Productivity in Buildings: the Killer Variables: Twenty Years On

Adrian Leaman and Bill Bordass

© Adrian Leaman and Bill Bordass 2016. [This notice to appear on first page of chapter]

Introduction

Productivity in Buildings: the Killer Variables first appeared as a presentation at the Workplace Comfort Forum in 1997 [Leaman and Bordass (1997)], and has subsequently been updated in three versions, including earlier editions of this book. The older versions contain additional material: these and many other references can be found at www.usablebuildings.co.uk .

Twenty years on what have we learned? Has anything substantially changed? The second question is easier to answer than the first. Our conclusions remain basically similar, with many of the same mistakes being made as twenty years ago. Despite a new batch of UK studies into building performance in use [Lorch (2016)], and much wider appreciation of the importance of feedback to help get the best out of people in their workplaces, recent longitudinal studies [e.g. Bunn (2016a)] continue to show that workplace productivity is being unnecessarily compromised.

Buildings are complex, interconnected systems; so outcome indicators like perceived productivity are usually associated with others, like perceived health. The cats' cradle of causality and association differs from one building to the next, making it dangerous to be over-assertive about causation without careful appreciation of contexts. For example, two technically similar buildings may have very different performance outcomes, depending on their occupation and management. In a badly performing office, people with window seats may report much better levels of comfort, health and productivity, than those in the middle, while in a better designed and managed building the 'window effect' may disappear. Similarly, people who only use a building once or twice a week will usually respond more positively than those who are there five days a week.

Here we cover the lessons learned - from our investigators' perspective - then reflect on what we saw to be the killer variables in the past and how we see them now. By 'killer variable' we mean those aspects of buildings which most directly affect perceptions of workplace productivity by building users. By 'perceived productivity' we mean how people think their activities at work are enhanced or reduced by the conditions in the building. Our main standpoint is building performance - how well buildings work to meet the needs of occupants and how successful buildings are technically and environmentally. This necessarily involves understanding the needs of individuals, their host organisations, and the building's fabric, form and technology. Twenty years ago we were also interested in how buildings work from an economic perspective. But we have never studied this in any detail because of the extraordinary difficulty and expense of obtaining robust data [Bordass (2000)].

What have we learned?

Our approach to building performance concentrates on aspects over which clients, designers and to a lesser extent facilities managers have some influence and are potentially able to intervene to affect outcomes, hopefully for the better. We draw a clear boundary around things we can examine with confidence and those we cannot. For example, we might ask occupants if their working environment is too noisy, but not about the 'morale' of their colleagues. Occupants will normally be able to tell you accurately whether it is too noisy, but a topic like morale may not mean much to them. So the recent preoccupation with the wellbeing of building occupants - a diffuse, if not impossibly abstract concept - is outside our terms of reference.

When building occupants know the answers and therefore do not have to speculate, results are more useful. This is like an exit poll after an election. The respondent, having just voted, is likely

to give a more accurate response because they actually know the answer. Opinion polls in advance of election day will be less accurate because respondents will tell you how they might vote, not how they actually do. If you ask a building user “How do you think your productivity at work is affected by conditions in the building?” and ask them to rate a percentage increase or decrease on an interval scale, most can attempt this with a degree of honesty if not accuracy - though a few may say: "With respect to what? I have no yardstick to judge this by.” [Endnote 1] Perceived productivity measurement like this is close to the limits of what can be achieved effectively with questionnaires. So, as a general rule, only include questions that respondents are likely to know the answers to.

There is also the question of subjectivity. “The answers are only subjective so cannot be trusted.” say some. But how is it possible to practically measure productivity at work practically and objectively across all kinds of buildings and their occupants? It's fruitless, because each separate type of activity (e.g. software development, marketing, etc.) will require a subtle change to the metric and to the method of measurement, all within changing situations, the vast majority of which will be inaccessible to the researcher.

Although perceived productivity might well be the first variable a researcher might seek to remove from a questionnaire on methodological grounds, from a manager’s point of view workplace productivity is one of the most important criteria of success. It is one of the twelve key variables (out of forty-eight altogether) used to create a Summary Index of occupant satisfaction in the BUS survey [Endnote 2]. Despite debate about its pitfalls [e.g. Oseland (1999)], no-one to our knowledge has successfully found a practical alternative.

So also with absenteeism. If you ask about absences, responses may be misleading in various ways. Respondents need to be confident that their honest responses will not be used against them: if they feel they might be identified, they may be nervous about managers seeing what they say. Data of absences from staff or medical records will not pick up people going absent for a few hours because it will only refer to longer periods of time, e.g. when covered by a doctor’s sick note. Data culled from, say, Human Resource Department records may also be hard to associate with a particular building. Organisations will say that such data are available, but when examined more closely, interpretation becomes difficult. ‘Workplace absenteeism’ may be the headline, but the support data may just be based on sick leave, which is not the same. [Economist Intelligence Unit (2014)].

We ask respondents how their behaviour changes as a result of being in the building. This an indirect way of getting at absences. It also picks up comments on more subtle aspects like wearing headphones to mask unwanted noise, or escaping from the building briefly for respite from poor conditions. Figure 1 shows the distribution of percentages of respondents who say “Yes, they change their behaviour as a result of conditions in the building”. The mean and median are just over 40% across 174 buildings [Endnote 3]. Almost invariably the reported behaviour will be a coping strategy to help mitigate perceived problems. A typical comment might be: "I take my lunch breaks outside the building wherever possible, and go home exactly on time every day." Only a few comments will be positive like: “I dress more smartly” and “I try to sit next to the atrium because the quality of light is good there”.

We contextualise statistical ratings with users’ comments. For example, if you want to examine how the quality of daylight relates to perceived productivity, you should not choose the study buildings solely on the basis of ratings on lighting quality. Over the past twenty years, most buildings score better on daylight and artificial lighting, largely owing to improvements in lighting and computer screen technology. However, in some buildings, lighting may be the *only* variable that scores well, and may mask other things that are rated poorly. This is one reason why studies that set out to examine educational performance and lighting quality, for example, never seem to reach publication: the method may not properly describe or control for context; and the analysis may be swamped by ‘noisy’ data that makes results difficult or impossible to interpret.

Analysis by Baird and Dykes [(2012)] suggests that comments boxes in the BUS questionnaire are usually filled in by about one-third of the respondents. They found that negative comments outweighed positive or neutral and suggested that a ratio of 5 to 1 should prompt an alert, while anything approaching 10 to 1 should warrant immediate investigation. Comments - positive and negative - are significantly associated with the numerical ratings for the corresponding variable. Ratings and comments are usefully associated, so where occupants comment negatively on a topic, they are likely to rate it negatively too. For perceived productivity, the significant correlations are r = 0.67 for positive comments and r = -0.82 for negative comments.

Giving respondents plenty of opportunity to comment is an good way to keep down the length of a questionnaire and get bellwethers of things to come. There is no need to ask about everything: a well-designed questionnaire will extract the answers anyway. For example, the BUS questionnaire does not ask specifically about problems in reception areas, but elicits responses where such problems occur. In schools, clashes between daylight strategies and the now omnipresent electronic whiteboards were first detected in a teacher's remark in 1995, well ahead of their widespread use.

When studies are repeated at intervals over time, the 'fingerprints" - the general shapes of the average rating scores - tend to be similar, a good indicator of 'robustness' of the method. Figure 2 [Bunn (2016b)] shows three fingerprints for the Elizabeth Fry Building [Endnote 4] from surveys in 1998, 2011 and 2015. The respondents in the buildings may change over time, but the overall pattern of average responses is discernible.

Figure 3 overlays data for the Rivergreen Centre for studies in 2007 and 2015 [Bunn (2016b)] . Mean scores for 2007 are denoted by double-ended vertical arrows and those for 2015 by coloured shapes [Endnote 5]. For perceived productivity, the score changed from plus 2% in 2007 to plus 4.8% in 2015. Although the value is 2.8% higher, this is still within measurement limits, so not significantly better in the statistical sense. Outcomes for all twelve summary variables including perceived productivity are shown in Figure 3 and Table 1.

Rivergreen is written up in more detail in Bunn (2007). As far as occupants are concerned, the BUS survey shows it is a good building overall, in the top quartile of the British dataset. In 2007, only one indicator - noise - scored significantly worse than the British benchmark. By 2015, noise scores had improved, as a result of changes to the internal layout and treatment of noise-reflecting surfaces. Most of the other scores were maintained over the 8-year period, apart from wintertime conditions, which deteriorated. The scores for *Image* are an order higher than the others: where a building is distinctive, respondents tend to give this higher ratings. Conversely, in common with many recent British buildings, the rating and benchmark for *Health* tends to be lower. The comments on perceived productivity reflect the ratings: "This is a relatively comfortable place to work and I don't have a need to fiddle with the controls to try and find a comfortable temperature". However, "Productivity drops in summer because of the higher temperatures".

Rivergreen is a naturally-ventilated office. Like many other UK office buildings today, occupant densities have been increasing. It is also relatively rare: most recent UK offices are deeper in plan form, requiring greater management intervention to keep on top of the heating, cooling and ventilation, with all the increased complexity of the technologies required. We might speculate: "Is the performance of simpler, shallow-plan buildings like Rivergreen less likely to deteriorate over time?", but there are not yet enough longitudinal studies to test this hypothesis. What we do know from case studies is that performance of complicated, highly-serviced buildings can collapse suddenly if economies are made on maintenance and facilities management.

A rare longitudinal study of a naturally-ventilated office is the Woodland Trust's headquarters, Bordass et al (2014) . Here feedback from detailed studies of an earlier building by the same design team: the National Trust's Heelis building was used to inform design and management practices [Nevill, (2007)]. Its design philosophy was similar to the Rivergreen's - "Keep it simple,

and do it well" - an approach that post-occupancy studies have consistently shown to work but many projects sadly lack. The Woodland Trust had better energy performance than Heelis, especially for heating and lighting; good quality at a normal cost (£1,800/m^2) and occupant satisfaction levels above British benchmarks on 10 out of 12 indicators. The exceptions were *Noise,* and *Perceived Health.*

One comment from the Woodland Trust 2012 survey is worth quoting fully:

> "As I am home based and (only) come into the building for specific meetings, my productivity suffers little, if at all. I must be absolutely focused and productive during the time I am in the building. Long periods in the building could decrease productivity from past experience of working there full time, or it's more likely that it's more difficult to be as productive as there's a need to concentrate harder, and if I stay longer than a few hours, although my productivity doesn't decline, as I don't allow it to, I do not feel comfortable and actually begin to feel unwell again."

This observation has many of the features of interest here: a preference to work from home to permit complete concentration and escape noisy distractions; a tendency for people who use the building less to give higher ratings; and deteriorating perceptions of health from those who spend longer times in a building.

The perceived productivity score for Woodland Trust in 2012 was plus 4%, a good result. It tempts some to take such a figure, multiply it by the number of staff and their average salary, monetise the total 'gain' and promote this with an eye-catching headline. Search online by "office productivity dollars saved" and you will see a list of studies with claims of this kind. As with most modern research you must ask first: "Who is paying?". Often this will be organisations with vested interests peddling their wares. We think that monetising value like this is a step too far (see Ive (2007) for more). By all means find out the relative levels of perceived productivity and how the findings compare - better or worse than others; increasing, stable or declining - but do not gild the estimates with spurious authenticity. It is enough to know that the likely gain is 4% (not 4.09%, there is no need to take everything to two places of decimals). Perceived productivity is a relative indicator - it works as a nominal or ordinal statistic (i.e. this is better than that, this is placed here on the scale compared with others), but when used as an absolute real or ratio figure (4.09% , 95%) it loses traction.

The Heelis, Woodland Trust, and Rivergreen are all examples of buildings that work relatively or very well, and are future-proofed to some extent [Endnote 6] . Their performance may well decline over time, but any fall-off is likely to be slowed because they possess many of the features listed in the following sections.

What of buildings that work less well? We can often learn more from these than the better ones (it is easier to improve building performance by getting rid of the poor features than by adding good ones to a flawed chassis), but these are much less likely to reach publication. For example, recent occupant survey results from an Australian building with a 'five-star' GreenStar [Endnote 7] rating (which suggests it is energy efficient and has many features lauded as 'sustainable') revealed that its occupants think less well of it, with perceived productivity scores of close to minus 10 per cent. We may privately know why such buildings are failing by users' criteria, but the findings are unlikely to reach publication, because they will reflect badly on the developers, owners, designers and management, and the fear is that they will damage professional reputations.

So it cannot be assumed that just because a building rates highly in a tick-box, feature-rating system such as BREEAM, LEED or GreenStar, or is given plaudits and awards for its architectural design, that it will work well for its occupants or for the environment. In fact, awards often give the impression that buildings work well, but rarely take advantage of an assessment to check whether this conclusion is justifiable. Users often know better and can be very insightful about things going wrong. For example, comments from the poorly-performing but glamorous building mentioned in

the previous paragraph: “Too much focus on aesthetics and not enough consideration of functionality … Wasted space for strange-shaped rooms … Privacy is entirely lacking … Goldfish have more privacy.” A UK award-wining school was rated very poorly by the staff, while a student said: “The architecture showed next to no sense. It leaked in the rain and was intolerably hot in sunlight. Pretty perhaps, sustainable maybe, but practical it is not”.

User perceptions can be paradoxical. For example, questionnaire responses may reveal that a building is too hot in summer and too cold in winter but occupants regard overall thermal comfort as OK. This contrariness might baffle survey methodologists who want consistent answers, but it is quite normal. Occupants may nit-pick with their criticisms of the details of humidity, glare and noise, for example, but then say: “We quite like the way it looks, we feel better for being there, and it’s much nicer than where we were before.” We calculate the difference and call it “forgiveness”: users may tolerate some drawbacks as long as they are compensated in some way. For example, occupants will be happier if they have personal control with some elements of choice (e.g., too hot with the window shut or too noisy with it open, but not both together) - what is known as adaptive opportunity. In the Australian building described earlier, the “forgiveness” score was at the 25th percentile in comparison with the rest of the dataset (that is, in the bottom quarter in comparison with the rest of the dataset), so despite the sparkling aesthetics, the occupants did not think good looks compensated them for the building’s failings.

The Killer Variables - twenty years ago

A “killer” variable is one that has a critical influence on the overall behaviour of a system. The original version of this paper - Leaman and Bordass (1997) [Endnote 8] - related to workplaces, particularly offices, and identified four clusters of variables, outlined below.

1. **Personal control**
   Research in the 1970s revealed that the range of conditions occupants found “comfortable” was wider in field studies than in the laboratory. Avoiding discomfort appeared more important than providing comfort, with people more tolerant of conditions where they had more opportunities for control - windows, blinds, switches, thermostats and so on. This later became known as adaptive comfort theory, which also includes control over personal situations: e.g. where people are not tied to a specific workstation or bound by a dress code. Perversely, the trend in buildings was towards automatic systems that took control away from occupants. In the late 1980s we discovered that, if not well-designed, built, maintained, managed, and cleaned, buildings of this kind could easily end up as “sick”, particularly the deep plan ones.

2. **Responsiveness**
   If personal controls work well, one attribute is system responsiveness: you make an adjustment and conditions rapidly begin to change for the better. In the early 1990s, we began to find the occasional building where occupants reported relatively high degrees of control, even though few control devices were available to them. The reason turned out to be proactive facilities managers, that responded rapidly to occupant needs (e.g. if telephoned), and sometimes even learnt to make adjustments in anticipation. Responsiveness is not restricted to environmental controls, but anything that may need adapting to meet changing needs, e.g. reconfiguring furniture and spaces. Sometimes this is physically difficult (with triangular rooms, for example), or where organisations adopt a completely uniform workstation standard, although space requirements may differ substantially with task, e.g for surveyors needing to look at large drawings and marketing people working with samples. Sometimes problems are administrative, for example in some Private Finance Initiative (PFI) buildings, even simple changes have to be made by the contractor not the occupier; and delay, misunderstanding and high cost often stops people requesting them.

3. **Building depth**
   In deeper-plan buildings, scores for occupant satisfaction and productivity tended to go down. Greater depth correlated with more complication, presence of air conditioning, less personal control, and more dependence on facilities management, which was often slow to respond to occupants, particularly in public sector buildings. Naturally ventilated buildings tended to perform better, with shallower plans, more window seats, more personal control and less dependence on management. However, we warned that the "green" trend to introduce natural ventilation into deeper-plan buildings might not necessarily carry the perceived benefits of natural ventilation with it, because the occupant satisfaction problems associated with air conditioned buildings were more to do with depth, complexity and management than the air conditioning itself.

4. **Workgroups**
   In offices, perceptions of productivity were higher for smaller and more integrated workgroups, either in their own rooms, or in clusters within an open-plan space. An important reason for this was seen to be the "mapping" between the workgroup's activities, and the available environmental controls. Where the relationship is one-to-one (i.e. everything coincides, as it often does in a single room) the sole occupant will have full control over lighting, blinds, ventilation, heating, cooling, privacy and noise, and can fine-tune these to suit their needs. While this is no longer possible for a workgroup, its members are more likely to come to an agreement: indeed, sometimes we found workgroups using environmental controls - particularly lighting - to reinforce group identity. Overheard conversations by other members of a workgroup may also convey useful information, while noise from unrelated groups may well be regarded as intrusive and distracting.

As is apparent in the discussion above, the four variables are inter-related, and can combine in vicious and virtuous circles. In well-designed and well-managed buildings, we found positive associations between comfort, perceived productivity and energy-efficiency [Bordass et al (1995)] . Conversely, the "sick" buildings common in the 1980s and 1990s [Endnote 9] exemplified vicious circles of associations and causes: an extreme example being the infamous Inland Revenue building in Bootle, Lancashire (BBC News (2001), which was eventually demolished after all attempts to rectify endemic problems failed. Initially researchers, using large-sample statistical studies, blamed air-conditioning as the "cause", but this turned out to be wrong. There was no single design or management problem, but a system of interactions that spun out of control - including deeper-plan spaces with air-conditioning, little or no occupant control of comfort conditions; lack of natural light and outside awareness; complex and poorly-maintained building services technology that often did not work properly; and facility managers who lacked both the diagnostic skills to put things right and adequate resources to do so.

The lack of a single cause was the reason why so many of these buildings never improved: it was a question of systemic failure. Many of us will have experienced something similar. In an empty room, conditions may not be exactly to our liking - it might be too cold - but may well be tolerable. As more people come in, the room gets warmer and noisier, and perhaps more convivial. At some point the room's carrying capacity - its ability to support the needs of those in it (like face-to-face conversation) - reaches a threshold, which will vary for different people. Things become uncomfortable, too hot, too noisy for reasonable conversations, and too crowded, at which point people may try to leave or at least move to a cooler or quieter spot.

A version of this is played out in many office buildings around the world. Physical and organisational constraints often mean that flexibility and adaptability is poor. Increasing or reducing densities is one of the few variables that may be manipulated in the short term - but increased density may take the building over its carrying capacity threshold. Meeting rooms may be converted into desk zones, touch-down workstations introduced (perhaps breaking up working group propinquity), storage areas reduced (or taken offsite), and primary circulation compromised with the original design intent ignored. Users' objections will be over-ridden. A well-regarded building may deteriorate quickly.

The Killer Variables - ten years ago

In the second edition of this book, we expanded item 3 into “Ventilation type and building depth” and added a fifth variable:

5. **Design intent**, and how it is communicated to occupants By design intent we mean how designers expect particular features to work, how they should be used or operated; and how users interpret this. In practice:

    - Some features might work well if they were actually used. However, occupants do not always appreciate what they are for, perhaps because the item cannot be seen (e.g with natural ventilation through grilles); its purpose is not clear (e.g. trickle ventilators in office and hospital windows, often present but rarely used); nobody explained the intent (e.g. staff in open-plan offices may not know they are free to use the cellular offices as quiet rooms); or there may be cultural problems (e.g. staff reluctant to use quiet rooms for fear that managers will think they are not at work).

    - Some features may need insight to use, which in turn may require explanation and training. This applies not just to electronic controls (lighting controls are too often incomprehensible) but to much simpler things like windows. For example, in a thermally massive building the design intent might be to close windows during the day and open them at night in hot weather: however, occupants may not understand this, or security and cleaning staff may close them anyway.

    - Some may be unusable, for example where insurers do not allow windows intended for night ventilation to be left open. In one case - a university library - automatic ventilation primarily for night cooling was switched off by management because of fears that students would steal books by throwing them out of open windows to their co-conspirators below!

Donald Norman, writing about everyday artefacts generally [Norman (2013)] identifies the “design model”, “user’s model” and “system image”. Designers tend to know why things are how they are, and may assume that users will see things the same way. But users’ mental models are often very different: even when conversing with designers they may not share the same system image. Design intent should be made crystal clear: Norman argues that if this is not possible intuitively, then ideally people should only need to be told once. Clarity of design intent is also associated with other effects that improve building performance and the productivity of occupants, including:

- People are more forgiving of sub-optimal conditions when they understand the design intent. We first became aware of this when studying recently-completed office buildings designed for and occupied by research organisations and design practices. The clients for these studies expected the occupants - being designers themselves and thinking that they could have done better and sometimes having said so - might be particularly critical of items that did not work quite as well as anticipated. In fact, the opposite was true, possibly because the occupants understood the design intent better and were more tolerant as a result.

- Virtuous circles, where understanding of design intent helps buildings to become better in multiple ways, e.g. with both low energy use and high perceived productivity. Here we have identified two main influences: 1). Design intent tends to be easier to understand in buildings that are intrinsically simpler (e.g. shallow-plan with openable windows), have more components that users can adjust themselves, and where users can clearly perceive the outcomes of their actions. 2). Design intent is more likely to be carried through to operational reality where special care has been taken in briefing, design, construction, commissioning and subsequent management and monitoring. We therefore helped to develop the Soft Landings process [Way and Bordass (2007), Way et al (2009)] to make these outcomes more likely.

Buildings that work well

Our five killer variables still appear valid. In rather different words, buildings, especially offices, appear to work best for occupants when the following are present:

- ***Comfort and Control.*** An environment that is comfortable for the most of the time, with plenty of opportunities for changing things should conditions deteriorate.

- ***Usability***. Clear communication of design intent, so users of all types (not just permanent occupants) understand how things are supposed to work, can intervene to make changes if necessary and get rapid feedback on whether or not the change required has occurred.

- ***Rapid response*** in meeting immediately perceived needs, not necessarily by having good local control devices. Other strategies include the ability to move about and the responsiveness of management to requests for changes.

- ***Shallow plan*** forms, preferably demanding less technically complex and less management-intensive systems (with the added benefit of better energy performance).

- ***Natural ventilation*** of some sort. Some of the best buildings we have reviewed incorporate mixed-mode schemes in which properly integrated and managed mechanical systems are able to supplement or replace the natural ones when necessary. However to create a good mixed-mode system needs care in design, construction, commissioning and operation which are often lacking.

- ***Zoning and density***. Activities that properly fit the spaces and services that support them, not only in spatial capacity (e.g. enough room for everyone, well-integrated workgroups), but for zoning and control of heating, cooling, lighting, ventilation, noise and privacy.

- ***Proven low energy use***. Apart from the obvious benefits of lower emissions, this tends to be associated with better briefing, procurement, management and monitoring, which is also likely to lead to better human performance in the workplace.

If you want accurate and believable feedback to help designers and managers improve the next generation of buildings, we think the above list would be a good starting point. However, this is not enough for some. They want proof. Unfortunately, this may lure researchers into the territory of large-sample surveys, physical measurement, statistical modelling and simulation, the scope of which may be hobbled by onerous methodological and inferential requirements. Too often, uncertainty generated by too much emphasis on theory and method create interpretational barriers which designers, in search of practical advice, find hard to negotiate.

We prefer to start with case studies of real buildings in use, apply tried-and-tested methods to extract indicative and diagnostic information, and only rarely go deeper into further investigation and measurement. This “drill-down” strategy takes you only to the level of detail you need. You do not collect too much information unnecessarily, or create a muddle with too many results. Flybjerg (2006) is an excellent justification for the misunderstood virtues of case studies.

For example, an occupant survey may tell you that perceived productivity is low, as in Figure 4, where the average score for the study building is six percentage points below that typical for others in the dataset. From the comments boxes in the questionnaire, it is clear that traders are dissatisfied with a new market hall, in particular the high ambient temperature and a low footfall of customers: the two may even be related. The levels of proof required depend on circumstances of the investigation and what you are trying to do. For design and management diagnostics, the information already collected on the market hall may be enough, particularly as it is an unusual

building type, for which there may be little comparative information. The next steps would probably be to investigate the reasons for overheating and to carry out a survey of the shoppers who do visit and perhaps do not visit the hall to discern the reasons for the low footfall.

For more detailed academic studies, stricter criteria may apply. (e.g. Robson (2011)). Whatever prevails, we think the most fruitful approach is a case-study building visit coupled with straightforward data-gathering, preferably based on direct contact, interview and measurement. Working remotely with, for example, internet-based occupant surveys or 'smart' metering databases may miss gross anomalies, especially if data cannot be double-checked and resolved.

The increasing emphasis on finding proof may be leading researchers up blind alleys. Take, for example, two growing productivity killers in office buildings - noise and increasing occupant densities. These are related: a trend to more intense use leads to higher occupant densities in open-plan offices, so noise and unwanted interruptions increase too. In the worst cases, high density may also be associated with higher temperatures, poorer air quality, less cleanliness, perceptions of unhealthiness and other knock-on effects. A vicious circle of deterioration has started, which may become increasingly difficult to reverse. A solely statistical approach will miss such dynamics, unless backed by on-the-ground case study investigation.

What has changed since the 1980s?

In the past quarter century we have identified the following trends.

- **Control**. Occupants tend to have less control because more and more systems are automated, despite evidence that occupants are happier when they can intervene for themselves. With smartphone interfaces, this might now be changing - but there is a danger that systems might then become too complicated and difficult to manage.

- **Facilities management and maintenance.** In the 1980s, many of the "sick" buildings we surveyed were poorly managed, maintained and cleaned. The 1990s saw considerable improvements, but since then things seem to have stalled. Reasons include cost-cutting and a trend to outsourcing - so often facilities management contractors do not fully understand the buildings they are managing (particularly if they have unusual design and engineering features) and the occupants they are serving. After a few years some teams eventually do, but this experience can easily be dispersed when contracts are re-tendered, increasingly across whole organisations at 3-5 year intervals. A terrible forgetting curve.

- **Response times** also tended to improve and then get worse, as a result of this outsourcing, to companies who also turn to specialist contractors to correct faults, often adding time-lags, increasing costs, and frequently leading to the treatment of the symptoms of a problem (e.g. replacing a component), but a neglect of the underlying causes (why did it fail?). One aspect of responsiveness has however improved: in modern workspaces, occupants (or at least some of them) have more opportunity to move around and so escape from an uncomfortable environment to somewhere different.

- **Deeper plan forms** are widespread, which is leading to more complaints of noise, unwanted interruptions and a lack of perceived control, and makes natural ventilation more difficult to engineer, at least at an economic cost.

- **Natural ventilation** is not achieving its potential, even in shallower buildings. Where present, there are often shortcomings in window design, control and excessive heat gains. If well executed, mixed-mode buildings may offer the best of both worlds, but they are still rare. There seems to be a lack of design and management expertise, and perceptions that natural ventilation and mixed-mode systems are riskier, too expensive or too much trouble. This applies particularly in the (growing) rented sector, which needs to accommodate a

wide range of tenants, and in spite of arguments for the greater flexibility of mixed-mode.

- **Zoning and workgroup integrity** is breaking down under intensification of use.

- **Energy and environmental rating schemes** are commonly treated as tick-box compliance at the design stage, rather than underpinning root-and-branch reform of management attitudes and practices to achieve better performance in use based on proven outcomes.

One thing that has definitely improved is user satisfaction with natural and artificial lighting. We first started noticing this in about 2000. The main reason was not the lighting itself but the arrival of flat computer screens. The older cathode-ray (CRT) screens were curved, so could pick up reflections from anything, particularly windows and light fittings, while LCD and LED screens could often easily be angled away from the sources of glare.

The change in screen technology also had a big impact on the layout of open-plan offices. CRT screens tended to be tucked into the inner corners of cruciform or triangular workstation clusters, so some screens almost inevitably picked up glare from the windows. With LCDs, workstation clusters could become long benches perpendicular to window walls - reducing glare but allowing occupation density to be increased.

Why aren't we doing better?

We have defined some circumstances under which people respond well in buildings and the environmental gains that can result. So why is the market going largely in the opposite direction? The answers may lie somewhere in the following:

- Myth-making about workplace performance, especially the supposed efficacy of open-plan offices and the generic assumption that they increase productivity. Do people really communicate better in open-plan spaces, if we factor in their real work tasks? Some will, some won't. What about the increasing numbers that wear earphones and headsets to keep out the unwanted noise (while probably listening to something distracting)? Corporate management and designers seem to be more at ease with the concept of open-plan than the many who have to work in it.

- Increasing complication of requirements, process and products, with deliberate over-complication often cynically treated as a business opportunity.

- Excessive focus on capital and running costs - especially through increasing occupant densities and contracts with supplier handcuffs attached.

- Outsourcing of technical and operational skills, with the subsequent loss of in-house knowledge, experience and, in many cases, speed of service.

- Increasing virtualisation of education and design practice and enduring lack of designer engagement with consequences and outcomes.

- Professional judgement trumped by public relations veneering, suppressing feedback and protecting reputations at the expense of learning from admitted mistakes.

- Public-interest professionalism demonised as anti-competitive or elitist.

1 A memorable response from an Australian building user was: “My productivity is reduced by answering bloody stupid questions like this one”!

2 Our primary sources of data are 1) occupant surveys using the BUS Methodology and 2) investigative, empirical, building performance surveys using a portfolio of methods pioneered in the Probe series of post-occupancy studies, and subsequently developed *ad hoc*.

3. This sample of n=174 is drawn from the BUS Methodology international database and refers to those buildings which have been studied with this question. The question was added in 2010.

4 Please note: 1) the scale used in Figure 2 graphics Perceived Productivity has been changed from plus and minus 20% to plus and minus 40%. This is a cosmetic change only. The data are directly comparable as the question on the questionnaire remained the same. 2) Benchmarks change over time.

5 Please see caption to Figure 3 for details of significance.

6 For more details go to http://www.usablebuildings.co.uk/Pages/Unprotected/RIBACPDBirminghamPartThree27Nov14.pdf Last accessed Feb 2016

7 GreenStar is a feature-based rating system developed by the Green Building Council of Australia. Buildings are rated on a scale from 1 to 6.

8 Versions have also appeared in Building Services Journal, 41-43 (June 1998); Facilities Management World, 1998, September-October; Building Research and Information, 1999, Jan; chapter of Clemence-Croome D. (ed.) “Creating the Productive Workplace”, E&FN Spon, London, 2000 (First edition), 2005 (second edition); Ecolibrium (5-parts, April-September 2005) and in translation.

9 The terminology is now less brutal. Sick building syndrome is now known as building-related ill-health.

References (alphabetical)

Baird G and Dykes C., The Potential for the Use of Occupants' Comments in the Analysis and Prediction of Building Performance, Buildings 2012, 2, 33-47

BBC News http://news.bbc.co.uk/1/hi/england/1688081.stm Last accessed Feb 2016

Bordass W., Burgon P., Brough H. and Vaudin M., Trees of Knowledge, CIBSE Journal, Oct 2014, pp 20-26.

Bordass W., Cost and Value: Fact and Fiction, Building Research and Information 28 (5/6) 338-352, 2000.

Bordass, W., Bromley, A., and Leaman, A., Comfort, Control and Energy-Efficiency in Offices, BRE Information Paper 3/95, February 1995.

Bunn R, Tales from the Rivergreen, BSRIA Delta T, October 2007 pp 12-16. Downloadable from http://www.usablebuildings.co.uk/Pages/Protected/RivergreenCentre.pdf Password required for copyright reasons. Last accessed May 2016.

Bunn R., Making Performance Visible, Research for EngD thesis, 2016, private communication.

Bunn R., Occupation satisfaction signatures: Longitudinal studies of changing comfort perceptions in two non-domestic buildings, CIBSE Technical Symposium, Edinburgh, UK, 14-15 April 2016.

Economist Intelligence Unit, Out of office: an overview of workplace absenteeism in Europe, London, 2014

Flybjerg B, Five Misunderstandings About Case-Study Research, Qualitative Inquiry, Volume 12 Number 2, April 2006 219-245

Ive G., Re-examining the costs and value ratios of owning and occupying buildings. Building Research and Information (34(3), 2007, pp230-245.

Leaman A. and Bordass W., Productivity in Buildings: the Killer Variables, Workplace Comfort Forum, London, 1997, October 29-30.

Lorch. R. http://www.usablebuildings.co.uk/Pages/BRIArticlesForUBTFeb2016.pdf Last accessed May 2016

Nevill, G., So, how are you doing?, CIBSE Journal, 32-37, November 2007.

Norman D., The design of everyday things, Second Edition, New York: Basic Books, 2013.

Oseland N., Environmental factors Affecting Workplace Performance: a review of the evidence, Chartered Institution of Building Services Engineers (CIBSE), Technical memoranda TM24, 1999.

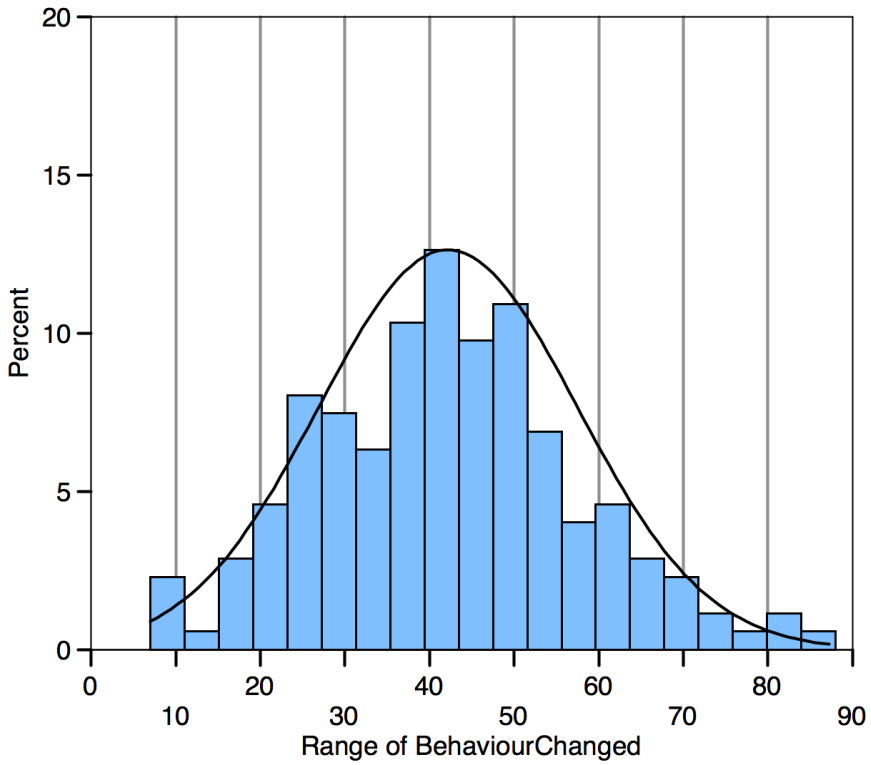
Robson C., Real world research : a resource for users of social research methods in applied settings, Wiley, 2011.

Way M. and Bordass W., Making feedback and post-occupancy evaluation routine 2: Soft Landings - involving design and building teams in improving performance. Building Research and Information 33(4), 2005, pp 353-360.

Way M, Bordass W, Leaman A and Bunn R, The Soft Landings Framework, BSRIA BG 4/2009, Building Services Research and Information Association (BSRIA) and Usable Buildings Trust, UBT) July 2009.

Figure One

Distribution of surveyed occupants who say that they change their behaviour as a result of conditions in the building

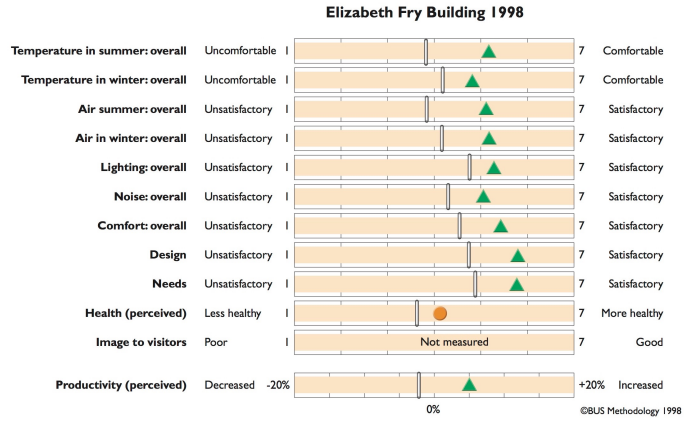


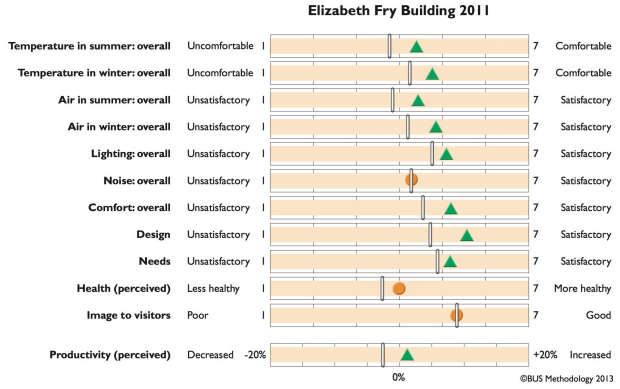
The distribution of percentages of respondents who say that they change their behaviour as a result of conditions in the building. Data drawn from a sub-set of UK buildings in the BUS Methodology dataset.

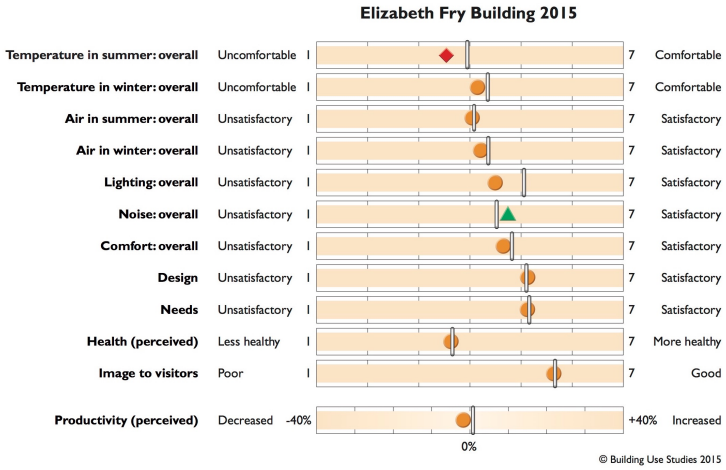
Mean of distribution = 42.1%; median = 42%; SD = 15.3 ; Count = 174.

Figure Two

‘Fingerprints’ of BUS Occupant Survey Summary scores for the Elizabeth Fry building. [Endnote 4.]



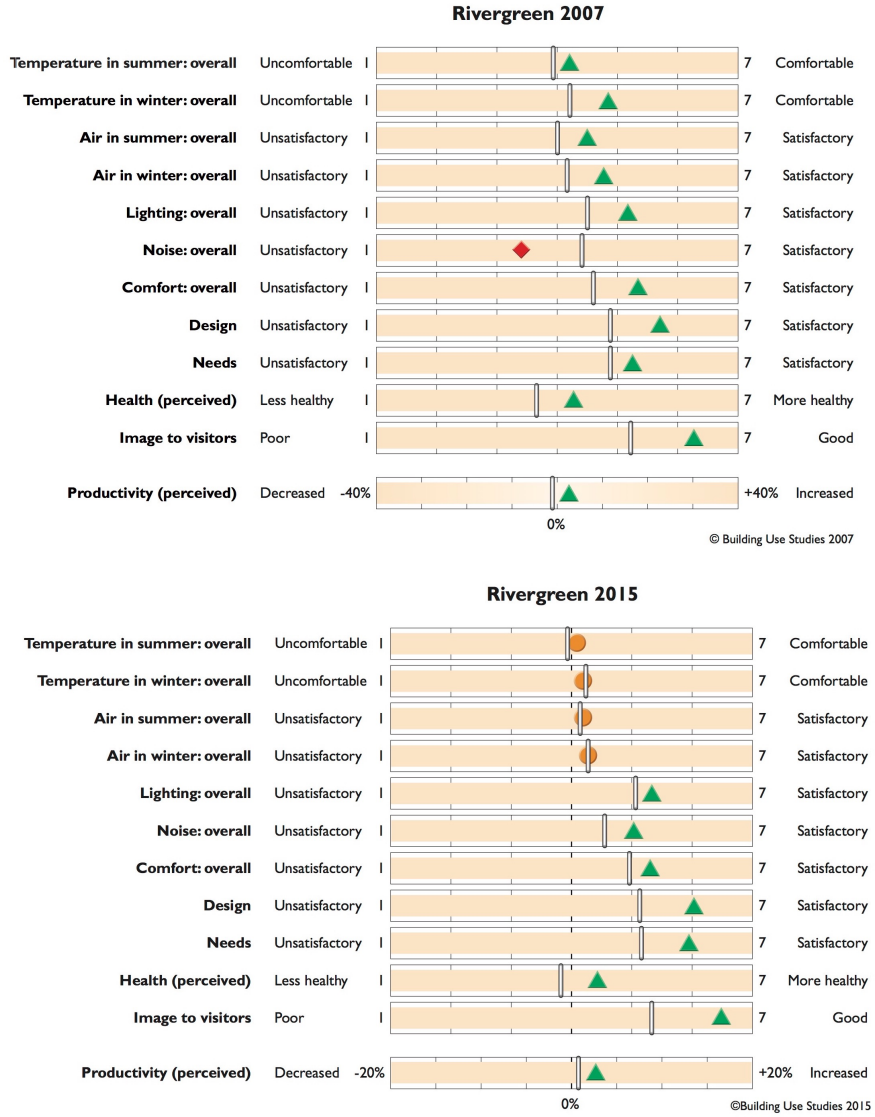




Graphics kindly supplied by Roderic Bunn. These are redrawn from the original BUS survey outputs. Triangles indicate scores better than benchmark; circles are scores no different from benchmark; diamonds are scores lower than benchmark. Benchmarks differ from year to year.

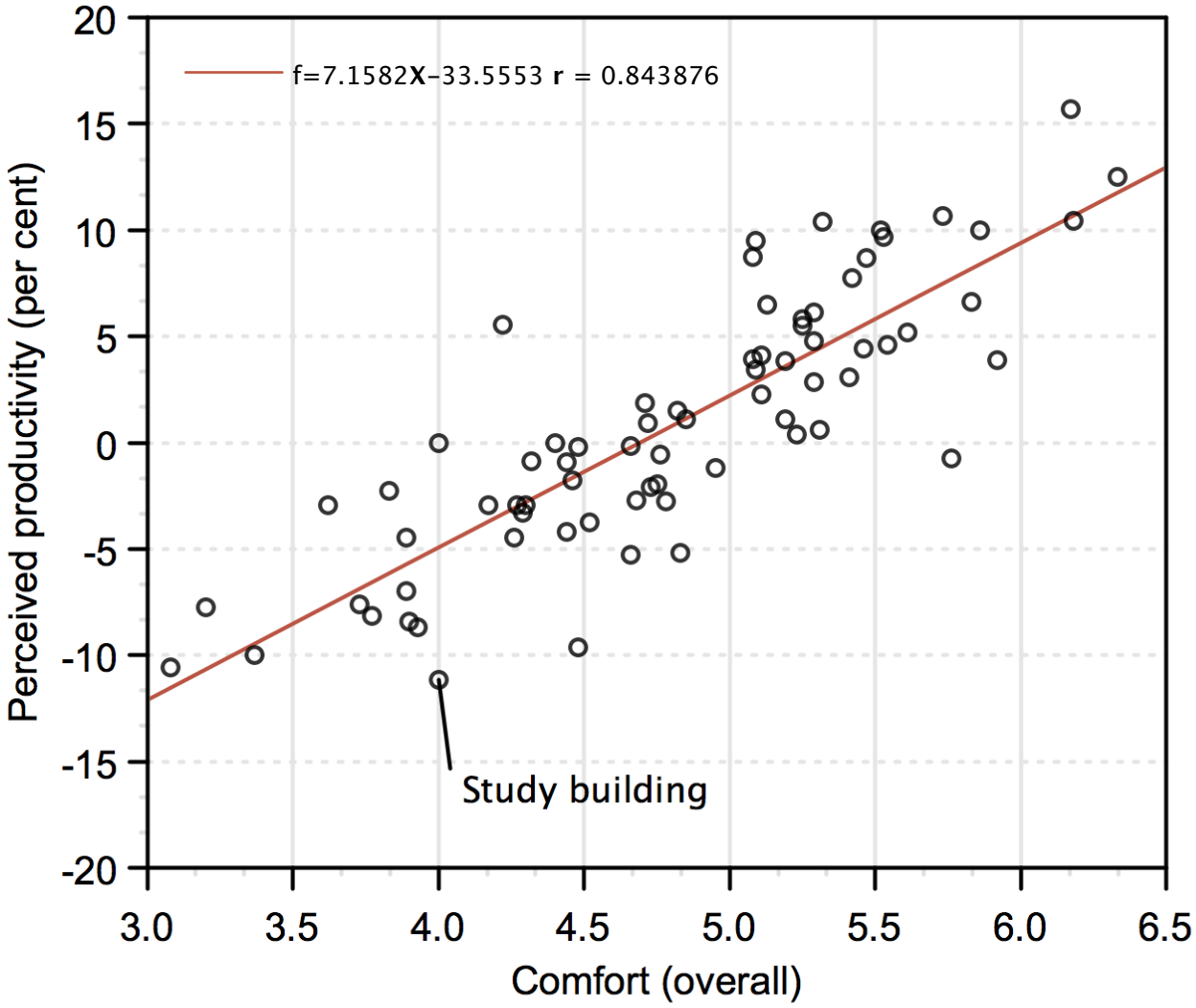
Figure 3

Rivergreen Centre: Longitudinal survey scores for 12 principal survey variables, 2007 and 2015.



Graphics kindly supplied by Roderic Bunn. These are redrawn from the original BUS survey outputs. Triangles indicate scores better than benchmark; circles are scores no different from benchmark; diamonds are scores lower than benchmark. Benchmarks differ from year to year.

Figure 4: Expected levels of perceived productivity



Perceived comfort overall score means by building (horizontal axis) plotted against mean perceived productivity scores (vertical axis) for UK buildings from BUS 2014 dataset.

The study building highlighted is scoring six percentage points lower than might be expected from the distribution overall.

Table One: Rivergreen Centre 2007 and 2015 comparisons and outcomes

Variable	Mean 2007	SD	SE	SE x 1.96	Lower	Upper	Mean 2015	Outcome
TSOver	4.24	1.69	0.19	0.3724	3.8676	4.6124	4.15	Same
TWOver	4.89	1.63	0.16	0.3136	4.5764	5.2036	4.21	Worse
AirSOver	4.54	1.53	0.17	0.3332	4.2068	4.8732	4.28	Same
AirWOver	4.81	1.74	0.17	0.3332	4.4768	5.1432	4.4	Worse
LtOver	5.19	1.7	0.16	0.3136	4.8764	5.5036	5.28	Same
NseOver	3.44	1.86	0.18	0.3528	3.0872	3.7928	5.03	Much better
ComfOver	5.35	1.44	0.14	0.2744	5.0756	5.6244	5.29	Same
Design	5.78	1.16	0.11	0.2156	5.5644	5.9956	6.02	Better
Needs	5.23	1.6	0.16	0.3136	4.9164	5.5436	5.83	Better
Health	4.29	1.51	0.15	0.294	3.996	4.584	4.4	Same
Image	6.32	1.08	0.10	0.20	6.124	6.516	6.5	Same
Perceived productivity	2.16	15.07	1.49	2.9204	-0.7604	5.0804	4.78	Same