests.

HOW WOULD IT BE PAID FOR?

To undertake and publish the proposed first series of eight Probes would require a six-figure sum, far beyond the means of *BSJ or CIBSE*. How could this be found?

- While some projects in the 1980s had received similar amounts just to monitor a single building in detail, these government programmes were over.
- In the 1970s and 1980s, the fuel industries had been generous in funding studies of building performance and energy-efficiency, but with privatisation of electricity, gas and coal this source had shrunk away.
- The proposed approach was seen as too multidisciplinary and not sufficiently rigorous to suit academic research priorities.
- R&D for government ministries had been largely undertaken through their own research laboratories, research associations, or by invitation. Fortunately, however, in 1994 the Department of the Environment[3] announced that, in order to encourage innovation, anyone could put forward project proposals for a part of their R&D budget under its new *Partners in Technology (PiT)* programme[4].
- Unfortunately, the maximum available PiT funding was 50% of total project costs. However, we discovered that the "hidden" costs of journal production, and time spent by the owners, occupiers, designers and users of the buildings in supporting the research were eligible as matching contributions; and had a similar value to the cost of the necessary research. In practice, it didn't quite work out like this, and team members had to put in some extra time at their own expense.

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[3] Which at the time was responsible for the construction industry, building regulations, and environmental performance. These tasks were split between three ministries following the election in June 2001, when PiI (see below) was transferred to the Department of Trade an Industry (DTI).

[4] Subsequently re-named *Partners in Innovation (PiI)*. The scheme ceased in 2003, so it is no longer possible for ad hoc teams to make unsolicited proposals for R&D funding specifically earmarked for buildings and construction. Proposals will now have to compete in DTI's schemes, more designed to suit laboratory R&D for manufacturing industry (transport, electronics, pharmaceuticals etc).

General outcomes

SUCCESS

The proposal was successful. We were probably lucky that the Probe idea coincided with the first round of a new programme where the rules were uncertain and there was much less competition for funding than in later years. If our first proposal had been submitted to a more established programme, it might well have been regarded by the reviewers as being too difficult and too risky. As it happened, however, the team submitted a series of three successful proposals for:

- Probe 1 in 1995-97, with eight published building studies.
- Probe 2 in 1997-99, with seven published studies including air pressure tests.
- Probe 3 in 2000-02, including four "traditional" Probes (as in Probe 2, but with one of an office in The Netherlands) and a series of "Probe interventions".

RELIABILITY

By Probe 3, the process had become less experimental and more routine, with well-honed survey tools, in particular:

- A pre-visit questionnaire, used to get information on the building, its operation and its utility consumption from the facilities manager. Although this was seldom fully filled-in and sent to the team in advance of the first visit, it helped to structure the visit and to secure the missing information, if not on the day of the visit, then normally within the following week[5].
- The standard TM22 Excel workbook – with supporting material where necessary – showing the breakdown of energy consumption and CO2 emissions.
- The BUS occupant questionnaire survey and report including benchmark comparisons and classified comments by occupants.

The results of all this, together with plans, diagrams, photographs and other information were put in a *Resource Pack,* a ring binder containing typically 25 mm of material. The need to systematise, accelerate, streamline and make more cost-effective all the techniques used in building performance assessment is discussed in another paper to this conference (Leaman, 2004).

POTENTIAL LITIGATION

Many people have cited the risk of litigation as being the reason why they do not publish (and in many circumstances do not undertake) studies of the performance of named buildings. Probe demonstrated that it was possible to publish this kind of material routinely; at least with clients and designers who were sympathetic to the idea of learning from feedback.

PROBE INTERVENTIONS

[5] WBA had learnt the value of a pre-visit questionnaire on its earlier office energy case studies. Here we discovered the hard way that managers who were not able to complete the questionnaire within a month of receiving it (and after two reminders) were unlikely to be able give sufficient support to a study –i.e. in terms of their and their staff's time, availability of information, and support by senior management. If we did not have the information after one month, it was best not to continue to press for it, but instead to withdraw. Fortunately, only a small number of the possible Probes terminated prematurely for this or any other reason. This was partly because the occupier's ability to provide support and information to BSJ had already been tested in the course of preparing the first article.

Getting published insights from the Probe interventions introduced in Probe 3 proved to be less reliable, for four main reasons:

- Our input was informal and advisory: we had potential influence but no authority.
- Most of the projects to be reviewed were subject to delays outside the Probe team's control, e.g. changes in client priorities, funding difficulties, and statutory approvals. Hence our work became inefficient and deadlines were missed.
- Neither the client nor the design and building team was paying us, so they had no incentive to use us efficiently.
- It was sometimes difficult to present things fairly. For example, many things raised by Probe team members, had been 'in the air' already and so could not be ascribed directly to the Probe intervention – making for good teamwork but not good stories! And occasionally we did encounter major (but by no means unusual) problems in the relationships between client, designer, contractor and user which it would have been instructive to report, but impossible to write about.

On the other hand, these direct experiences improved our general understanding of what needed to be done to improve client and industry practices.

CONTINUATION

Readers of *BSJ* and others began to take for granted the continuous flow of new information on the performance of new buildings, through which one could look at the performance of innovative approaches and technologies. Some universities also began to use the Probe reports routinely as teaching aids. However, the team itself could not take funding for granted without continuously re-inventing its offering. The proposal for continuation in 2002-04 therefore included:

- more broadly-based studies (for example to include issues of design quality, cost and procurement system);
- additional publications to reach a wider audience, including clients and architects in particular; and

collaboration with other activities including the BREEAM environmental assessment system, in order to help close the credibility gap which can so easily yawn between design expectations and actual in-use performance.

EXTINCTION

Unfortunately, even this did not convince the funders, who felt that the time for government support was over and that the exercise needed to be made self-sustaining on a commercial basis. This was a tall order for what was essentially a public domain activity. Progress has however been made since 2002; and is summarised in Bordass (2004).

PUBLISHED SOURCES

In addition to the original articles and reviews in *Building Services,* Probe's findings have been reviewed in a number of places, in particular a special issue of *Building Research and Information* (Lorch, 2001a) on POE, in follow-up commentaries (Three in Lorch 2001a, six in Lorch, 2001b and two in 2002), and in a response by the Probe team (Bordass, Leaman and Cohen, 2002).

What did Probe reveal?

INTRODUCTION

Probe tried to look through its studies of individual buildings (which, in spite of sometimes having problems, were all good examples of their kind) into the state of UK buildings in the 1990s generally: what worked well, what didn't, how they suited a changing world and the changing needs of their clients and users; and what could be learned about both the process and the product to improve future buildings. Some results (for example the poor airtightness of many new buildings, including ones which were ostensibly "sealed") were already well-known through other research. However, to see that even high quality buildings could sometimes have the same problems somehow made the issue more real than research statistics[6].

IT's DÉJÀ VU ALL OVER AGAIN[7]?

Probe found that niggling problems tended to recur in building after building: somehow the industry wasn't going up the learning curve fast enough. Perhaps this is not surprising: by-and-large those who procure, design and construct buildings are "project people", who move on to the next job as soon as the last is physically complete. Consequently, even the good buildings can have undetected flaws which needlessly subtract some of their value to the owner and particularly the user. Frequently, we found sophisticated design features delivering at best marginal benefits and might have been best omitted, releasing money to be spent on missing essentials which would have made the building better, more comfortable, more manageable and more sustainable. "Keep it simple and do it well" is a useful catchphrase, but because the feedback loop is often absent, designers may not realise how well some simple solutions can actually work. True innovation should rest on these firm foundations, rather than just being wilful novelty (Fisk in Lorch 2001b).

SOME TECHNICAL PROBLEMS

Widespread technical problems included, for example:

- Uncomfortable reception areas. Nearly half the Probe buildings had received major attention to lighting, heating, draughts, solar gain, glare and noise between completion and the Probe team's arrival.
- Leaky natural ventilation systems. Often the facilities provided to improve summertime cooling also increased heat loss and draughts at other times.
- Control systems and devices which did not suit occupiers or managers: from incomprehensible BMSs[8], to missing or unusable local controls. Manual controls could be troublesome too, for example openable windows with unreachable handles or falling shut with wind or gravity.

[6] In the case of airtightness, there is a direct link from a Probe report to a campaign by CIBSE's president. In turn, this almost certainly brought forward CIBSE's publication on the subject and the inclusion of air pressure testing in the 2002 Building Regulations Part L for England & Wales.

[7] A quotation by Yogi Berra.

[8] Electronic building and energy management systems.

KNOCK-ON EFFECTS

Frequently the problems led not only to frustrated, uncomfortable, dissatisfied and consequently less productive occupants; but energy waste too. For example:

- A building with poor airtightness may not just use fraction more heating or cooling energy for air treatment: instead the plant may be left running 24 hours a day to help overcome the problems; and occupants may still be uncomfortable.
- If an attempt to maximise daylight also leads to glare problems, the result may be "blinds down – lights on" and very little daylight and view.
- Incomprehensible, unusable or intrusive control systems can often be over-ridden, causing the controlled systems to default to ON – the scourge of many modern buildings and a cause of massive energy waste.

WIN-WIN-WIN OR LOSE-LOSE-LOSE?

Better sustainability promotes the triple bottom line: happier and more productive people in valuable cost-effective buildings which place fewer strains on the environment. But the monitoring and feedback necessary to get this benign result were often absent, so the desired virtuous circles with vicious ones, particularly where buildings proved to be too difficult and complicated for the management skills available. Probe buildings which achieved good results included:

- The domestic-scale Woodhouse Medical Centre (Standeven et al, 1996). Promoted by the designer as a "thick" building with superinsulation and very simple controls, this combined low energy use with high occupant satisfaction. In spite of some shortcomings as far as the internal environment was concerned, the occupants appeared to forgive it because it was obvious how it worked.
- The sophisticated, very deep-plan Tanfield House (Bordass and Leaman, 1995). In the 1980s a building of this kind could well have been "sick", but a combination of a good design, a thoughtful client and well-resourced, effective and responsive facilities and engineering management avoided the pitfalls.
- The Elizabeth Fry Building at the University of East Anglia (Standeven et al, 1998). This was designed to be robust and simple to run, but had initial problems which, after monitoring, required considerable work to its control and management systems to achieve its objectives and establish the required virtuous circle. However, the final outcome was one of the most comfortable, energy-efficient and low-maintenance buildings in the dataset.

MAKING BUILDINGS BETTER

To improve the process and the product, some simple themes emerged (Bordass, Leaman and Ruyssevelt, 2001):

1. *Occupants like buildings that can respond to them.* People tend to be happier if they can adapt their environment (or adapt to it). Unless the environment (and its management) is perfect, that is. Which brings us on to
2. *Don't procure what you can't afford to manage.* Design "solutions" to client problems can look good but actually put unsupportable demands on management. Simpler may often be better. Sadly, since building performance is seldom evaluated, simple-but-effective solutions can easily be overlooked.
3. *Comfortable buildings can also be energy efficient.* These win-win solutions tended to be the outcome of good briefing/programming, good design and good management rather than the blind application of any particular technical formula.

4. *Get the essentials right.* Buildings need to be robust platforms upon which innovations can be soundly based. Prevention is better than cure.
5. *Buildings are more like ships than cars.* In the UK a lot has been said about making the building industry more like the car industry. But the car analogy should not be stretched too far. Many buildings have to respond to their context, both in their design to suite the location and in fine-tuning (as in sea trials) in early use with the designers on board.
6. *Promote virtuous circles.* Really good buildings tend to emerge when the client's ends are clearly expressed, the design is clearly seen as a means to that end, and monitoring keeps first the process and then the product on track. Without such commitment, strategy and feedback, vicious circles of decline are almost inevitable.
7. *Review everything.* Don't take anything for granted

WHO SHOULD DO WHAT?

We identified some key actions for the various players involved. In particular:

- *Clients who build* need to be clearer about what they want strategically and to review how the developing design maps onto (or alters) these goals. Manageability needs to be a key briefing objective.
- *Project managers* (for the client and for the design and building team) should manage the brief and make sure that the means fit the ends.
- *Design team members* should seek robust solutions to their client's goals, be careful in managing expectations, get the essential features right (they are not optional extras), keep things simple, manageable and efficient where possible, try to avoid downside risks, and be more involved in follow-through, fine tuning and feedback after the physical work is completed.
- *Builders and suppliers* should seek to establish good "no surprises" standards of materials, workmanship and service, plus effective after-sales support once the works have been handed over.
- *Occupiers* need to be clear-headed in assessing facilities in relation to their real needs, get alterations and fitouts done thoughtfully, and make sure that "sea trials" take place on their new premises. They must be careful not to outsource their feedback loops on building performance and occupant satisfaction.
- *Facilities managers* need to appreciate the importance to the occupiers or an effective service with rapid response, particularly in the more complex buildings in which the dependence of users on management is high. They also need to get more directly and creatively engaged with the providers of buildings.
- *Professional institutions* need to encourage their members not only to make better, more sustainable buildings, but also to obtain feedback on the performance actually achieved. They should also provide support in terms of standards, benchmarks, collaborative working practices, data sharing, and incentives such as competitions.
- *Governments* need to promote all-round improvement in the public interest, not a multiplicity of single issues. They should encourage designers and builders to be much more closely engaged in understanding and improving performance in use, with transparent reporting and benchmarking, and effective data management.

Probe in context

GOING WITH THE FLOW

In the UK, Probe coincided with a growing interest in building performance by clients, users, designers and particularly government:

- In the 1980s, both central and local government tended to privatise, outsource, disband or at the very least downsize their departments concerned with the design, construction and maintenance of their buildings.
- In the 1990s, there was also a trend to outsourcing property entirely, with sale-and-leaseback of the asset and the use of support services companies for its management and maintenance.
- Having outsourced their buildings and their operations, occupiers began to discover that buildings affected their organisational performance more than they had thought, a sentiment also expressed in North America by the Federal Facilities Council (2002), which argued that, at the very least, clients must ensure that effective monitoring and feedback systems are in place.

RETHINKING CONSTRUCTION

The UK government's dissatisfaction with the construction industry and its products led to its commissioning a report by the Construction Task Force (1998) into what might be done. The report, *Rethinking Construction,* concentrated on the process of construction much more than the performance and sustainability of the product, though these deficiencies are now being recognised and corrected, with the emphasis shifting from construction to buildings.

SPECIFYING BY PERFORMANCE

From the mid-1990s, there has been a trend for government to outsource its property entirely, with many new UK projects procured under PFI – the Private Finance Initiative, in which a team tenders not only to design and construct a facility, but includes finance, management and maintenance in the package. At the outset, it was presumably the hope of government that by using "the experts" to provide their property, they would automatically get better and more cost-effective facilities. For the most part, the opposite seems to have happened, at least for the early projects (viz Audit Commission, 2003). One of the many reasons is that an industry that has not routinely engaged with the performance of the products can hardly be expected to achieve anticipated performance levels. It first needs to develop and use effective feedback systems to monitor the performance actually being delivered.

PERFORMANCE INDICATORS

The Egan Report advocated the use of performance indicators. Since then Key Performance Indicators (KPIs) have appeared in vast numbers. Government clients increasingly require their suppliers to report KPIs, causing a bit of a backlash from those that see them as blunt instruments to satisfy the bureaucrats without always adding value. Since these were predominantly focused on process (e.g. delivery on time and to budget), others began to be developed on product, for example on sustainability and design quality. All these can potentially dovetail with developments beyond Probe, as discussed further in Bordass (2004), but there is a long way to go.

Did Probe have a wider impact?

INTRODUCTION

Now Probe is over - or at least the public domain aspect temporarily suspended – what are we left with? Quite lot of publications, a growing trickle of POEs around the world using similar techniques (particularly the occupant survey) for clients, university researchers and increasingly designers, but how much influence? Did Probe signal or reflect a move towards greater understanding of and engagement with building performance, or would it – like the work of the Building Performance Research Unit thirty years earlier (Markus et al, 1972) – run alongside practice for a time but not quite enter the mainstream?

IMPACT ON DESIGNERS

There is little doubt that, at least in a small way, Probe has helped UK building services engineers to be more open with their peers, about problems that have arisen on past projects and how the situation might be improved on present and future ones. However, it can be more difficult to spread these messages to other members of the design and building team (who sometimes regard Probe as exclusively about matters exclusively for services engineers, like comfort and energy efficiency!); or to clients, as discussed in a subsequent paper (Bordass, 2004). Baird (in Lorch, 2001b) laments the fact that the Probe studies were published only in the relatively limited-circulation *BSJ*. However, exclusivity was part of the commercial arrangement that unlocked the government funding; and it was probably necessary to have this sheltered incubator to get things going. Now the bridgehead has been established, one can broaden out.

BROADENING OUT INTERNATIONALLY

Although all but one of the published Probes was on UK buildings, responses from around the world informally, to the BRI special issue (Lorch, 2001a)[9], and to conference papers have been encouraging ("you could be talking about us too"). In spite of the local differences, clients, users, buildings and construction industries in different countries appear to have many things in common. Certainly a lot can be learnt by exchanging information on building performance more widely.

COMMENTARIES ON PROBE

The invited commentaries (Lorch 2001a, 2001b and 2002) on the Probe papers in the BRI Special issue (Lorch 2001a) threw insightful shafts of light on Probe's potential impact and the likely obstacles. Issues raised by the commentators included:

- Will POE become yet another time-wasting initiative foisted on busy people by bureaucrats (Cordy in Lorch, 2002)? Who "owns" it anyway (Cooper in Lorch 2001a)? Properly done, feedback clearly adds value but will pay for it? Best to make it simple, efficient and routine, as discussed by Bordass (2004)

[9] From which all five papers on Probe were actually republished in TVVL Journal in the Netherlands, with colour illustrations.

- Fisk (in Lorch 2001b) says that buildings are already a boardroom headache and poor results from performance evaluations could easily demotivate senior management yet more. Not necessarily: results accompanied by clear recommendations can spur improvement. However, in our experience "good but not great" is the most effective call to action: it shows that an organisation's procurement and management staff and their design and building teams have performed well and tends to release support for them to do better.

- Markus (in Lorch 2001b) regretted that Probe had not followed more in the academic tradition that he had helped to pioneer (Markus et al 1972), and that we had missed the opportunity to develop new models. Probe, however, was more concerned to raise awareness, to influence decision-makers, to provide some simple principles to improve the dialogue between clients, designers and users, and to inspire people, including academe, to further action. We are pleased to find that the Probe material is used quite widely as a teaching resource. Probe's findings have also been reviewed and its techniques used in postgraduate dissertations around the world.

- Is that all? Several commentators felt that Probe did not tackle a sufficient number of issues, and that it did it only once rather than at regular intervals throughout the life cycle. The short answer is that you have got to start somewhere, we did as much as we could afford, and even that was more than most organisations were prepared to spend. We leave the last word to the manager of one of the Probe buildings who was still making good use of the results in 2003, three years after the survey. *"Probe's coverage is more than enough: anyone who says it isn't probably doesn't appreciate what it offers"*

Conclusions

Probe was by no means the first exercise of its kind, nor the most thorough. It was 50% government-funded not as a research project but as an initiative to improve innovation in the industry. Its validity came from the convergence of four proven streams of activity: energy surveys, occupant surveys, design advice and publication. It looked at buildings of topical interest to its audience, examined both "soft" and "hard" issues (starting with an energy survey) in a consistent and systematic manner; both using well-established conventions and benchmarks. The exercises were relatively quick and affordable (and have been further speeded-up and made more competitive since) and produced robust published results which have stood up to public scrutiny.

In some ways Probe can be seen as a symptom of current trends towards performance-based building. At the personal level it was the result of the team members' frustration at the slowness of the construction industry and its clients to learn from their completed projects - particularly how they perform in the hands of their users. Hence problems persist, successes are overlooked, and innovations miss their targets.

Feedback is not routine in the industry: there are many barriers and not enough drivers. Perhaps the greatest barrier is that the benefits are spread around, so no one party sees themselves as reaping enough of them to bear the cost – a version of the economist's law of the commons. Some designers also fear attracting responsibility for any problems that their investigations might expose. Sometimes their insurers won't let them!

Clients are becoming aware that a lack of routine feedback within the industry is a problem for them too. They are beginning to understand that buildings cannot be taken for granted, but can add considerable value to (or subtract it from) their businesses. But many clients have outsourced their technical expertise and feedback loops, and put themselves more at the mercy of the supply side of an industry which does not always ask the right questions and does not know exactly what happens to its products once handed over and in use. While abject failures may come back to haunt designers and builders, disappointing performance often does not, so faulty prescriptions can easily be regarded as successful and continue to be repeated virtually indefinitely. Conversely, simple, effective solutions can be overlooked because performance is not systematically evaluated.

By their nature - innovations cannot always be "right first time". However careful you are in planning and testing, there will always be surprises, as is well known in R&D with its all-pervasive "Murphy's Laws". That is why scientific method is based on hypothesis, followed by experimental testing. Except for the most repetitive projects, every new building is a hypothesis and its performance in practice is the experiment. But where are the designer/experimenters? In the distant past, when technology and user requirements changed slowly, one could perhaps rely on evolutionary feedback. More recently, one could perhaps rely on academic study and the test of time. But today, when things are changing so fast, there is no alternative to learning on the job. Now we all need to collaborate to make it happen!

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