User and Occupant Controls in Office Buildings

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Summary

Modern control and energy management systems promise to improve individual comfort and reduce energy consumption at the same time. However, fully automatic control is only part of the answer: the user interfaces also need to be better understood. BRE studies have revealed that:

i   Control systems need to be matched more closely to the way in which buildings are actually used and managed, particularly in multi-tenanted buildings. Otherwise systems tend to be left on "just in case", causing considerable energy waste, particularly with air-conditioning.

ii   Individual occupants require systems not only to provide comfortable conditions but also to respond rapidly to alleviate discomfort when it is experienced. Air-conditioned buildings tend to be short on the latter, which may help to explain why occupants often seem less satisfied with them than one might expect.

iii   With suitable management, today's controls can already deliver high levels of comfort and energy-efficiency. However they and the systems they control are often too complex for the average user, and need to be designed for better and easier manageability.

BRE will be taking these studies further and using their findings to develop design guidance.

Introduction

Modern control and energy management systems offer the potential to improve individual comfort and reduce energy consumption at the same time. However, fully automatic control may not be the complete answer. Studies of building-related ill-health (for example the Office Environment Survey, "OES", reference 1) reveal fewer symptoms and greater productivity as the perceived level of individual control increases (Figure 1). For energy efficiency, BRE is finding that the more advanced control systems do not always stop building services running wastefully and unnecessarily, and in some circumstances can act as barriers rather than aids to effective operational management. Overall, there appear to be problems with the user interface, both for the individual and for building and organisational management.
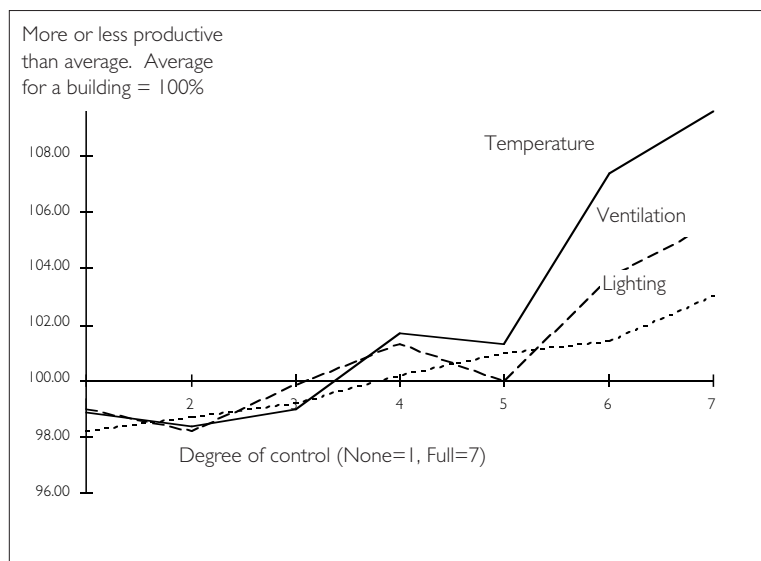

Figure 1 Productivity versus degree of control

The ways in which controls in buildings are actually perceived and used by people (both management and individuals), although vital to performance and to human comfort, seems to have been little researched and is usually treated only incidentally. Textbooks and guidance material tend to present a "process control" viewpoint, implying that controls only need to be designed, installed and commissioned in the engineering sense ("to keep the measured variables within the required tolerances") to do the job properly. General texts on systems behaviour (for example: reference 2), however, present a more holistic view. They review the context in which controls are used, the interactions between different types of

control operating simultaneously, and the operational requirements of the user interfaces; they also recognise that users will want to alter the targets the systems are asked to achieve. Systems should therefore not only:

1 keep the measured variables within suitable tolerances, but also
2 be able respond effectively when, for one reason or other, the measured variables or the set parameters become regarded as unsatisfactory.

When systems design is overly influenced by the first point above, building users often come to be regarded as uninformed and sometimes malicious nuisances, who must have as much control as possible taken away from them. The second point, however, makes users integral to the system. They do, after all, set the systems objectives and close many of the feedback loops. The wish to take users out of the system may have developed in an attempt to make life easier for the building manager. However, the opposite seems to happen: less local control, more discomfort, and more management time to respond to complaints. But is today's siren call of "more individual control" the full answer? What types of control do occupants really want, how should it be provided, and will it create new problems? And in the "green" buildings of tomorrow, will occupants welcome the additional automation of natural light and ventilation now advocated to improve comfort standards and to reduce energy consumption?

There has also been a tendency to consider controls in isolation, but the effectiveness of a control device is often influenced by the context in which it is found. This applies not only to automatic systems, take a window blind, for instance. It might be intrinsically difficult to operate; or it might be hard to use because its cord was designed for a vertical pull but has to be drawn forward because there is a desk in front of it; or it might conflict with other elements, for example cutting-off ventilation.

The context change between individual rooms and the open plan can be great. In the open plan the one-to-one relationship between the occupant and the various control devices: the window, the blind, the light switch, and the radiator valve tends to vanish, making effective individual control much more difficult. Occupants are well aware of this, as shown in figure 2, which is based on data from reference 3. The open plan also tends to be more energy-intensive, see reference 4, and not just because it tends to be deeper and require more artificial lighting and air conditioning. With less

well-defined control interfaces systems are more likely to operate inefficiently, be left on unnecessarily, or have to be on when only a few people are there.
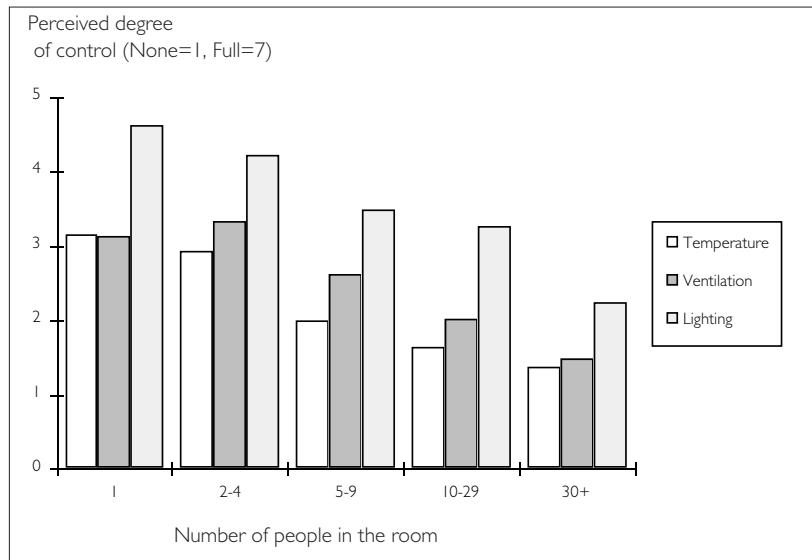

Figure 2 Perceived control versus room size

The current project
To help identify how things might be improved, BRE is looking into the relationships between building design, building management, control systems and energy performance. The work forms part of DoE's Energy-Related Environmental Issues (EnREI) programme, which aims to reduce atmospheric carbon dioxide emissions associated with energy use in buildings. So far there have been two sets of field studies.

The first study started in late 1991. Six office buildings were investigated by a team of social scientists and engineers, using questionnaire surveys of individual occupants, structured interviews of building management staff, professional assessments of the control installations, and energy survey techniques. The buildings were chosen to illustrate a diverse range of occupancies, qualities, servicing and management. All were completed in the 1980s and were predominantly open plan, with relatively small proportions of cellular offices, and questionnaires were undertaken in the open plan areas. Some questions on comfort and control were identical to those used in the OES, for comparability with this large survey of nearly 5000 people.

Meanwhile, two other technical projects in the EnREI pro-

gramme: Passive Solar and Air-Conditioning and Minimising and Avoidance of Air-Conditioning, had found that some measures advocated to improve comfort and to save energy were very sensitive to assumptions on how the controls were actually implemented and operated. Their field studies also revealed that controls were not always operating in the manner anticipated, for instance windows intended to provide good daylight had the blinds closed and/or the lights on. In 1991 BRE has also found control problems in offices designed to use thermal mass and/or night ventilation for summer cooling (reference 5), where summertime temperatures and energy consumption were generally higher than anticipated, though not always uncomfortably so.

In the second study, ten of these case study buildings were visited, the management interviewed, and impressions recorded. In five of them questionnaire surveys were also undertaken. The emphasis was on naturally-ventilated buildings and on the relationship between the individual and local control systems, and particularly features such as the openable window, electronic lighting controls, and automatically-operated solar blinds, which are currently being advocated for low-energy offices. More advanced controls, such as occupancy-sensed, dimmed, and telephone-switched lighting have yet to be studied.

While the sample size is still small and the analysis not complete, the preliminary results are interesting. Some key points are outlined below: many of them are only hypotheses yet to be tested by further analysis and future surveys, but they do seem to have a ring of truth to them.

The overall pattern

7-point scales were used for questions on perceived comfort and control: comfort ran from 1=unsatisfactory to 7=satisfactory and control from 1=none to 7=full. Figures 3 and 4 show the sample average scores for the eleven buildings surveyed. Buildings 1 to 5 at the top are air-conditioned, buildings 6 to 10 naturally-ventilated. In each group, the buildings are sorted in order of their annual energy cost for building services, with the highest consumers at the top. As it happens, all the lowest-energy buildings are pre-lets. Although this may be a maverick result, it does suggest that strong, well-informed clients may be able to influence the market in a positive manner.
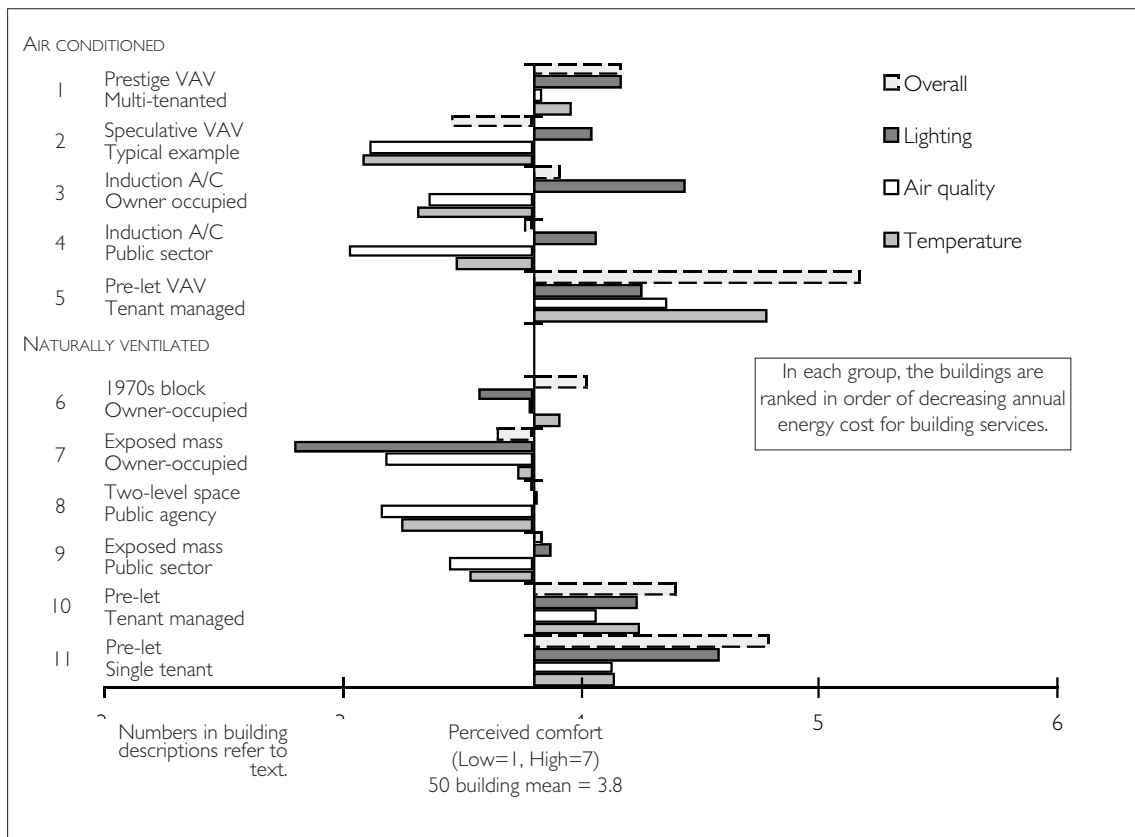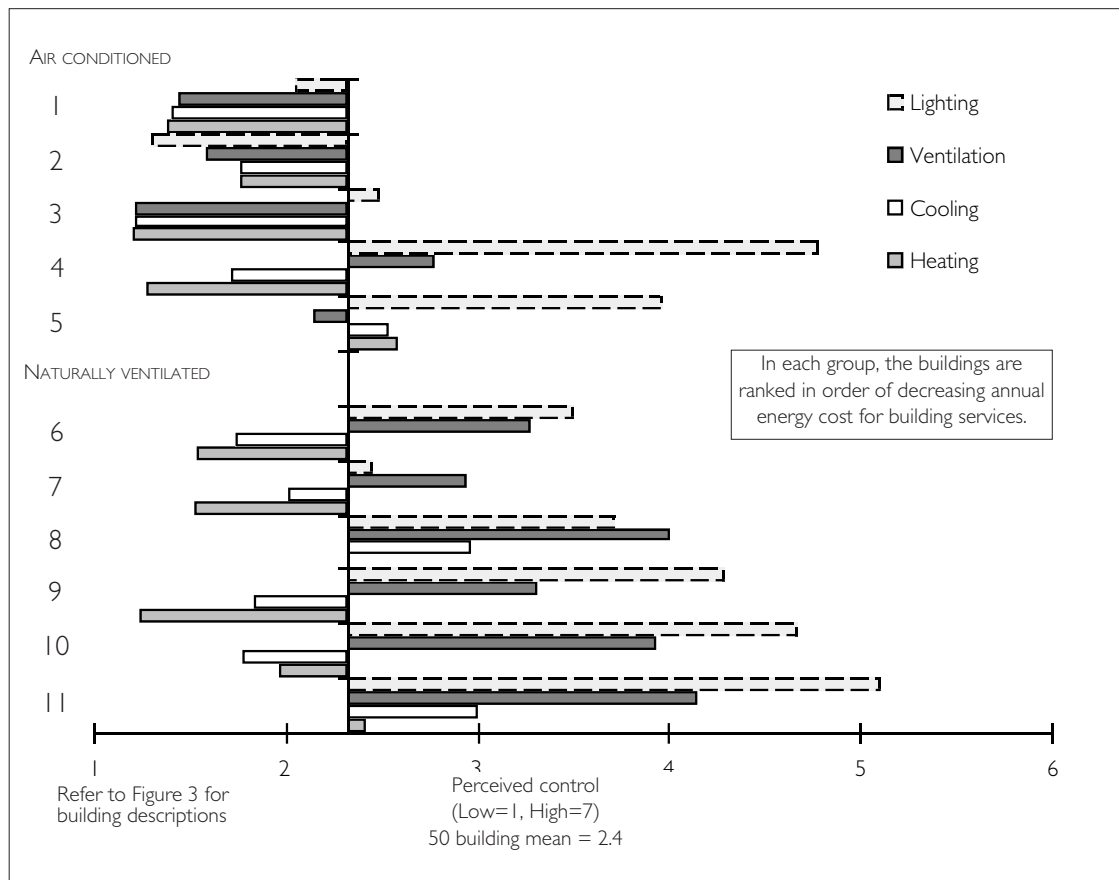

Figure 3 Perceived comfort

Figure 4 Perceived control

For clarity, figures 3 and 4 show the scores as positive and negative deviations from the whole-sample averages. The patterns are interesting:

i   Average comfort and control tends to be higher in the lower-energy buildings.

ii Across the sample, there is little difference in overall comfort between the naturally-ventilated and the air-conditioned buildings. However, the two least comfortable buildings (2 and 4)   and the most comfortable (5) are air-conditioned. Love it or loathe it?

iii The naturally-ventilated buildings show higher degrees of control, but really only for lighting and ventilation. Only two of them showed above average control of cooling.

iv The naturally-ventilated offices with poorer ventilation scores had poorer window design. However, even in those with good scores, the windows could have been far better, especially for summer night ventilation and for draught-free cross-ventilation.

v The buildings with good lighting control tended to have individual manual or electronic controls. Of the best, Building 11 had individual infra-red dimmers, building 5 ceiling pull switches, and Buildings 9 and 10 locally-switched uplighters with central over-ride.

vi Not surprisingly, Building 3 (with block central switching only) and Building 2 (with group switches by the door) had poor lighting control scores.

vii Buildings 3 and 7 scored badly in spite of having individually-controlled lighting with central over-ride. In Building 3 the individual controls had been gathered up into large gang switches when the partitions were removed in 1990. In Building 7, metal halide uplighters were not only slow to strike but their local switches were on the ballast units, inaccessibly stowed under desks. Since many workstations also required adjacent lights to be on, both control and comfort were rated as poor.

viii At 2.4, the whole-sample average score for degree of control was low, and similar to the average in the OES, so the benefits to productivity from improved control promised in figure 1 could be fairly elusive, at least in open plan offices.

In 1993 BRE hopes to extend the study to cellular offices and to the new generation of personal and demand-responsive environmental controls in open-plan offices.

Two similar buildings?

Buildings 1 and 5 were completed at the same time, are both multi-tenanted, have very similar specification and occupancy, were fitted out by the same designers, and have both been recognised for excellent facilities management. However, in spite of having heat recovery and a more advanced BEMS, the building services energy costs in Building 1 are nearly three times as high as in Building 5.

The main differences seem to be in procurement, management, and control. Building 5 was developed as a pre-let for a tenant who wanted quality, simplicity and low running costs and insisted on items (primarily a BEMS and high-frequency lighting with good controls) that the developer would not normally have provided at the time. The tenant also runs the whole building and appointed a good facilities manager with an engineering background.

Building 1 was speculative, had no energy or control brief for the fit out, and has intrinsically less efficient services (for example higher lighting loads and air-conditioning system pressures), plus third party management who have no incentive to operate the building economically. While the tenanted area is very well managed as an office, the tenants have no separate facilities to adjust settings, time schedules etc. on their floors, or to monitor operation and energy consumption, and so systems run for excessive hours, poorly-controlled.

While Building 1 has relatively good comfort scores, Building 5 is considerably better, with an overall score which is very high not only for this sample but in relation to other surveys with the same questions. It also shows a higher degree of individual control, although objectively there is no significant difference other than for lighting. It appears that the occupants are reacting positively to the good, responsive management, as discussed in reference 6.

Unfortunately, Building 1 may well be more representative, and BRE has found other recently-completed air-conditioned offices with similar energy wastage. While it is easy to blame the excessive running hours on the management of the building, the problem is actually more deep-seated. Essentially systems and controls are seldom designed and set up to suit the way in which the building is likely to be managed, as the designers, developers and occupiers do not really know exactly what is required. The comparison also suggests that requests for more individual control may also be a reaction against poor, unresponsive management. But will poor management be any better able to look after a plethora of increasingly complex control devices?

Preliminary conclusions

The results suggest that many controls do not suit management and users, so systems waste energy by running longer and less efficiently than they should. Many systems whose use should vary with demand can easily go fully-on when the requirement is only small or marginal. Once on, they tend to remain on as it is usually difficult for occupants to make rational switch-off decisions.

Control designs do not take enough account of how buildings are actually used, in the process often creating obstacles to effective management, and causing unnecessary discomfort and wasting energy. Improvements require the right designs compatible with the management environment. Simplicity and comprehensibility of control is best and there is more scope for demand-responsive controls.

Sophisticated features in automatic systems can make their operation difficult to understand. More effort needs to be devoted to alerting management when systems seem to be operating incorrectly or wastefully. For example, none of the night cooling systems monitored in 1991 made a simple check on the difference between ventilation supply air temperature and outside temperature: in practice this could be as high as 8°C owing to a whole range of problems which had not been identified until the study was done.

Perceived comfort and control appears to come not so much from the particular individual control device but from systems which can respond quickly when people find conditions unsatisfactory. Whether the response is manual, automatic or by management action is less important than its being fast and reasonably effective. Rapid, comprehensible response may help to explain reports that occupants often prefer naturally-ventilated buildings over air-conditioned ones, sometimes even when measured conditions in the latter are better. Rapid response of comprehensible systems may be at least as important as the naturalness of the ventilation itself: if
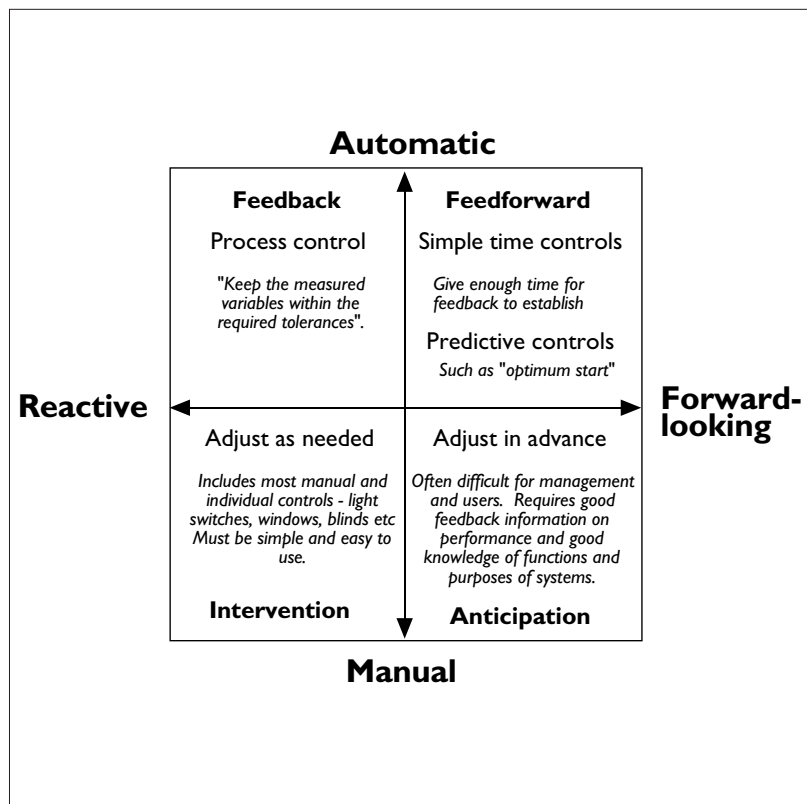
Automatic

Feedback	**Feedforward**
Process control	Simple time controls
"Keep the measured variables within the required tolerances".	*Give enough time for feedback to establish*
	Predictive controls
	Such as "optimum start"

Reactive ←——————————→ **Forward-looking**

Adjust as needed	Adjust in advance
Includes most manual and individual controls - light switches, windows, blinds etc Must be simple and easy to use.	*Often difficult for management and users. Requires good feedback information on performance and good knowledge of functions and purposes of systems.*
Intervention	**Anticipation**

Manual

Figure 5 Controls in buildings: the essential attributes

tomorrow's "green" buildings lose these attributes their occupants might no longer give them the benefit of the doubt.

Complaints about comfort and control have also been identified where people are adversely affected by the actions of others not within their immediate working group, or by automatic systems which make abrupt and seemingly capricious changes. The Phase 2 study found considerable occupant hostility to automatically-controlled venetian blinds for this reason. Those advocating fully-automatic control of natural light and glare should proceed with caution.

Figure 5 shows the essential attributes of controls in office buildings. Feedback, feedforward, intervention and anticipation must all be present for the building to perform well or excellently. Buildings are often designed to provide conditions within a certain "comfort envelope" using feedback loops (top left, Figure 5). However, if people want something different or if circumstances change for the worse, the facilities for intervention can be found wanting. While there is now talk of giving occupants more control, too much control (bottom left) may produce irresolvable conflicts which may make things worse, not better.

Designers must desist from swamping people with over-complicated or unnecessary features and think more about making systems easier to manage and use, and providing suitable feedback on system performance (bottom right). The trick is to think of the building's passive, active and human interface features as one complete system, not as unconnected entities. This way, strategic design thinking about buildings will get better, as will their comfort and energy efficiency.

Better-configured controls offer great opportunities to improve health and comfort and save energy in both existing and new buildings. However, more emphasis needs be given to systems which are designed for manageability, which operate according to need and respond to perceived discomfort, and where the range of environmental conditions available is broader and more sensitive to individuals' working contexts and preferences. BRE is currently considering how to develop guidance on this.

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