Comfort and Complexity: Unmanageable Bedfellows?

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This paper looks at complexity in office buildings and its consequences, desirable and undesirable, including those for occupant comfort. It draws on evidence from studies of comfort, control, productivity, health, energy efficiency and human satisfaction carried out over the past decade, predominantly in UK offices. Not enough of these offices function as well as their designers intended, and their occupants often perceive them to be uncomfortable. The result is lower human productivity, a substantial hidden cost to many organisations.

It is commonly argued that high levels of energy consumption are essential for the well-being, comfort and productivity of staff. Indeed, many of the offices surveyed use large amounts of energy, and consequently are responsible for high levels of pollutant and greenhouse gas emissions. However, the data suggest that, in relation to the norms for their type, occupants find energy-efficient buildings more comfortable. Comfort and energy-efficiency appear to be complementary attributes of well-specified, designed and managed buildings.

Are naturally-ventilated or air-conditioned offices more comfortable? In the UK, our surveys suggest that on average there is not much in it, although both the best and the worst examples in the samples to date have been air-conditioned. However, there are this does not mean that air-conditioning can be abandoned in safety. Some features of sophisticated non-air-conditioned designs might be perceived by occupants as having some of the faults which were previously associated with air-conditioning.

In the 1980s, positive associations were identified between chronic low-level symptoms of ill-health and air-conditioned offices, and the term "sick building syndrome" was coined. It was easy to conclude that the air-conditioning itself was the cause of the problem, although typical air-conditioned and naturally-ventilated offices tend to differ by much more just than the air-conditioning. Subsequent studies have revealed the complexity of the problem, of which complexity itself also seems to be a cause.

The paper is in three parts: 1) Introduction, which includes terms and definitions needed for the subsequent sections; 2) Evidence, on the most pressing issues which affect comfort, health, productivity, satisfaction, energy efficiency and performance and the relationships between them; and 3) Strategy, which offers ideas about how to avoid problems and to manage those which remain.

Introduction

Basic dimensions

Occupants utilise space, equipment and technology of office buildings to help them perform work tasks. People usually strive to give their personal environment as much variety as they think is necessary to carry out their range of tasks comfortably - not too hot, not too cold, not too much space, not too little, and so on. If the requirements cannot be met, people can become uncomfortable or dissatisfied. Tolerance ranges (sometimes termed "envelopes", as in "comfort envelope") differ from one person to the next, and vary with status, roles, tasks, goals and working situations.

To satisfy all this, there has been a tendency to strive for a higher degree of flexibility. However, this in turn can lead to complexity and management burdens which create their own problems. For instance, where there are high levels of building-related ill-health symptoms we often find that an underlying cause is that the demands of the building and its engineering systems exceed the management resource and budget available to deal with them, something which is particularly common in public sector offices.

Surveys are revealing that the best work spaces are often those where variety is not excessive, and where systems are as simple as possible for people to manage and change. Two basic dimensions - one concerned with the physical properties of space and the environment, and the other with management processes over time - fundamentally affect the performance and satisfaction of office occupants.

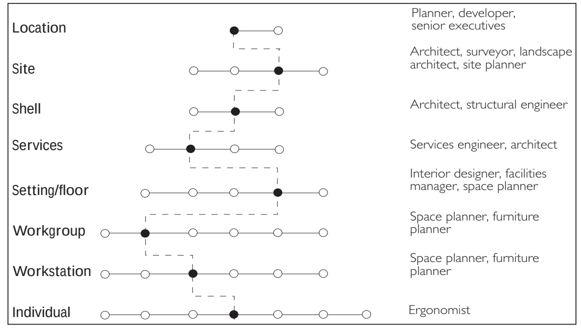
Sources of complexity

The first type of complexity arises from how systems and sub-systems are organised physically in space into different "levels", see Figure 1. Office buildings usually have six to eight, depending on how spaces (and their management) are sub-divided. The more levels there are, the more complex the building becomes, and the more difficult it usually becomes to organise (both spatially and managerially) so that it works well in all respects. Complexity comes from the ways in which physical and human systems interact together: by creating more useful variety in space one can also increase the chance that things may go wrong.

This risk of failure, in the form of uncertainty, is a second source of complexity (see quotation below for elaboration). For people and organisations to

Figure 1 Hierarchy of constraints for office buildings

Source: Revised version of Figure 2.2 from LEAMAN A. and BORDEN I, The Responsible Workplace: User Expectations, chapter 2 of Reference 11.



use buildings as effectively as possible to support their work tasks and activities, uncertainty should be kept as as low as possible. To help achieve this, one needs simple and clear technical interfaces, effective and unambiguous decision-making hierarchies, and, when people want to make interventions, rapid responses and predictable outcomes. Potentially, this can be done by first-rate managers with god-like powers - as is often envisaged by designers - but these are few and far between.

If people cannot immediately get what they want from the management and control systems, they will often take the easiest perceived alternative route, however technically inappropriate this may seem. In practice, robust, adaptive procedures often work best. Systems which require high management input break down in all but the most exceptional organisations.

Resolving the complexity types

Experience shows that to work to best effect, office buildings must:

1. provide an acceptable variety of types of usable space; and
2. help to keep uncertainties for occupants as low as possible.

> "In simple cases uncertainty arising from exogenous events can be handled by estimating the probabilities of these events, as insurance companies do - but usually at a severe cost in terms of computational complexity and information requirements. An alternative or supplementary measure is to use feedback to correct for unexpected or incorrectly predicted events. Even if the anticipation of events is imperfect and the response to them less than accurate, adaptive systems may remain stable in the face of sizable jolts. their feedback controls continually bringing them back on course after each shock displaces them. Although uncertainty does not therefore make intelligent choice impossible, it places a premium on robust adaptive procedures instead of strategies that work well only when finely-tuned to precisely known environments."
>
> HA Simon [Reference 1]

In reality, these requirements usually pull in opposite directions. Increased variety in usable space tends to bring with it greater uncertainty and complexity in the user/management dimension. On the other hand, trying to simplify the management requirement can reduce spatial carrying capacities below acceptable performance thresholds.

A successful strategic approach will consider both design and management and will aim to recognise and resolve these inconsistencies by:

1. examining the likely effects of actual and potential constraints imposed by the spatial properties of the building;
2. ensuring that these spatial constraints create as few obstacles as possible for the occupier.

Note that these obstacles can be either physical (such as walls getting in the way) or managerial (the open space that results takes too much effort to plan and keep running).

Useful variety

Up to a point, the more potential for variety the building has, the better. However, adding more complexity both increases the likelihood that functional requirements will clash with each other (such as noise from one area intruding on people trying to concentrate in adjacent areas) and usually brings greater uncertainty in the user and management dimension.

For the facilities manager, for example, a furniture system which cannot be easily re-configured introduces periodic inefficiencies, which in turn will be passed on to staff who will build up frustration with unsatisfactory arrangements and require management support to make adjustments they could have otherwise done themselves.

At the building level, systems, such as automatic lighting controls, are often abandoned altogether either because the system does not work properly (it may have been poorly designed and/or commissioned badly) because people cannot understand how the system operates, or it does not match their behaviour patterns, or because too much time and effort is needed to operate it effectively.

For individuals, inability to adjust building controls freely (like radiator valves, window latches and blinds) and the failure of the associated control systems to produce the desired effects (temperature controls which give no feedback indication

Figure 2i **Complexity from the designers' point of view**
Source: Authors

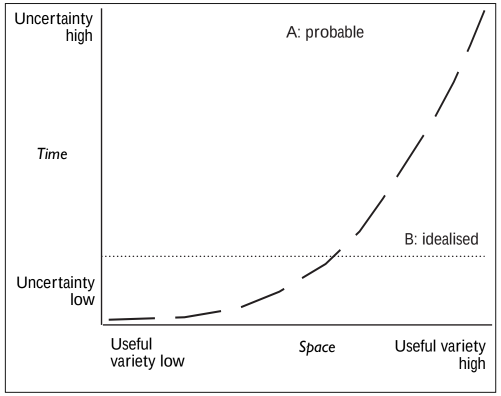
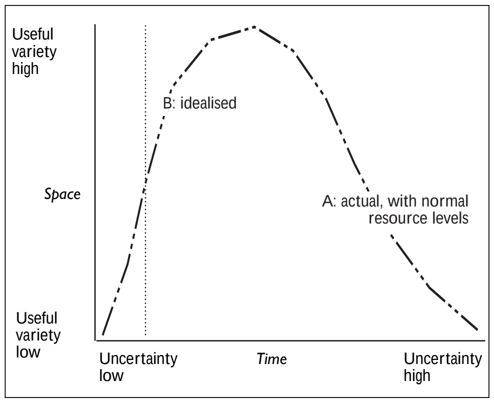


Figure 2ii **Complexity from the managers' point of view**
Source: Authors



whether they have operated, for instance) can create enduring discomfort and frustration.

Wherever the physical and management systems fail to respond properly to demand, waste results, leading to inefficiency, low morale, lowered productivity, and higher energy consumption. Figure 2 shows how these are related, first from the perspective of the designer (2i), then of the occupier (2ii) and then of the management of the occupier's building (Figure 2(iii).

Design viewpoint: The J-curve (Figure 2i)

Space is placed on the bottom axis because it is the independent variable (the variable the designer manipulates). Ideally, but unrealistically, the designer hopes (and may even claim) to create infinitely useful space for little extra management cost, as shown by curve B.

Curve A, the more probable situation, is J-shaped because of discontinuities resulting from the physical properties and functions of the building system as a whole. For example, when building depth exceeds the limits of simple natural ventilation the additional systems required significantly increase the complexity (and thus the uncertainty in use) of the building. In the past, these additional systems have often included air-conditioning but today's attempts to include natural (or combinations of natural and mechanical) ventilation in deeper and more spatially complex buildings are also tending to do the same thing. Unless these additional systems are extremely robust and stable in their operations and functions, and their functions are readily understandable by users, facilities managers and maintenance staff, then uncertainties arising from their operations (which may often be small-scale and seemingly trivial) may accumulate and create the possibility of larger-scale failures.

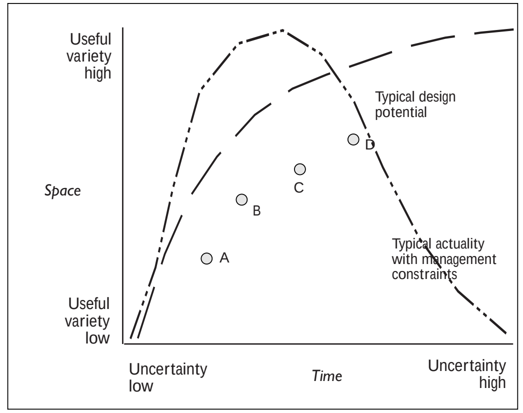
Management viewpoint : The inverted U-curve Figure 2ii

Managers normally want uncertainty to be as low as possible, so that their actions can have predictable outcomes and risk is as low as possible. They also want infinite useful variety (line B) and can be indifferent to any space constraints that may exist.

This objective is just the same as in Figure 2i: it is only the perspective that differs. Again it is usually unattainable in reality because of real-life constraints. Generally speaking, occupants try to reduce operational uncertainties at every opportunity, and often take the easiest course of action rather than the most rational, to the chagrin of the building designer. For example, to control glare on VDU screens, they may find it easier not to adjust the window blinds as necessary, but to leave them down and have the lights on instead. Similarly, the operation of the automatic blinds introduced to overcome this problem may themselves be resented and the controls over-ridden.

The shape of the management curve (2ii) is different because the major constraints are not primarily the physical properties of the building, but the constraints imposed by the organisation and the people within it, its culture, goals, objectives, budgets, mission and ways of working. At first useful variety increases with uncertainty, but it then declines as the situation becomes increasingly difficult to control relative to the other constraints, particularly those on management time, alteration and maintenance costs, and speed and effectiveness of internal communications. Essentially, the demands of

Figure 2iii **Designers' J-curve and managers' inverted U-curve superimposed**
Source: Authors *For explanation , see text.*



managing the features which were intended to provide the variety themselves become the management problem!

The building in use: Figure 2iii

The J-curve comes from the constraints imposed by the physical systems of the building: the inverted U-curve from management constraints. A building in use must resolve both, see Figure 2iii. (To adopt the occupier's perspective, uncertainty runs along the bottom axis as the independent variable, so the J-curve from Figure 2i is transposed and reversed).

To the left of the diagram, uncertainty increases more rapidly than useful variety, but the payoffs may nevertheless be reasonable if management resources to look after the uncertainty are available. Points A, B and C represent the best achievable compromises and may correspond to three characteristic types of office building [Reference 2] - Type 1, naturally-ventilated, cellular (point A); Type 2, naturally-ventilated, open plan (point B); and Type 3, air-conditioned, standard (point C). By point C the gap between expectation and reality has begun to open up, which may help to explain the high variability in performance of air-conditioned offices. Point D, which gives a higher useful variety, is off the normal management curve. Unless the building is resourced to suite this higher level of performance (as in, for example, in a new head office [Type 4]), failure is likely.

The most noticeable feature of Figure 2iii is how the curves separate somewhere between points B and C, where the cost of adding marginally more useful spatial variety is rapidly increasing uncertainty. To remain properly functional, the building should stay on or close to the (now transposed) J-curve, but the extra management and maintenance costs involved may mean that this becomes difficult to achieve. For most purposes, it is best to aim for a building where the most economical balances between useful variety and uncertainty occur.

Simplicity and variety

Variety is simultaneously a beneficial source of potential uses and a threat that functions will eventually conflict with each other and introduce inefficiencies. Simpler environments have fewer options and are often less costly to run; more complex environments have more carrying capacity to support wider ranges of activities more successfully - but they are usually harder, and for some organisations impossible, to manage. Planning and managing space effectively is a matter of balancing the competing demands of the J-curve and the inverted U-curve. Rarely will they be optimally resolved.

For some people, "simplifying" a building may mean increasing usable spatial variety with the risk of increasing conflicting functions; others may wish to reduce uncertainty. Knocking down walls and partitions and making spaces deeper and more open is often thought to both increase usable variety and reduce uncertainty, but may do exactly the opposite by restricting individual choice and increasing management burdens! Physical "obstructions" like walls and partitions can discipline a space and make it more self-managing.

Change

Much of the uncertainty dimension is concerned with how people require, trigger, make and respond to change. This again works at different levels, each with different frequencies and magnitudes of requirement and effect.

Recent work [Reference 3] suggests that the speed with which a building can respond to changes at the different levels has a significant effect on occupant comfort, and consequently health and productivity. For example, to work best for the occupants, physical systems should not only maintain reasonable comfort conditions but be able to respond rapidly and unambiguously when occupants think that conditions are unreasonable. When the building fails them in this respect, people become frustrated and uncomfortable.

One of the best-kept secrets of comfort research is that comfort is defined as the absence of discomfort. A logical consequence of this is that good buildings should have both comfort-provision and discomfort-alleviation strategies. While - at least in theory - air-conditioned offices tend to have better systems for comfort-provision, naturally-ventilated ones are often richer in features for discomfort-alleviation. Maybe this is one reason why occupants' assessments of comfort in both types are similar, and why people appear to accept higher summertime temperatures (typically up to 3°C higher) in naturally-ventilated offices

Best of both worlds

People usually want the best of both worlds in their buildings - simplicity in the management processes, plenty of options in the use of space, and the ability to re-configure or change the space quickly. Achieving this in practice means buildings having:

a) capability to deal with change at all levels in the hierarchy (see Figure 1); and,

b) "baseload" capability which suits the organisations' main requirements - this can vary greatly with the organisation and the type of work they are carrying out.

Buildings which work best usually meet baseload functional requirements without being extravagant, have enough "clarity" in management and control systems to respond to change in a positive and direct way, and are not swamped by uncertainty.

Lack of understanding of decision-making strategies.

Many problems experienced in office buildings can be traced to constraints passed down the hierarchy (Figure 1) with the tacit assumption that either they will be "solved" at the next level down or that there is a plug-in-and-go technological solution waiting somewhere to resolve any problems that develop. The effects too often surface only when people at their workstations start complaining of discomfort, ill-health, or go absent. Often, the root cause is that the building is too complicated for the management resource which can reasonably be made available to look after it.

Evidence

This section illustrates some of the consequences of increasing complexity, using recent evidence about people, their work performance and the indoor environment. It deals with individual topics, like the importance of perceived control, health, comfort and productivity, and then shows how these are related to each other.

Control

People say that control over heating, cooling, ventilation, lighting and noise in offices is important to them, but the actual levels of control that they perceive are often low or very low. Control is so obviously important for human comfort that it has even been suggested that the association between greater comfort and more control is almost trivial! [Reference 4] Control over cooling and heating seems to be more important than control over ventilation, lighting and noise [Reference 5].

Despite this, there has been a trend to remove manual environmental control from occupants and replace it with central, automatic systems. Many factors are relevant here. UK offices have become deeper in the search for greater spatial efficiency, floors have been more densely populated with people in open-plan layouts, office machines have proliferated, and the need to air condition these spaces has increased (though not to the degree that was predicted in 1980s).

With increased depth fewer people have window seats. But people in window seats perceive that they have more control, whether or not they actually do, and their satisfaction and comfort goes up accordingly. The people in the middle perceive less control and report lower satisfaction; they are often of lower status and sit at their desks for more sustained periods in conditions which are objectively worse - noisier, hotter and dustier, for instance. Even the visible windows may turn into a nuisance because they are not in control of them, in naturally-ventilated just as much as air-conditioned buildings!

In air-conditioned buildings, lower levels of personal control appear to make people less tolerant, even though conditions may be objectively better. For example, failed air-conditioning makes people hypersensitive, perhaps because they do not know how bad things are going to get or because of the perceived total loss of control [Reference 6]. People who have control are also less critical of actual conditions, as in naturally-ventilated, "free-running" buildings.

From the perspective of controls it is important that:

1. the building in operation keeps environmental variables within generally acceptable tolerance bands as much as possible;
2. it can be predicted with reasonable accuracy when the building is likely to move outside these thresholds, so that
3. there are appropriate means to adjust the conditions effectively and quickly if and when occupants want to change them; and
4. workable management systems give occupants and managers the opportunity to adjust settings in advance of need should they need to, rather than simply in response to it;
5. occupants' communications environments (the spaces in which they communicate with each other and carry out their work tasks) and their controls environments (areas of office space under occupants' direct control through windows, blinds, thermostats and other control devices and strategies) closely correspond.

In Britain, the best office buildings, measured by

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occupants' perceived comfort and the buildings' energy efficiency [Reference 5], normally work well in all five. The tendency in office design, though, has been to concentrate only on the first one, with "close controlled" buildings being expected to provide good personal comfort through automatic systems without either individual control or simple, effective means of management intervention. Occupants need to perceive that they can change the conditions, if they so wish, and that change in the right direction happens quickly. The inter-relationship of the operation and effects of control devices need to be arranged in such a way that conflicts do not occur in control actions between different individuals or groups. Too often, actions of one inadvertently affect the comfort of others, leading to conflict and sub-optimality.

Control action contexts

Many aspects of human comfort in offices are context dependent. Scientific efforts to understand and explain the basic parameters of human comfort have tended to concentrate on closely controlled comfort chamber experiments. This creates a predicament because occupiers' perception of control itself seems to be one of the most important determinants and the comfort chamber cannot replicate the complex and often perverse conditions of real life.

Comfort

Are air-conditioned buildings more comfortable than naturally-ventilated? In Britain the mean occupant satisfaction appears to be about the same in both [Reference 7]. Buildings vary, of course, and some are much better than others. For example, in occupant surveys carried out by Building Use Studies (BUS) in 1992/1993, both the least and most comfortable buildings in detailed studies of eleven office buildings were air-conditioned [Reference 8].

As a general rule, owner-occupied buildings perform better in comfort and energy terms than multi-tenanted ones. However in BUS' surveys, "pre-lets" - buildings which were let in advance of construction by a developer for occupancy and management by a known tenant - did best. Where a strong tenant had some influence on the design and thereby "owned" some of the problems, significant performance improvements were observed. This suggests that "comfort" is at its highest not simply where the design criteria are met but also where appropriate building procurement and management systems are in place.

Health

Over the past decade, much effort has been put into discovering why certain office buildings seem to create chronic ill-health in occupants. The answers for this often come in the form in which the problem is stated: for example, ventilation engineers see it as an air quality problem, ergonomists as a property of lighting and workstation design, physicians the increased propensity of the building to harbour pathogens and reduce the performance of the immune system, and social psychologists regard building-induced stressors as important in lowering individuals' tolerances.

There is little doubt that the risk of ill-health is higher in certain environments, for example, air-conditioned, deep-plan plan offices with higher proportions of sedentary, clerical staff [Reference 7]. However, the root cause should not be seen as air-conditioning itself. Such buildings may also be relatively poorly resourced in terms of their management being able to cope with the demands that the building's complexity places upon them. The consequent operating, cleaning and maintenance failures, in turn, may create the physical and attitudinal conditions under which chronic illnesses are likely to develop. Once created, these attitudes may predispose people to think that their building is poor, or to project onto the building problems which properly belong elsewhere. This often makes it difficult to disentangle causes and effects.

Ultimately, many health problems come down to lack of cleanliness particularly in buildings which are intrinsically difficult to look after because they are too complex. Thus a ventilation system which is simple to maintain and clean is more likely to be kept clean: and even if it gets dirty it will be easier to put right.

One reason why naturally-ventilated buildings often come out better from the health point of view is their simpler technology, shallower plan form, higher air-change rates and more occupant control (for example, opening windows, radiator valves and light switches) lower maintanance demands. They are not necessarily cleaner though, nor is their air quality necessarily better!

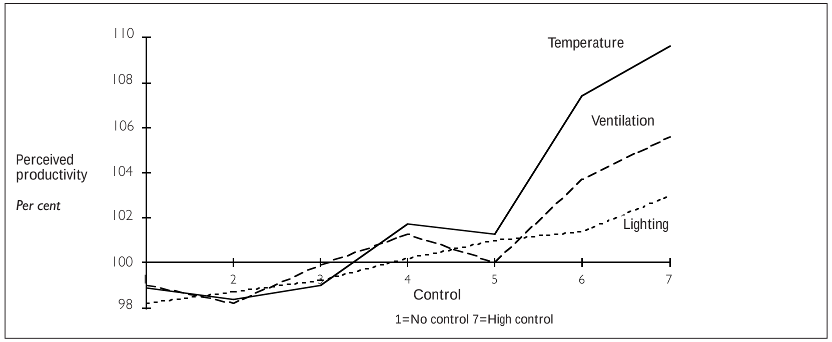
Productivity

Productivity is extremely difficult to measure in an office environment: there is much interest in the subject but little data to substantiate claims. Some routine tasks, like data entry or time on the telephone, can be monitored, but many managerial tasks have no obvious objective measure. Several authors have shown [References 7 and 9] that the less the perceived control, the more likely occupants will say that their productivity is reduced. Since perceived control is also linked to satisfaction and low incidence of chronic illness, control, comfort, satisfaction and productivity are all positively associated.

High perceived control and high actual control are not necessarily the same thing. In the "best" air-conditioned buildings in Reference 8, the actual level of control was quite low, but occupants perceived it as relatively good because the systems worked quite well and the management responded

Figure 3 Perceived productivity and perceived control over temperature, ventilation and lighting

Source: RAW Gary, ROYS Michael, and LEAMAN, Adrian
Further Findings from the Office Environment Survey: Productivity
Proceedings of the 5th International Conference on Indoor Air Quality and Climate, Toronto, Canada, 1, 231-236 Ottawa: Canada Mortgage and Housing Corporation.1990



immediately to any complaints. The siren call to give people more individual control may therefore have the opposite effect to that intended: for example, where controls are included gratuitously, conflicts between control functions are unwittingly introduced, or the consequent system becomes more difficult to maintain and manage.

Relationships in the data

Control and Productivity

Figure 3 shows how perceived comfort and perceived productivity are related. Control over temperature yields the best productivity gains; control over ventilation is next in importance, then control over lighting [Reference 7], normally the same order of difficulty of providing these services. This implies that designers should pay particular attention to supplying control over heating and cooling.. For the same variables, the building correlations are higher than for individuals, so building design is having a measurable effect.

Comfort and Control

Figure 4 shows how perceptions of thermal comfort in houses change under constrained and unconstrained conditions [Reference 10]. The temperature curve predicted by thermal comfort theory is much steeper (that is, there is much less tolerance) than when occupants are allowed to set their own temperatures. These data complement the work of De Dear in offices [Reference 6] which additionally suggests that tolerance is *reduced* in sealed, air conditioned offices.

Control and Depth

Perceptions of control decrease as spaces get deeper (Figure 5). Control tends to be subjectively lower where conditions are also worse, often in the middle and whether or not the occupants objectively have less control. There are strong positive associations between perceived comfort and occupants with window seats.

Productivity and Ill-Health

Figure 6 shows the relationship between perceived productivity and ill-health symptoms. Mean scores for perceived symptoms are on the bottom axis, and perceived productivity on the vertical axis.

Energy efficiency

The relationships between control, productivity, health and comfort described above are, to some extent, self-evident. Less so is the connection between control, comfort and energy efficiency [see Reference 5]. As with many effects in buildings, intervening variables make the link, for example a motivated facilities manager backed by a clearly-targeted corporate mission which has procured or identified the right building.

Conclusions

What are buildings for?

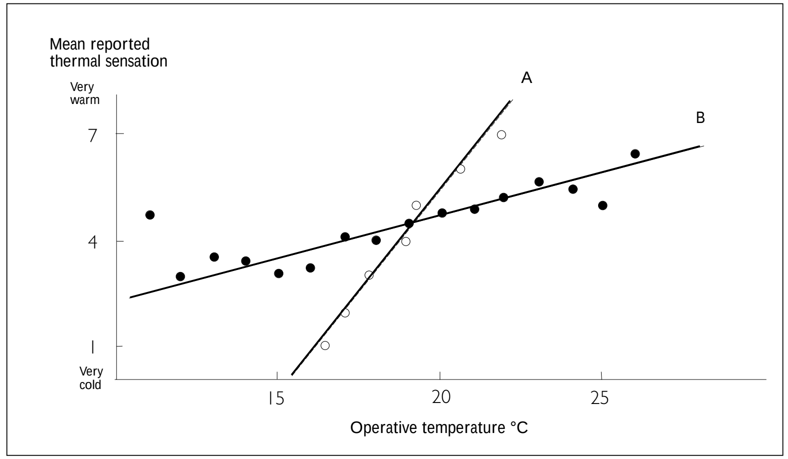
Buildings increase human potential by reducing variation in the natural environment. In doing this they must, and can, be relatively economical. As soon as wealth and potential-creating activities are threatened by discomfort, ill-health, excessive cost, or resource depletion then buildings lose value and may become obsolete.

Constraints and opportunities

Designers and managers usually have the same overall strategy. They try to minimise the actual or predicted effects of constraints in order to maximise opportunities. But they do it from different standpoints. Designers have to operate within pre-

Figure 4 The relationship between temperature and thermal comfort under constrained (dashed line) and unconstrained conditions in houses

Source: Nigel OSELAND Reference 10. See also De Dear et al Reference 6 Figure 3.17, p64.



dominantly prescriptive (often legal and budgetary) constraints in order to provide usable space for the often unforeseeable requirements of management and users. Occupants, on the other hand, have to work within buildings which have already been prescribed or fixed for them, and within changeable conditions created by the fluctuating needs of their organisation, the external environment and the marketplace.

The designer has to "second guess" management and user behaviour, often by stereotyping it or by making assumptions about its availability and its capacity to know, to do and to communicate. Our studies indicate that in the process it is easy to make unrealistic assumptions about management capabilities and resources. Managers often connive in this by entreating designers to deliver "flexibility" in order to make their task easier in an uncertain environment. What they mean is "maximise opportunities, minimise constraints".

Well-intentioned actions can easily have unintended consequences, difficult to predict in advance and even more difficult to reverse when they occur. These externality effects are at the heart of modern environmental problems: they include other peoples' noise, pollution and waste, for instance, indoors as much as outdoors.

Constraints are determined by physical, technical and spatial properties on the one hand, and users' behaviours and expectations on the other. They can never be removed completely or avoided, as many would like to think. Removing physical constraints frequently creates operational ones.

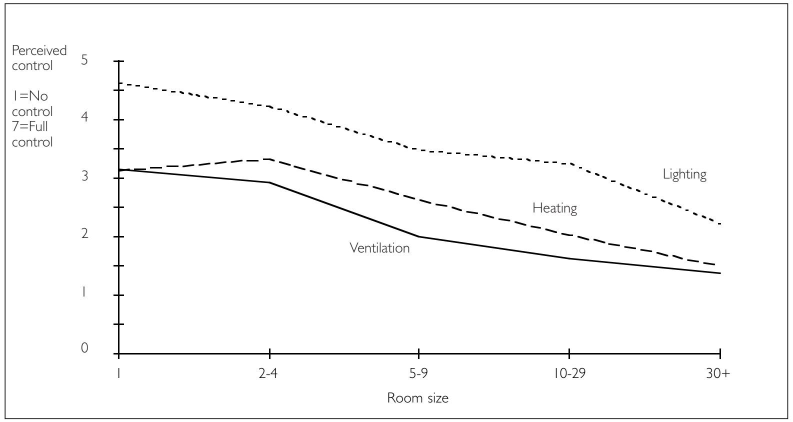
Good design creates opportunities out of apparent constraints, and minimises externality effects as much as possible. Bad design, however, can deny opportunities and remorselessly uncover new constraints and unwanted interactions.

Increased constraints

Because of the hierarchic properties of buildings and their sub-systems (Figure 1), designers should aim to pass on as few constraints as possible to the levels beneath. Otherwise, options are progressively removed from the functions lower down. One the other hand, some discipline is usually helpful, particularly if it makes the correct use of the building more intuitively obvious to occupants. Today advances in materials and technology are increasing the number of possible theoretical design solutions. However, more and more prescriptive constraints are being added, both through legislation and through increasingly stringent and detailed client requirements, and the number of potentially successful solutions may be shrinking. The result could be that managers and users will not have sufficient degrees of freedom to operate effectively..

There is also greater turbulence, instability and uncertainty in the constraints with which managers must deal. Designers thus look to managers for help: "Define the brief more clearly!"; managers look to designers and consultants: "We want flexibility!"; and users look to managers "We want control!" "We want window seats!"

Figure 5 Perceived control and room size
Source: Building Use Studies



It is now probably unrealistic to think that most types of office can properly satisfy all the required theoretical constraints. Outcomes are not just sub-optimal with respect to all criteria, but may only meet a sub-set of criteria. Consultants hired to increase management options may unwittingly reduce them because they fail to appreciate how constraint-bound buildings are. Space planners, for instance, may re-plan an office floor on the basis of furniture configuration and layout alone, without considering how the new arrangements affect control and servicing for heating, ventilation and lighting. This can be an expensive way of increasing occupant discomfort and energy costs!

Furniture planners often find that constraints such as grid dimensions, floor depths, circulation routes, cabling and location of services restrict their options. The resulting layouts then, in turn, affect individual users' capacities to fine-tune their workstations as their own requirements change in response to varying conditions. For example to avoid glare, they may wish to change the orientation of their computer screen as the sun moves round the sky, but may be prevented from doing so by the fixed workstation and the VDU itself, and so lose a means of discomfort-alleviation. Countless similar examples, many of which seem too trivial or anecdotal to bother about, can add up to a significant failure of design to meet need.

This paper has put some recent evidence about people and their performance in office buildings in a wider strategic framework of complexity, design and management.

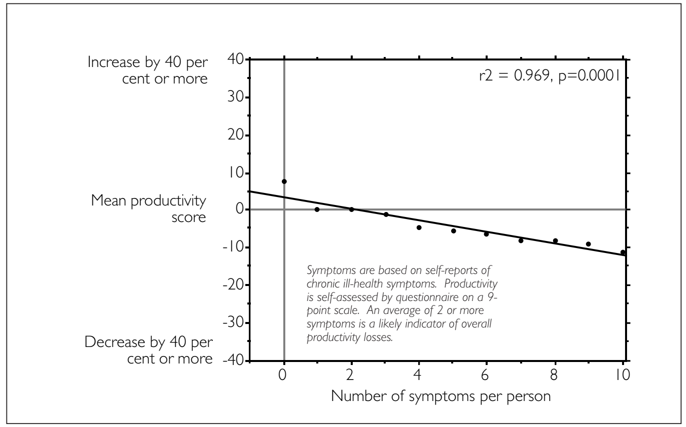
Two types of complexity have been identified: one concerned with usable space, which is primarily related to the physical performance of the building; and the other with the ability of people to carry out their tasks, which is related to reducing uncertainty in operation, and attempting to create predictable, responsive outcomes when people want to make interventions or changes. The first type is underpinned by spatial considerations like density, conflicts between competing functions and variety: the second by time considerations in relationship to decision-making, especially uncertainty, risk and speed of response.

Commonly, one type of complexity is exchanged with the other leading to opposite effects to those intended. For example, large, open, more densely occupied spaces with more activities in them may introduce uncertainties and management inefficiencies which make them less usable than anybody anticipated.

In order to cope with all this, office buildings must become more demand-responsive. In the terms described in this paper, this means bringing the designer's J-curve and the manager's inverted U-curve into one strategic briefing scheme.

However, change will require a radical alteration in perspective, with much greater sensitivity to demand criteria. More attention must be given to the building brief and design objectives, and to assessing whether or not these have been met. Organisations will need to convert their missions into coherent programmes for design, so that there is a consistent overlap between everyday management practices and design outcomes. Many people pay lip-service to "user needs"

Figure 6 Perceived productivity and ill-health symptoms
Source:
Building Use Studies and Reference 7



(almost a byword for ignoring them!), but rarely monitor complaints, act on them properly (managers are often fearful of being shown up to be incompetent), or build up a clear picture of what they should really be thinking about and asking for next time round. Many still only cursorily acknowledge environmental requirements without realising that bonuses for the environment can also benefit organisational performance and bottom line profit.

Most of all, offices must be more manageable to meet the complexity challenge, because lack of manageability is the greatest cost to the occupiers in lost productivity, comfort and health. The search for management efficiency and quality will force people to think more about strategic options earlier in the design process, and, in so doing, place much greater emphasis on design for manageability. As a guide, Figure 7 lists features which we consider to be present in the best office buildings [Reference 12] and which should be striven for in their planning, briefing and design.

Figure 7 The best buildings ...

1. Respond rapidly and positively to triggers of change at all spatial levels (individual, workgroup and department).
2. Have enough management resources to deal with adverse or unpredictable consequences of physical or behavioural complexity.
3. Are comfortable and safe for the occupants most of the time, but use the properties of 1. if they become uncomfortable or unsafe.
4. Optimise relationships between physical and human (managerial) systems at all life-cycle stages (such as briefing, design, commissioning, use).
5. Are economical of time in operation for all user types (individuals at their workplaces, workgroups, management and visitors).
6. Keep resource inputs to a necessary minimum, as well as minimising undesirable effects which potentially infringe the rights of others.
7. Allow higher levels of functional integration to be retrofitted, if needed.
8. Do not introduce irreversible failure pathways.

References

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12 Figure 7 is developed in more detail in LEAMAN AJ and BORDASS WT, Design for Manageability: Pointers from a decade of research into occupied buildings, London, Euroforum, 1995, April 25. Also LEAMAN, AJ, Strategic facilities planning: pointers from a decade of user research, National Conference of the Facility Management Association of Australia, Sydney, 30 November - 2 December, 1994.

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