The Balance Between Central and Local Control Systems

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1 Introduction

1.1 Surveys of office users often reveal dissatisfaction over the perceived lack of control individuals have over heating, lighting and ventilation, sometimes even where means of local control do actually exist. Psychologists have observed that the human factor - for example the openable window - is disproportionately significant to perceived well-being, and sick building syndrome (SBS) may be as much the symptom of social alienation as of medical and comfort issues (reference 1).

1.2 A number of researchers into user behaviour (e.g: David Tong at last year's Conference - reference 2) suggest that automatic controls need to include the occupant within the system. However, the traditional building services engineer's reaction often goes something like this: *"We've tried all that before and it doesn't work. The engineer knows what is best. People fiddle with and mess up control systems. If you must, give them a few dummy thermostats - they'll never notice the difference!"*.

1.3 Predictions of energy use in buildings tend to assume that things in the proposed design will work perfectly: lights will be off when daylight is adequate; heating controls will adapt to make optimum use of passive solar gains; plant will be optimally efficient whatever the loads placed upon it. Meanwhile reference designs are assumed to be bone-headed. In reality, the gap often narrows: the new design not only suffers from some of the old faults but has some sophisticated ones of its own, while the reference proves to be not quite as bad as all that!

1.4 But no fear: the intelligent building is at hand! With the new generation of networked electronic building and energy management systems (BEMSs), controls can be much more sophisticated, much more integrated, with more power both centrally and locally. Now the technology and costs are such that Big Brother can control room-by-room rather than zone-by-zone. Motorised blinds (or possibly electro-chromic glasses) can respond to sunshine, lights to occupancy and daylight, heating and ventilation to occupancy and temperature levels, and all to individuals' pre-determined requirements.

1.5 But still we are not happy:

1. the sun came out and the blinds plonked down before we had a chance to enjoy it
2. now the lights have gone off too but we can see the clouds rolling-in and we'll have to get up to switch them on again soon
3. this morning it took half an hour to get through to the building manager to say we wanted it cooler - he sounded hard-pressed and cross, and now we are frozen.

1.6 So all is not well with controls. As Peter Mill has observed in the preceding paper (reference 3), we have been technology and producer-driven rather than user-driven. We jump at the techno-miracle cure rather than spending time on the diagnosis. How might we do better? In this paper I would like to give a few examples of do's and dont's, based partly on examples from my own experience of building design and energy consultancy, and partly from case studies (and also-rans) of energy use in offices which I have been working on recently for BRECSU and the EEO, together with the Davis Langdon & Everest Consultancy Group. I will then try to come to some kind of conclusions.

2 What are controls for?

2.1 I see the prime function of environmental control systems as being *to allow the equipment installed to operate to meet the needs of the users as closely as possible,* subject to three main constraints: to do so safely, reliably and efficiently.

2.2 Having coined this definition for this paper, I looked at CIBSE's Applications Manual on Automatic Controls (reference. 4), and found that their nearest equivalent was *"(to maintain) the conditions of the measured variables within the specified tolerances"*. So now we immediately understand why to the engineer the user is a nuisance: the user's views are only significant is as far as they can be - or have already been - quantified. And short of plugging-in to each person, one has to rely upon statistical averages from laboratory tests, usually of reactions of people to one variable with all others constant. But as someone once said at a conference on transportation modelling *"Does the speaker suggest that because common sense cannot be quantified, we should not use it?"!*

3 The human factor

3.1 Human perceptions of well-being are complex and include social as much as design and health issues. For example, reference 1 observes that *"individuals measure their worth within an organisation as much by the control they possess over their environment (in the broadest sense) as by expenditure, however lavish, from an invisible and unfeeling corporate exchequer"*. While the organisation and its management may be the more important determinant of people's feelings, grievances may focus on shortcomings in the building and its environment (reference 5).

3.2 But often these shortcomings are real, and while the building can't do everything, it can help a lot if it is well-designed with well-engineered, properly-controlled and managed control systems. The office case studies have revealed that:

- The most effective energy-saving systems are usually simple and unobtrusive. Indeed, where more assertive methods had been used, the results were often disappointing. By simple, I do not necessarily mean low-technology, I mean simple to understand, to use and to maintain.
- Many environmental control systems did not work as well as potentially they should: not only the sophisticated electronic ones, but also simple things like light switches, window gear, sunblinds and room thermostats.
- The better-performing buildings were not usually expensive. Good integrated design, good execution and good management were their main distinguishing features. Things which were unnecessarily complicated tended to have been ignored or by-passed.
- Perhaps the main obstacle to cost-effective energy-efficiency and sensible controls was that clients seldom asked for them, and so building teams were not united in their response to the problem.

3.3 Precise control in the engineering sense may not be what people require, and may even reduce comfort and productivity. For example (see reference 6), most people would prefer an outside window (preferably with an individually-controllable blind) to an interior position with precisely-controlled illumination: the contact with the outside, the changing view, and the changing light levels, are much more positive attributes. Similarly, nobody desires exactly 21°C 50% RH: this is an acceptable setpoint, but personal comfort is subjective and depends on individual, time of day, season, task, emotional state, clothing, time since lunch. etc.. The best one can hope for with a single controlled environmental variable is to satisfy about 80% of the people at the same time: with multiple variables the dissatisfaction level naturally becomes higher, particularly for people who can neither move around nor influence the settings.

3.4 As Ian Cooper said at last year's conference (reference 7) *"The traditional approach of specifying comfort in terms of psyco-physiological criteria just won't do any more....there are just too many other factors...we have to take into account"*. But this does not necessarily mean that we need increasing engineering complexity: people are not industrial processes, or laboratory animals where we can only find out what suits them by experimentation. We can be asked questions and make decisions. We get bored: we want interest, much of which comes from variations and contrasts in the environment. While it is important to avoid disabling levels of heat, noise, light and draughts, conditions should not be monotonous either. We want to be able to do our job and have the environment largely taken care of, but we would like to fine-tune it if we find we need to.

3.5 Fine-tuning is most easily achieved in the cellular office, where one person can enjoy their preferences without disturbing others. Cellular offices are also energy-efficient - at least in terms of energy cost per unit area - as although an extended building form may require a little more heating, it can usually be naturally-lit and ventilated, making major electrical savings (in sealed office buildings electrical costs usually dominate). Summertime overheating can be limited by window size, solar control devices, heat storage in masonry partitions, and if necessary by automatically-controlled natural or mechanical ventilation overnight. Local control in open offices is a more complex problem owing to the conflict between individual and collective requirements, and we also have less experience in knowing what is acceptable and how to design and manage it.

4 A plea for better ergonomic design

4.1 A long time ago, I worked on a transportation project with Institute of Consumer Ergonomics at Loughborough. They impressed upon me that ergonomics was not designing for the mean but designing for a range. Science told you the characteristics of the range and therefore the region of interest. Design flair and engineering skills helped you to design something to meet the range: sometimes with a single item, sometimes by adjustability, sometimes with a range of products, and science helped you evaluate your success in having done so.

4.2 Somehow this ergonomic thinking has not got through fully to the building industry: people are regarded as laboratory statistics rather than thinking individuals. As a result, things are "not user-friendly", a euphemism for badly-designed. The lack of ergonomic skill extends not only to the design objectives but to the way we achieve them: not only in our controllers and control panels, but also the little things, like thermostats, light switches and where you put them, window catches and sunblinds. And vital features are often tucked-away in the plant room (often within the control panel which frightens nearly everybody off), rather than perhaps at the reception desk or in the facilities manager's office.

4.3 With a few isolated exceptions, (eg: Reference 8) ergonomic studies of environmental services are virtually absent from the literature, reinforcing the impression that the industry is technology- rather than user-driven. While no ergonomist, I would like to outline a few experiences which may be relevant.

5 Some anecdotes

5.1 These are all taken from real buildings designed with energy-efficiency in mind, and often performing reasonably well overall in spite of everything. Their problems are by no means unique. What a lot of silly little things, you may well say: they won't possibly happen in my buildings. But don't be too sure!

5.2 HEATING

i An office building had been designed with low-energy heating & air-conditioning plant. When I visited it, the control panel was set at "auto" but a little switch on the optimiser was set at a tiny symbol of the sun rather than a clock. There was no indication that this meant "continuous run". Unbeknown to the proud client, the system had been running 24 hours/day, probably since completion two years before.

ii An all-electric building with a sophisticated load management controller had a relatively high energy consumption in the hot summer of 1989. On investigation, the heating was found to have been coming-on overnight when the windows were left open to cool the building down. The client was astonished that the controller couldn't tell summer from winter. The system had no summer/winter switch or indicator lights.

5.3 COOLING

i On visiting an air-conditioned office on a cool spring morning, I was surprised to find the chillers running. The exhaust air heat recovery was creating a cooling load. There was no interlock.

ii The degree-day curve for an air-conditioned office kicked upwards in cold weather. The controller was connected backwards and increased intake air for "free" cooling as the temperature *fell*, not when it rose.

5.4 NATURAL VENTILATION

i When open to the safety stop, the casement windows did not provide sufficient ventilation and blew shut. When the safety stop was unlocked, they blew off!

ii Tilt-and-turn windows in award-winning low-energy offices had no friction stays, and provide either too little or too much air, particularly where there was cross-ventilation.

iii High-level windows, controlled by cable devices, had no indication of open-closed settings. Once open, they were seldom shut until they caused discomfort.

5.5 MECHANICAL VENTILATION

i The maintenance engineer thought he was saving energy by not running the perimeter heating for building preheat. The fans ran instead, adding electrical power and air-heating loads during the warm-up period, which was extended as local heat losses from exposed parts of the building were not easily dealt with by ventilation alone.

ii The ventilation plant for a private dining room was controlled by a local on/off switch. It sometimes ran for days on end.

5.6 LIGHTING CONTROLS

i The landlord installed electronic lighting controls and managed them. The lighting was not sub-metered to tenants, who paid for it as part of their service charge. They objected to the landlord depriving them of what they were paying for. The controls were abandoned. (NOTE: in a similar building, the landlord - and main tenant - had a very able and responsive facilities manager, who listened to tenant's comments and explained the benefits to them. It has very low lighting bills for a sealed building).

ii Light switches provided a status input to an energy management system which then decided what to do, depending on time of day and prevailing light levels. It could take 30 seconds to respond. The occupants got cross.

iii To avoid VDU screen glare, some people needed to have their blinds down and a light on. But the lights still went off when it was bright outside.

iv HID uplights could be switched-on or off individually by the users, and off centrally and automatically. But there were no switches by the door so that people - or cleaners - could switch off all the lights in an area as they left. So they stayed on. There were also no "starter" lights for the run-up and restrike period, so people were afraid to switch them off in any event, and preferred Security to put them all on first thing.

5.7 ELECTRONIC ENERGY MANAGEMENT SYSTEMS

i A smallish office building (3000 square metres) had a sophisticated BEMS, with additional special energy-saving features designed by the consulting engineer. The software designer moved on to another company and the user client could not afford to to train anyone to operate the BEMS. The logic seemed to bear no relationship to the user's perception of the building. Annual maintenance costs of the BEMS exceed the theoretical value of any energy saved: actual savings are lower.

ii A smaller office (2000 square metres) had a multifunctional electronic controller in place of conventional heating controls. Neither the client nor the maintenance contractor could understand it. They would have been better off with a time switch.

iii A larger office entered into a maintenance contract for plant operation. The maintenance contractor was not asked to - and did not - know anything about the requirements of the tenants. Many of the BEMS features had to be disabled.

6 A way forward

6.1 Somehow we must learn to eat our cake and have it. We need to provide:

- central controls which make sure that plant works safely and efficiently, and continues to, and which can be easily adjusted by management to suit changing requirements;
- central controls to keep conditions locally within reasonable limits;
- local controls for occupants;
- ergonomic design to match the controls to the needs of management and users, taking into account patterns of tenure and responsibility; and
- feedback so that people can notice if things are going wrong.

6.2 We need appropriate technology, not always advanced technology. BEMS' don't run themselves: they need considerable effort at the design stage to make them user-friendly, care during installation and at handover, careful training, and constant vigilance during operation. They are a management tool and not a fit-and-forget item. And while the management needs to be good, if the effort required is seen as an excessive burden upon the organisation, it will not get done. So if control decisions can be delegated and not brought back to the centre, so much the better.

6.3 Murphy's Law ensures that faults never occur when anyone is watching. Some feedback and logging is necessary: sometimes in a very simple form, for example: a simple energy monitoring and targeting system based on monthly meter readings (and *please* may we have more sub-meters on the things that matter, and particularly large kitchens and computer rooms); a red light to say that the heating was on overnight: should it have been?

6.4 Individuals are the best judges of whether they are comfortable and need energy-consuming systems to run or not, but they are not usually interested in the most economic mode of operation (viz: reference 9). This leads me to prefer using automatic controls to avoid waste and to optimise system performance generally, with local controls to allow the occupant to do some fine-tuning. Manual on - auto off is a good rule: occupancy-sensing can waste energy and annoy people by switching things on whether they are needed or not.

6.5 Considerable attention to detail is required to select effective and durable controls which will do their job accurately and reliably. We hear enough about high-tech intercommunicating BEMS controls, so let me go down-market and conclude with a couple of simple examples: interval timers and room thermostats. If the job can be done at the local level, why clutter-up the BEMS with it, or retain the BEMS for monitoring and optimisation only: you might learn something about how the occupants actually wish to use the building.

6.6 INTERVAL TIMERS

Interval timers, which bring systems on when there is a local demand, and switch them off again after a pre-determined time, can be very useful, particularly for places like meeting rooms and private dining rooms, where otherwise systems tend to run for wastefully long hours. For example, a lecture-room ventilation system ran for 35 hours a week under time clock control. With a BEMS, operation was matched to occupancy programme (at some cost in management time), approximately halving the running hours. But when an on-demand interval timer was fitted in the lecture room itself, average weekly running hours during the heating season dropped to three! In the summer it was operated more, to limit overheating.

6.7 ROOM THERMOSTATS

Freely-adjustable thermostats can be a problem because people either turn them up too far and waste energy, or down too far and then complain of being cold the next morning. The conventional "tamperproof" thermostat doesn't help much:

- If people are hot, they open the window and the thermostat call for more.
- If it is too cold, the vandals break into the thermostat and turn it up, but the law-abiding won't break in to turn it down and so have to open the windows instead.

At York University, we found we needed three specifications of room thermostat, depending on the room occupancy:

i For individual offices and living accommodation, freely adjustable with high and low limits to avoid waste and freezing.

ii For larger rooms such as libraries and seminar rooms, accurately-calibrated with pre-set high and low settings, selectable by the users, sometimes with interval timers for the high setting in intermittently-used rooms.

iii For large rooms, such as lecture rooms and dining halls, BEMS control including occupant-responsive push-buttons in certain areas.

Selection of the best devices, for durability, precision and price was a lengthy process.

7 Conclusions

7.1 Controls need much more thought, both generally in relation to principles and concepts, specifically in relation to the ergonomic design of standard control equipment, and in detail in relation to the individual building, and to the individual within it. Not even the simplest things should be taken for granted.

7.2 The rewards are potentially great. But to tackle the problem effectively will require quite major changes to the way we do things. The responsibility for controls in a building is often hopelessly divided, with no clear central focus:

i Controls are not seen as an architectural problem, though window design, control device location, and the overall concept from the user perspective certainly should be.

ii Engineers tend to specify specify building services controls in outline only, and seldom with user needs uppermost .

iii The controls supplier designs the controls for their own convenience, but often in ignorance of the users' or engineer's real needs.

iv Commissioning may be poorly or hastily done. However, it is interesting to find that in the UK we do more commissioning than on the continent, where they make more use of self-balancing designs and pre-set regulating devices (reference 10).

v The end-user only becomes involved late in the process, sometimes of necessity in speculative buildings.

vi Controls are not seen as a space planing problem, and fitting-out details may also undermine some of the facilities which were there originally.

7.3 With the developments in electronics, potentially a lot of the problems can go away: systems can be reconfigured in software rather than hardware and intercommunication is possible between local and central devices. But the technology needs to be suitably configured, and this needs understanding, strategy, and attention to detail. New controllers still tend to offer us extra gee-whizz features rather than useful user interaction and information.

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