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Buildings in the Age of Paradox

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National Power

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Left to right: Professor John Worthington, Director, IoAAS; Adrian Leaman; Danny Hann, National Power Plc; Bill Bordass; Terry Trickett; David Fisk.

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PREFACE

In 1974 the Club of Rome published the seminal *Limits to Growth.* Although a confined exercise, it awoke people to great profligacy in the use of the world's resources. Energy conservation seemed to suit everyone. The fuel industries generously subscribed to it on the basis of good publicity at a cheap price. It suited the architectural profession, who needed a cause in the public interest, and the fuel industries financed in major part the RIBA energy initiative. Above all, energy conservation suited the Government because they could point to how seriously they were taking it all and 'saving it'.

There were some surprises. I remember telling the RIBA Council in 1975 that 50 per cent of UK energy was used in buildings and that they were responsible for much of its waste. There was a chatter of disbelief. At that time, delivered energy costs in the UK were about £13 billion.

No one could believe the returns on investment of conservation, and I suspect many economists still don't. Repayment in six weeks could be achieved for wrapping hot-water tanks (at the time 75 per cent of British hot water tanks had no insulation). About 10 per cent of energy costs could be saved virtually free by the management techniques of switch it off and turn it down. Liverpool city saved £4 million a year in running costs for the investment of £1 million in energy conservation measures in their public buildings following an RIBA Energy Group report. Returns of this kind were surprising and unbalanced comfortable assumptions.

Do you remember the inspired use of aerial infrared photography? We developed the infrared technique as it proved invaluable in tracking down heat loss for buildings. Few could believe what results could be achieved with this technique. For instance, it was discovered that one factory had been unknowingly heating its vast playing fields since the 1940s where an underfloor heated factory complex had stood on the site!

In 1976 the professions really woke up. The RIBA started an interprofessional programme of education with over 3,000 professionals targeted in two years. This was the beginning of Continuing Professional Development for architects. We illustrated exemplars, leading in 1979 to the exhibition, international conference and book *Buildings - the key to energy conservation.* And we made tools – the RIBA energy calculator. Maybe our most significant move was to influence the Department of the Environment, and in particular the authors of the Building Regulations.

All seemed set fair. We had done all the necessary thinking, we had separated new from existing buildings, we had a national strategy based on the 'Clean Air Act' method of approach for treating all buildings and this was all costed. We could have increased employment, we considered town-planning and transport policy. We could have been exporters of electricity, we could have used our coal instead of wasting our gas. Then there was the change in Government. They thought that price would control energy use. We now know that raising prices is also politically damaging, so of course this strategy did not work.

So where are we today? Today pollution, rather than depletion due to profligacy, is the driving force. Pollution affects not only health in the short term, but long-term survival theories are also formulated - global warming, for instance. Fortunately the evidence is strong enough for both observations to create enough fear for some action to be taken. Also the seed that was planted in the DoE has continued to grow, and the Building Regulations have kept improving from the conservation point of view. Due to those 1970s' initiatives we are now saving about £1.5 billion per year in reduced energy use in buildings.

Our professions have absorbed the knowledge and are more conversant with the theory and practice. This is different from that time in the early 1970s when I told an architect about my interest in energy and she said "Oh, you mean gas fires." Energy use has joined perhaps twenty major issues which architects consider in designing a building. It has become a part of the theory of resource economics which touches on evaluating all resources. The design of our buildings is changing. There is a move to sensible passive solar gain and shading. Designers of glass are responding to demands for insulation and shading capacity. Insulation values are increasing, boiler efficiencies have improved, energy management is *de rigueur,* as is natural ventilation. The link between health and bad building is realised, if not totally understood. In the 1980s this was leading to energy being used to solve the problem, but in fact it made it worse. So treatment of existing buildings is taking place, but on an ad hoc basis. There are energy programmes and the like, but what is missing is a concerted and co-ordinated policy which is initiated by Government in relation to resources, ***all*** resources. Instead, energy efficiency slowed down between 1985 and 1995 to half the rate of the previous decade.

And what of the future? It is always difficult but not impossible to say. In the 1930s the American President, Franklin D. Roosevelt, commissioned his administration to undertake a vast study of the coming technologies. When the study was published it made a big impression. Indeed it was enthralling. There was just one problem: it had not predicted the coming of television, nor of plastic or jet planes, or organ transplants or laser beams, not even ball-point pens!

The one thing I am sure of is that the relationships between where we live and work will change. For many years I have promulgated a move to the city, higher densities, a walk to work. We will certainly have to change the fuel of personal transport in the city; the current high pollution levels will not be tolerated for much longer. Public transport will have to be rigorously controlled in terms of pollution, but certainly quieter, more energy-efficient systems will be developed. I think a theory of total resource use will be developed. But the key is one of architecture and town planning and politics, and bringing the city alive again with pleasant places to live and work and the realisation that cities are central to our future.

We have so many unused resources in this country. One of the greatest is the unused land and buildings in our cities. The other is people. The aim in the short to medium term should be to use these resources so that extended families can live together in our cities without being forced apart by property values. These values can be controlled by using our wasted land for building. There is plenty available, mainly in small parcels of land leading to small scale intervention, ideal for self build. Maybe that is enough to aim for today. Tomorrow we could revive some of the plans that were abandoned in the early 1980s which could lead to a large employment of labour and the creation of an ongoing programme based on the saving of the rich resources of this ailing country.

Richard Burton
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This is an edited version of an introductory talk prepared for Buildings in the Age of Paradox.

BUILDINGS IN THE AGE OF PARADOX

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Introduction to the
Vision 2000 Building Environment Study, as commissioned by National Power
February 1994, revised November 1995

Introduction

This paper is based on the introduction to a commissioned report prepared by Building Use Studies Ltd in early 1994 for National Power plc. National Power asked the project team (who also included David Tong, then of Building Use Studies, and Paul Ruyssevelt and Robert Cohen of Halcrow Gilbert Associates) to consider important issues likely to determine the pattern of electricity and gas consumption in buildings in fifteen years' time.

The study covered the domestic, commercial and industrial sectors and looked at the influence of:

- technological developments;
- lifestyle, behavioural and attitudinal changes among the public, building professionals and property investors; and
- commercial pressures....

on buildings, their occupancy, the environment and services within them, and hence their energy consumption.

In this extract from the study, some of the implications for buildings in the UK are explored for energy consumption, energy use, rates of change in the national building stock, key social and economic trends, influences in different building sectors and future building energy use.

Context for the study

The research undertaken suggested that we are in an Age of Paradox, an idea used by several writers on management. For example, John Harvey-Jones says

"so many things...... that we have failed to act upon in the past are going to turn into things on which we will need to have a change in perspective."[1]

Charles Handy[2] and Peter Drucker[3] discuss the change from value in material property to value in intellectual property, and John Naisbitt[4] identifies the increasing role of small players in the economy. Meanwhile habits of the past die hard, particularly in the political system and in collective expectations, with individuals, corporations and societies currently holding conflicting, paradoxical points of view.

Nowhere is this more evident than in the building environment. Investment in buildings is still, in both private and public sectors, often shortsighted and primarily driven by minimum initial cost. In the UK, the specification and quality of new buildings has tended to be dominated by their market price and investment potential rather than their value in use, and most commercial occupiers see their buildings as overheads, not assets. Nevertheless, buildings are now subject to more stringent energy-related legislation and voluntary codes of practice, and in use they are now beginning to be much more carefully evaluated for their costs and benefits.[5]

Seemingly the biggest paradox is between continued economic development and the new agenda of sustainability. In the study, *Beyond the Limits*,[6] Meadows, Meadows and Randers review worldwide trends under different scenarios and suggest that if major change does not occur over the next 25 years, the environmental consequences thereafter could seriously upset social, political and economic systems.

To our initial surprise, we concluded that, as we progress towards 2010, the agendas of business efficiency and environmental responsibility can become complementary: they are both ultimately about waste avoidance. We perceive that information technology can provide the means to meet the goals of improved economic performance and sustainability simultaneously.

The arguments in A Wood's, *North-South trade, employment and inequality*,[7] imply that time lags are a natural part of the development and maturation of socio-technical change: it is this that creates the paradoxes. It also means that, although not much change may appear to have been happening, and business may appear to be continuing as usual, this can be deceptive and the seeds of revolutionary change may already be well-and-truly sown.

Following the age of paradox in which different social and economic trends seem to be 'fighting' each other, the early 21st century is likely to become the age of transition, when more of a consensus emerges on how new social, environmental and commercial agendas will converge. The nature and timing of these changes is uncertain, but large corporations as well as governments can play a critical role in shaping outcomes. One additional catalyst which may help accelerate these changes is the millennium itself, which will provide a powerful sub-text of historical evaluation and futuristic thinking.

This general picture of paradox and uncertainty makes forecasting difficult. In some areas 'business as usual' may continue for longer than might appear to be desirable; in others, attitudes and practices may change much more rapidly than we might anticipate, as for example in the phase-out of chlorofluorocarbons (CFCs), in changing public attitudes to smoking, or indeed in the changing mix of fuels used for electricity generation. Extrapolating past trends is therefore even more unreliable than usual. While corrections are in progress, relatively slow superficial changes may also conceal the makings of radical long-term change. For example, while the aftermath of the oil crisis in the early 1970s was not as dramatic as many had predicted at the time, there was a long-term stabilisation in energy consumption in the industrialised countries, and major changes in fuel mixes in many of them.

Why the Age of Paradox?

The force behind the new perspectives is essentially globalisation, in particular the growth in world population, trade (and the associated economic disciplines) and infrastructure (especially information technology and communications). Under classical economics, this would be expected to bring much greater wealth, but Wood's analysis[8] suggests that time lags of decades are not unreasonable before the full impact is felt. Economic progress now also has to be reconciled with awareness of the constraints of a finite world, in particular, scarcity of resources and destruction and degradation of environments, either directly or via pollution. In individual countries, governments are finding that established public sector programmes, attitudes and practices consume an increasing - and increasingly unrealistic and unsustainable - proportion of total resources.

The effects of these changes are already with us in the form of international competition, world agreements on CFCs and greenhouse gases, anti-pollution legislation, and restructuring of public services (and of course utilities). These are leading to culture shifts of various kinds, forcing industries (including service industries) to increase efficiency (by reducing costs and/or adding value), shed staff, and concentrate on core activities. This in turn creates opportunities for new businesses. Competitive threats have accelerated some trends to centralisation (in spite of its relative inflexibility) although the new technologies can support more flexible arrangements and make economies of scale less obvious - yet another paradox. Indeed, the concurrent forces both to intensify and to disperse have been recurring themes in the study.

The most profound and far-reaching socio-technical change occurs when systems which were previously incompatible or in conflict suddenly become connected and start working towards the same ends. This is a large-scale social version of what Perrow[9] has called a normal accident. A major conjunction of this kind is already under way. Value management, the generic term given to the family of 'lean engineering' and 'flexible manufacturing' techniques developed by Toyota, Mitsubishi and others, seeks step-change improvements in efficiency through waste reduction, whilst also adding to the perceived value and quality of the product. Such methods have had a profound effect on efficiency in manufacturing processes, and on management thinking in the Western economies, but are yet to penetrate significantly into other sectors like construction.[10] Sustainable development is about fostering socially and environmentally responsible outcomes and behaviour. Until recently, these two systems - value engineering and sustainability - were separate, and often hostile to each other. Now they are rapidly converging. This can been seen, for example, in attitude shifts of stakeholders (shareholders, customers, governments, the public) taking an increasing interest in company activities (viz: the growth in ethical investment funds), and not just products and profits.

The sustainability argument

Energy supplies have always been vital components of political, economic and military power. Worries in the 1960s about growing scarcity were brought to life in the 1970s by the Organisation of Petroleum Exporting Countries' (OPEC) economic and political actions. More recently, concern has shifted to the dangers of pollution and global warming, and with the Bruntland Report and the Rio Summit, to the broader issue of sustainability. Sustainable development is now the policy of many governments. The UK proposals[11] are modest in relation to those of other Northern European countries, and are likely to need strengthening. For example, the UK aims to stabilise greenhouse gases at 1990 levels by the year 2000,[12] and perhaps to cut them by a further 25 per cent by 2025, while the Germans are said to be aiming for a 60 per cent cut by 2035.[13]

A study for the Dutch government[14] is considering the possibility of much larger reductions in rates of pollution and non-renewable resource consumption. In 50 years' time, it foresees world population twice (perhaps even three times) larger, at perhaps two to four times the prosperity level per individual (that is, taking third world development into account), in a world with no more (and quite probably less) capacity to furnish raw materials and absorb waste products. This implies that systems to meet the newly-emerging boundary conditions of sustainability should really be five or ten times more efficient than now.[15] Few technologies as we know them seem likely to evolve naturally to produce such large overall improvements, some radical change will be necessary and technological fixes alone are unlikely to suffice. Vergragt and Jansen[16] see the need for much change in social structure, habits and attitudes, and transitions will not necessarily be comfortable. However, they consider that the study and development of technological options will help to inform discussions about the structural and cultural changes required, and their feasibility.

Sustainability objectives will include large reductions of emissions and energy consumption, more recycling, extended life cycles including systems integration and 'cascading' (eg: re-use of waste products for other purposes), and less consumption of non-renewable raw materials.

Major changes are potentially achievable:

a) In the short term, say 5-10 years, better management, waste avoidance and minor alterations could curb unnecessary consumption and pollution by perhaps 25 per cent.

b) In the short to medium term, say 5-20 years, improved efficiency of existing technologies and end-of-pipe pollution abatement could save perhaps 25 per cent again.

c) In the medium term, say 10-30 years, better process integration could halve the remaining requirement.

d) But ultimately, totally new approaches may be necessary in many areas.

Of the four categories above, some will be mature, others newly emerging. Some may be short-term dead-ends, others will pave the way for further developments. Some will be responses to prevailing trends, opportunities and threats; others may need to be promoted by advocates. Some will happen spontaneously, others will need collective will to make them happen, for example using economic instruments (like extraction and pollution taxes) to favour more environmentally efficient technologies.[17]

Buildings, energy and carbon dioxide: the current national picture

Buildings account for half the UK's energy consumption and carbon dioxide emissions;[18] the other half is almost equally divided between transport and industrial processes. In recent years, UK annual total and building-related energy consumption and CO_2 emissions have been relatively stable, with energy-efficiency counter-balancing growth in building area, equipment and appliances. However, the proportion attributable to commercial buildings has been growing, owing to increasing stock, intensity of use, equipment levels and air-conditioning.

Industry's proportion of national energy consumption has been falling while transport's, particularly road transport's, has been rising appreciably. The government is committed[19] to stabilising CO_2 emissions at 1990 levels by 2000 and reducing them thereafter. The electricity supply industry's move from coal to gas is achieving important emission reductions. However, as the UK comes out of recession, emissions from transport are expected to increase, and industry's might too. The UK programme of reductions under the Framework Convention on Climate Change[20] therefore relies heavily on lowering building-related emissions, and in particular:

- 4 MtC (15 Mt CO_2) in the domestic sector, through measures including taxation, initiatives by the Energy Saving Trust and Building Regulations.
- 2.5 MtC (9 Mt CO_2) in business, including effects of energy advice & information.
- 1 MtC (3.5 Mt CO_2) by public sector targets.

The total of 27.5 Mt CO_2 is 10 per cent of 1990 levels. Extrapolating forward to 2010 one would anticipate target reductions in building primary energy demand of 20-25 per cent.

Energy use in buildings at present

Nearly two-thirds of the building stock is housing, and this accounts for a similar proportion of building-related fossil fuel consumption. Building-related electricity consumption is about equally spit between the domestic and non-domestic sectors. About 20 per cent of delivered energy consumption in housing, and nearly 30 per cent in non-domestic buildings, is electricity. The percentage breakdown to end uses is estimated in the table.

End use	% of total domestic energy	% electricity of domestic end uses	% of total non-domestic energy
HVAC*	57	(9)	70
Domestic hot water	25	(14)	7
Lighting	2	(100)	11
Cooking	6	(28)	5
Appliances & others	10	(100)	6

*Heating, Ventilation and Air Conditioning systems

Rates of change in the building stock

Normal replacement rates can greatly delay the impact, even of readily-available technological improvements. For example, refrigerators in the USA last 19 years on average.[21] Although refrigerators on sale in 1990 were nearly twice as efficient as in 1972, the average one operating was only as efficient as a typical 1978 model. For buildings and infrastructure, many time lags are longer. The building stock has tended to change only slowly: the underlying annual rate of new construction averages only some 0.75 per cent of total floor area. If historic rates continue, at least 85 per cent of the buildings of 2010 are already standing today. Existing housing is particularly inflexible, owing to the growth in owner-occupation: owner-occupiers do not demolish.

Nevertheless, building types on the margin can change rapidly and represent significant markets, as in the office, retail and warehousing boom in the 1980s. Within the existing stock much can also change: about 2 per cent of its floor area is subject to major refurbishment annually, and this could well be an underestimate as some activities such as shopfitting do not fall entirely within construction industry statistics. Perhaps 40 per cent of the existing stock is therefore likely to have received major attention by 2010.

Repair, maintenance, 'Do-it-yourself' (DIY) and minor alterations add to this, including specifically energy-related improvements, some of which will have been grant-aided. While services and equipment are replaced more rapidly, major items last typically 10-30 years, so unless replacement programmes are accelerated by new attitudes, governmental pressure or economic incentives it will take until about 2010 for the typical item in the field to reach the performance levels of the average item on the market today. Electrical appliances, with faster replacement rates, and disposable items (notably lamps), give opportunities for more rapid change, as do alterations to operation, control and management.

Freeman[22] argues that where changes in technology and understanding make radical system innovations possible there are five phases from innovation to maturation:

1. Initially, the main emphasis is on technical rather than organisational innovation.

2. Early adoption brings great difficulties and risks because systems (both of supply and of demand) are not yet integrated.

3. As the technology matures, the main problem becomes the diffusion from leading edge sectors to the economy as a whole. The emphasis then shifts to organisational and social innovation, and from supply to demand.

4. Advantages then become increasingly apparent and the logic self-evident.

5. Once mismatches have been overcome, the institutional factors which once contained and limited diffusion may create new 'best practice' rules and customs and encourage, stimulate and reinforce further technical innovation so that the process becomes self-fulfilling.

Until radical innovations are linked together, and give rise to new industries, services, attitudes and behaviour, their economic impact tends to be relatively small and localised. It takes a decade or more for a new paradigm to crystallise and much longer for it to diffuse throughout the system. Reviewing historic examples, such as factory automation, Freeman[23] demonstrates why the anticipated positive effects for the economy of all the recent investment in information technology have been slow to come through, as essentially we are still only entering Phase 3 (above).

Accelerating change can therefore be anticipated. Although his argument is about industrial production, because it includes a shift towards information-intensive rather than energy-intensive products, we consider that it can - and will - also pick up quickly on the environmental agenda.

Key social, political and economic trends

Two powerful drivers of change are operating at present:

- The economic system is forcing organisations to improve efficiency by minimising costs and/or increasing added value. Governments are supporting this by promoting free markets. This is helping the UK become a progressive economy with the potential to achieve higher growth and prosperity, but with a high likelihood of increasing inequalities in society,[24] which will restrict the overall impact and need tackling politically.

- Increasing awareness of environmental problems in a finite world is motivating reductions in pollution and in consumption of nonrenewable resources, and a quest for sustainability. Businesses, consumers and investors are already picking-up on these messages, while professional and industry bodies are developing new standards and codes of practice. Environmental legislation is a growth area, including energy-related building regulations. Fiscal measures are being seriously considered,[25] for example carbon taxes.

At first sight the two drivers appear to be contradictory, and indeed economic growth in the traditional sense has tended to ignore externalities and occur at the expense of the wider environment. In essence, however, both drivers are aiming at the same thing, waste avoidance, and this is likely to make them powerful allies. As National Westminster Bank's property division now says, Environmental Sense makes Business Sense, and indeed some companies that have grasped the environmental nettle have discovered important business advantages, not only in public relations (PR) but also in efficiency, profitability and morale.

The rapid growth in the power and utilisation of information technology makes the convergence of approaches and systems based on cost, value and sustainability not only feasible but virtually inevitable. It permits many things to be done more efficiently; undermines some of the past economies of scale which have tended to concentrate manufacturing, distribution, and office resources; while electronic communications can reduce long-distance movement of people and goods. As information technology matures and habits, attitudes and institutions consequently change,[26] the way we do things could alter more quickly than we might at present anticipate.

Under this scenario the value, costs and benefits of buildings will come under careful scrutiny, not just in their own right but as parts of larger systems, and with a view to avoiding waste and minimising adverse effects. There will also be a strategic re-examination of transportation: not only the technology but the means of reducing consumption of distance by people and goods.[27] Increasing objections to roadbuilding, out of-town development, and unrestrained vehicle use are foretastes of things to come, and will have major influences on the location and use of buildings. Although government has been slow to react, there are indications of changes in attitude.[28] It is not inconceivable that, within the time horizon of this study, present habits of hyperactive motorised travel might have become not only expensive, but unfashionable!

Legislation and standards

Legislative, professional and advisory standards are developing in different directions simultaneously. At present the situation is confused, and appropriate balances between health, comfort, energy and environment have not yet been reached. The UK situation is further complicated by directives from the European Union (EU), in which most countries' legislation is more prescriptive than the UK's.

Building regulations and institutional standards

Over the past 20 years, Building Regulations and Approved Documents to reduce building energy consumption have become progressively more stringent and far-reaching. The 1993 draft revisions to Part L propose extending its scope beyond thermal insulation and heating/hot water controls to requiring double glazing, considering means to limit air infiltration, and, in non-domestic buildings including lighting efficiency standards and the discouragement of air-conditioning and mechanical ventilation. Its scope is also extended to include building alterations and changes of use. Energy and CO_2 targets are also included, albeit rudimentarily. All these changes represent a radical widening of the agenda and are portents for more stringency in the future. More impetus in future can also be expected on standards for equipment efficiency, following US and Northern European models.

The Department of the Environment's present range of policy options to influence patterns of energy consumption in buildings includes building regulations, appliance efficiency standards, information dissemination and promotional campaigns, grants and energy/environmental labels. Other Government Departments may add fuel and carbon taxes, and business management and reporting standards.

The EU is proposing non-domestic energy labelling procedures, and has indicated that within five years, from a date as yet unspecified, 50 per cent of property transactions (eg: sales and leases) for commercial buildings should be so labelled.

Buildings are also affected by health, safety, and workplace-related legislation, and by standards and institutional codes. Frequently these are developed from expert consideration of single issues,[29] with little or no concern for their interaction, or their implications for design, management, energy and environment. They can therefore become strategically inappropriate, particularly if they are too prescriptive and aim too high, allowing little room for trade-off and discretion, and are now being challenged.[30]

Professional and voluntary codes

Non-mandatory standards for energy and environmental labelling include the voluntary National Housing Energy Rating (NHER) and Starpoint schemes in housing, and the Building Research Establishment Energy Assessment Method (BREEAM) in several sectors, including offices,[31] housing, retail and light industrial. These are beginning to gain authority: the Part L consultation paper suggests the BREEAM calculation for offices as an interim measure to determine whether air-conditioning is allowable, and for housing the Standardised Assessment Procedure has been developed to resolve the differences between NHER and Starpoint.

In addition to BREEAM, voluntary procedures such as the Building Services Research and Information Association's (BSRIA) Environmental Code of Practice[32] encourage the design and management of more energy and environmentally-efficient buildings. However, sometimes these documents reinforce the status quo by being obliged to reference 'single issue' standards,[33] even if they are strategically inappropriate.

The indoor environment

In recent years, there have been a succession of concerns about the indoor environment and its effects on health, with problems including asbestos; radon; formaldehyde and other volatile organics; dusts, fungi and spores; and sick building syndrome - this particularly with air-conditioning.

Many have brought ventilation performance under greater scrutiny. There are many aspects to this: outdoor pollution brought indoors; pollution generation by building materials, furnishings and equipment; introduction and circulation of pollution by ventilation systems; inadequate ventilation rates; and poor ventilation effectiveness - both actual and perceived. Recent studies[34] are exposing the importance of indoor surface pollution and the need for improving cleaning regimes and designing for cleanability. Ventilation systems themselves have also been shown to be significant sources of pollution, raising issues about the cleanliness and cleanability of plant and ductwork, the suitability of chosen air intake locations; and the practice of recirculating a proportion of outside air. Systems using 100 per cent fresh air are being advocated and designed: for economic operation, these normally require heat recovery.

Recent studies suggest that large increases in ventilation levels are seldom the right answer to these problems, and that for most purposes prevention is better than cure. Provided that materials are sensibly selected, fumes from 'dirty' areas and equipment are removed at source, gases from the ground are intercepted and prevented from entering the building, ventilation is effective and ventilation systems kept clean, there is no need for air change rates to exceed current good practice standards for building-related pollution to be reduced to satisfactory levels. Some allergic and hypersensitive people may, however, need special measures.

Chemical pollution of the outdoor air is a more insidious problem, and - other than providing coarse filtration - conventional mechanical ventilation and air conditioning systems do nothing about it. Again, prevention is better than cure, and the root cause is often vehicle emissions. However, if these are not brought under control, then in future we may see a growing need for high-purity ventilation systems.

Concerns about the indoor environment are not restricted to air quality. For example, there are serious disagreements about thermal comfort standards[35] and even about standards for museums and archives which can only be met by using full air-conditioning in spite of the fact that it is seldom affordable and often causes problems in practice.[36] The conflicts between what makes sense in traditional science and engineering terms, and what is appropriate for the individual, for manageability and for sustainability have yet to be resolved.

Property market standards

A large proportion of non-domestic buildings in the UK are rented, having been developed speculatively and held for investment purposes by developers or institutions such as pension funds. This means that the function of the property market is shaped by the attitudes of two communities, building users and developers/investors (and their advisors) with the latter being dominant. Users and investors have separate criteria of what constitutes a successful building. Users want buildings which help their businesses and organisations function effectively. Investors want secure and profitable investments for their shareholders or policy holders. Even offices which are developed by owner-occupiers cannot ignore investment criteria since an occupier may, in the future, wish to sell their building to realise its asset value and at that time the building will be valued for trading according to the investment market's criteria.

Investors' criteria are governed by the desire to procure buildings which, as far as possible, are designed to be a 'standard product' based on standard specifications such as 500 lux illumination, standard floor loadings, raised floor, and air conditioning. A standard specification is seen as desirable because it makes the valuation of a building easier and less open to dispute. Major investors cannot afford the risk of holding innovatory or unique buildings whose value is uncertain and may vary in unpredictable ways. This must not be seen as implying that institutional norms are fixed; they will change, but only if by doing so they can still achieve high return on their investment at low risk. Past examples of change to institutional norms, such as the abandonment of the 1960s narrow plan, slab-block office and the introduction of raised floors in the mid-1980s, show relatively rapid and dramatic adoption of a new standard rather than slow evolutionary change.

The property market currently works to standards which are not necessarily the most appropriate for occupiers. For example, the late-1980s office standard was substantially imported from the USA and required variable air volume (VAV) air conditioning and what is now realised to be unrealistically high structural loadings, electrical loadings, occupancy densities and air-conditioning capacity.

While the above is being questioned, and some developers have tried to achieve product differentiation during the recession, new agreed standards have not yet emerged. However, consensus seems to be moving towards shallower-plan (15 metres or less), lower-rise (three or four storeys), 'no frills' buildings, often with openable windows and a raised floor, which is often used for underfloor air supply, and supplementary cooling where necessary. Speculative development is also much less attractive (except possibly on prime sites), and joint ventures and 'pre-lets' (where the tenant, or at least the main tenant, is known before construction starts) are more common. Studies by

Building Use Studies and William Bordass Associates for the Building Research Establishment suggest that pre-let developments can produce more manageable and more energy-efficient buildings than either of the traditional speculative or owner-occupied procurement routes.

Building and organisational management

In addition to the codes already discussed which primarily affect building design and refurbishment, the importance of management is now being recognised in non-domestic buildings. The management requirements are also being addressed directly, for example by BS 5750 on quality assurance, BS 7750 on environmental management, the Energy Efficiency Office's Corporate Commitment programme, energy management initiatives, building benchmarking, and so on. These will lead to reductions in avoidable waste and pollution and accelerate investment to save energy and to improve environmental performance. They will also lead to further debate about the appropriateness of some of the technical standards laid down.

Influences on building sectors

Domestic buildings

The number of dwellings will need to grow to accommodate new and smaller households and an ageing population, though the trend to smaller households might begin to reverse within fifteen years. In addition, there will be a demand for larger houses, both through general growth if the economy improves, and through widening inequality even if it does not, and because more work and education will happen at home. The average floorspace per person will grow as households become smaller (in small units, living, circulation, kitchen and bathroom spaces are shared between fewer people), and a wider range of activities and equipment are incorporated.

Developments are likely to be on a relatively small scale and on infill sites, a result of attitude changes, planning restrictions, an increase in owner-occupation, leasehold reform and council house sales, all of which have created major obstacles to large-scale development and redevelopment. Redevelopment and major refurbishment of large estates suffering major technical or social problems will continue, with major reductions in heating energy consumption under the 'affordable warmth' agenda. Some redundant commercial buildings will be converted to domestic use.

There are no clear trends in intensity of use. For example, although more people are working at home, many more women are going out to work. The blurring of boundaries between home, work and entertainment will mean that dwellings are used for a wider range of activities than at present, and are more likely to be occupied during the day: this will also affect the demand for local shops and services. The use of the home as workplace will increase: for the self-employed, for outworkers, and for employed people in more diverse work patterns. This will often require dedicated rooms, frequently re-using space within existing dwellings, but also requiring new buildings and extensions, particularly where homeworkers collaborate or employ assistants. Re-assessment of planning regulations will be necessary.

Trends to smaller households and increases in floor area, equipment and appliances per person imply increasing overheads per person, but these overheads will be met more efficiently. In multi-person households, the tendency for people to do fewer things together and more on their own will tend to increase use of lighting and appliances, though possibly not for cooking with growth in eating-out and pre-cooked food. Average room temperatures are also likely to rise in bedrooms, etc. as more of them become occupied more like bed-sits, but increasing efficiency of boilers, controls and insulation will dominate and heating energy consumption will fall.

Non-domestic buildings

At present many organisations are re-examining themselves, making economies, and rationalising and intensifying the use of their buildings. In the process, they are not only shedding redundant space, but also finding other space inappropriate. This will stimulate demand for new buildings and refurbishment, leaving redundant buildings in its wake. Already vacancy rates are high and some redundant offices are being converted into flats.

The buildings that remain will often be smaller and well-located, for example in:

- prestigious and readily-accessible locations for head office functions requiring interactions with important people;
- readily-accessible locations for functions requiring public access, especially in buildings with large numbers of visitors, such as hospitals;
- attractive locations where highly-paid, flexible and intelligent staff need to be attracted and retained;
- low-cost locations (not necessarily in the UK[37]) for those requiring a cheap labour pool.

Locations which generate increased road traffic will cease to be favoured and towards the end of the study period motor travel distances may have begun to reduce. Poor-quality locations are likely to suffer, and towns, particularly medium-sized ones could become more attractive,[38] particularly if air quality begins to be tackled.

In offices, public, health and educational buildings, there will be general downsizing as the impact of new technology allows an increasing number of tasks to be undertaken remotely and sometimes at home. Information technology will become ubiquitous, but much of the terminal equipment will be lower-energy and more ergonomic, making fewer demands on the building environment. More attention will be given to support spaces, such as meeting rooms, storage areas and areas where specialist or vulnerable equipment is located. Equipment with more exacting requirements will tend to be put in separately-serviced spaces. The recent trend to sealed buildings with air conditioning will be partially reversed, but not necessarily reverting to traditional natural ventilation: new types of servicing will emerge (such as mixed-mode, see below).

Government buildings are likely to reduce in area with the trend to agencies and privatisation. In the past, government buildings have tended to use rather more fossil fuel and considerably less electricity than their counterparts in the private sector, so this - and the more commercial culture in government generally - may increase electricity demand.

Intensification of space use will increase demands for electrical services of all kinds: for equipment, for lighting, for ventilation, for cooling, but often with lower unit energy inputs, for example by using mixed-mode HVAC concepts. Beyond a certain point, space use intensification will require technologically more complex buildings, which are also more highly intensive in their building services and their management requirements. Some organisations may ultimately find these requirements too severe and may instead choose simpler, more self-managing buildings. Public sector organisations are already doing this.

In industrial buildings, area and building-related energy intensity will decline as buildings become better-insulated, services more efficient and process equipment and its services more self-contained. Process-related energy requirements are also falling, but electricity's market share is rising.

- Exacting processes will become increasingly specialised and automated, with dedicated building services to meet health, safety and product requirements, and the building, where required, wrapped around them all. However,
- many manufacturing and assembly processes will be increasingly undertaken by general-purpose machines in general-purpose space, and
- many tasks will become more office-like, be undertaken in office-like buildings and environments, and be subject to office-like trends.

In hotel, residential and leisure facilities, growth is anticipated. Hotels, conference centres, business centres, etc. will need to accommodate some of the functions and activities displaced by downsized business premises, and residential and nursing homes those displaced by hospitals. Recreational facilities at hotels will increase. Independent leisure and 'club' facilities will be used for some of the socialising which will no longer be accommodated to the same extent in workplace buildings, and differential pricing will improve utilisation by the general public.

In warehousing and distribution, there is likely to be continued high activity, but recent trends towards increasing space and larger units could well be reversed as more attention is given to reducing overall transportation needs. The widespread use of 'just in time' means, according to DTZ Debenham Thorpe,[39] that warehouses will perform a different set of functions than those undertaken at present. However, the effects of traffic congestion on Just-in-Time (JIT) strategies may alter this bringing about much greater emphasis on stock rotation, trans-shipment, break-bulk as well as re-packaging and more local assembly. This study concludes that a relatively small number of large distribution buildings will serve a network of smaller satellite depots.

Information technology and modularisation will permit better-managed and more efficient distribution services, supplanting some dedicated distribution systems. Companies which serve European markets are likely to develop distribution centres in the south-east, this trend will be reinforced by a proposed EU limit to heavy goods vehicle (HGV) driving speeds (50 mph in 1996) which, when coupled with existing tachometer regulations could severely restrict the extent of the market accessible in a single journey.

In shopping, growth in out-of-town centres, hypermarkets, and retail warehouses is unlikely to return to 1980s levels: there is already growing public and governmental pressure to favour local shops and town centres. While it is difficult to see how this could happen entirely by itself, such changes would support the changing work and locational practices outlined above, and the increasing realisation that road traffic growth will need to be curtailed, and when these all come together, a major shift could occur. Remote shopping is reported not to be favoured by the major UK retailers, however this will not prevent opportunities being seized by new players in the retail market.

As changes in the retail sector depend to a greater extent on changes in other areas, the future for shopping is less clearcut than in other sectors. New mixes of retail, service and location types may emerge to service foci such as airports, railway termini, hospitals and garages. New retail developments with smaller, low cost, intensively-serviced, lightweight, modular, pre-fabricated and short-lasting buildings [for example, Forte (Happy Eater), BP/Shell forecourts] will be more common. Local convenience shopping based on fresh food and fast food outlets (combined butchers/bakers/ greengrocers/fishmongers, perhaps) will serve people increasingly based at home for daily requirements. Development in town and city centres may concentrate more on weekly and seasonal needs, as well as leisure shopping. There will be a revival in local and village shops serving daily needs. Some growth in mail order, teleshopping, on-line access and data delivery, electronic mail and delivery services with local franchises is anticipated.

Influences on future building energy use

Energy and electricity use by the building stock will be affected by changes in:

a) The number of buildings, with perhaps a 15 per cent nett increase in domestic floor area, but smaller nett gains (and possibly even decreases) in the non-domestic sector.

b) The occupancy and use of these buildings, and their operating characteristics. Many buildings are likely to be used more intensively than today.

c) Their thermal efficiency, which will have improved, with new construction to higher standards and many older buildings having been upgraded, both substantially reducing heating needs.

d) Their equipment levels, which will have increased, and include more electrical equipment. On the other hand, there is likely to be less single-purpose and more multipurpose systems and equipment, viz: the convergence of computers, communications, controls, information and entertainment.

e) Equipment efficiency levels, which will also have increased, sometimes radically. Their operating characteristics will also change. For example the newer, more efficient gas boilers often incorporate fans, providing new demands for electricity.

f) Internal environmental standards, which change and often improve, but not necessarily in ways which require greater energy inputs.

g) Their environmental services, which in new and refurbished buildings are likely to make more creative use of ambient energy sources and rely less upon purchased energy inputs.

h) Effectiveness of control systems, which will have improved, considerably reducing energy requirements.

j) Effectiveness of management and waste avoidance, which will also improve, particularly in non-domestic buildings.

k) Fuel substitutions, both in the traditional sense and by on-site generation, both using traditional engines [particularly Combined Heat and Power (CHP)] and renewable energy systems. Gas is likely to supplant electrical resistance heating in existing buildings, but some new and well insulated buildings will bring new opportunities for electricity, particularly where there is mechanical ventilation.

Both existing and new buildings will be affected Although many of the changes will be incremental, some will also be radical, for example the 'zero-energy' building.

Changes will have different impacts on:

1. New construction. While it is only a small proportion of total stock area, new construction will occur in the areas in which the demand is most rapidly changing (eg: by sector, building type, location). Some of these will be to the industry standards of the day (we call them New Buildings) while others, which we call Innovative Buildings, will embody more radical changes in requirements, technologies and energy consumption.

2. Refurbishment. Some major refurbishments will end up very much like new buildings, for example where buildings are stripped-out or overclad. In more constrained circumstances, and for the growing number of buildings of architectural, historic or townscape interest, opportunities for major alterations in fabric thermal performance will be more limited.

3. Fit-out and refit. Many commercial buildings now have quite rapid interior refit cycles, with major impacts on energy requirements, both increases (eg: adding air-conditioning) and reductions. Refits also provide cost-effective opportunities for incorporating energy-efficiency measures, and this is likely be reinforced by legislation, with Building Regulations applying to alterations and energy labelling of property transactions highly probable.

4. Existing buildings. Repair, maintenance can have significant effects, for example as boilers, hot water systems, chillers, controls and kitchens are replaced. DIY in housing also includes energy-related measures. Grant-aided upgrading will also occur, in particular under the proposed Energy Saving Trust programmes and through existing mechanisms such as Neighbourhood Energy Action.

Generally, we expect trends to higher energy efficiency to outweigh those to increasing standards and equipment levels.

Endnote

The indications from this study are that the building sector in the UK will undergo rapid and perhaps fundamental change in the next fifteen years. Companion papers in this publication explore some of the strategic issues involved. They point to the importance of qualities like flexibility, robustness, sustainability and adaptability, terminology which is now in widespread use amongst building professionals and their clients, but with little consensus and wide potential for misunderstanding (a symptom of paradox, perhaps?).

Greater understanding of building performance through monitoring of use and occupants' opinions is helping to shorten once-lengthy feedback loops: for instance, the Probe post-occupancy studies[40] are examining new buildings about two years after move in and publishing the main findings. Quality control of the total building system, not just its component parts, common in manufacturing and service industries, is only just beginning to gain widespread acceptance. Links between monitoring (with research studies) and briefing (with user requirement studies), are much more important, especially for clients faced with major decisions about investment in future buildings.

Trends point to more strategic thinking and aids to decision-making, greater understanding of the consequences of decisions and more information for managers about costs, performance, utilisation and productivity. This will be much more multi-disciplinary and multi-professional than in the past with far more emphasis on users' and managers' needs and less on design-dominated criteria.

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SUSTAINABLE DEVELOPMENT AND BUILDING DESIGN

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Introduction

Sustainable development, the current theme of much of the environment debate, applies pressure on buildings in two respects. Most of the papers in this publication address pressures defining the interior form of buildings. This is very much the private world of the building occupant. But a building is also located in landscape, or townscape. This paper discusses those issues which may define its future value through its location and the functions it can perform.

Sustainable development

Let me first define sustainable development. It is a term widely used in the global environment debate. For most countries in the Third World the emphasis is on 'development'. Development is an aspiration whose legitimacy is hard to deny. The issue for many of these countries is whether the path of development that they have chosen is sustainable in the long run. This of course is no less an issue for a developed country like the UK. The most common definition of sustainable development is that given by the World Commission on Environment and Development - the Brundtland Report:

'Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.'

This definition is often brought to bear on the construction industry in terms of restrictions on the building design in order to ensure a sustainable use of natural resources. For example, we might consider that in order to obtain a sustainable level of greenhouse gas emissions, our buildings will need to be much more energy efficient. The use of air conditioning refrigerants other than CFCs is another example of an external sustainability constraint borne by the construction sector.

Renewable and non-renewable resources

The sustainable development debate is often presented as devising a strategy of moving from non-renewable to renewable resources. At the end of the 20th century this represents something of a paradox. The resources that are most under threat are not the non-renewable resources at all, but the renewable resources. Fish stocks, we are told, are perilously low in many parts of the world. The world's biodiversity is falling at an alarming rate. The world's forests are being cleared in vast areas. The world's construction industry is a large player in this latter process.

In contrast, our sources of non-renewable materials show no sign of decline. The US Geological Survey publishes estimates of known reserves of important metals. Despite the world's consumption of these materials, its revisions show largely the same level of reserves over the last twenty years. These estimates are supported by world market prices which have continued to decline over the same period. It is never wise to scoff at market prices, often excellent warnings of shortages. While the prices of copper and oil may have declined, the price of rhino horn has escalated.

The role of innovation

What has brought about this remarkable situation? The problems for renewable resources are clearly institutional failure in their management. The 'miracle' of non-renewable resources is clearly innovation. Some of this innovation is in extraction technology. When the UK first tentatively sought to extract oil and gas from the North Sea, this was very much a marginal technology. Now of course we are exploring depths and distances from shore quite unthought of twenty years ago. Some innovation is in end use. After all, if we could increase energy efficiency by 3% per annum, then each year a thirty year reserve of fossil fuel reserve would have been re-extended to thirty years.

Innovations diffuse through a marketplace. What we discover today in the North Sea oil fields will gradually diffuse to other markets with a time history described by that famous logistic S-curve. This means that the impacts of some innovations are often easier to anticipate at least quantatively than we might first imagine. Innovation also occurs through learning. A relationship between cost of production and *total accumulative* production - called the 'learning curve' - is often found in the manufacturing sector. Roughly speaking we obtain the same percentage drop in cost for the same percentage increase in total accumulative production. Here the accumulative production reflects our accumulated knowledge as to how to produce. We may be less conscious of this relationship in the construction industry because of our habit of making every building a novelty. However, the relationship implies that once an innovation has evolved we should expect its costs to drop and its availability to increase.

Buildings as assets for a sustainable future

Let me sum up so far. Buildings do have an impact on the sustainability of development through the resources they consume. The issues involved are

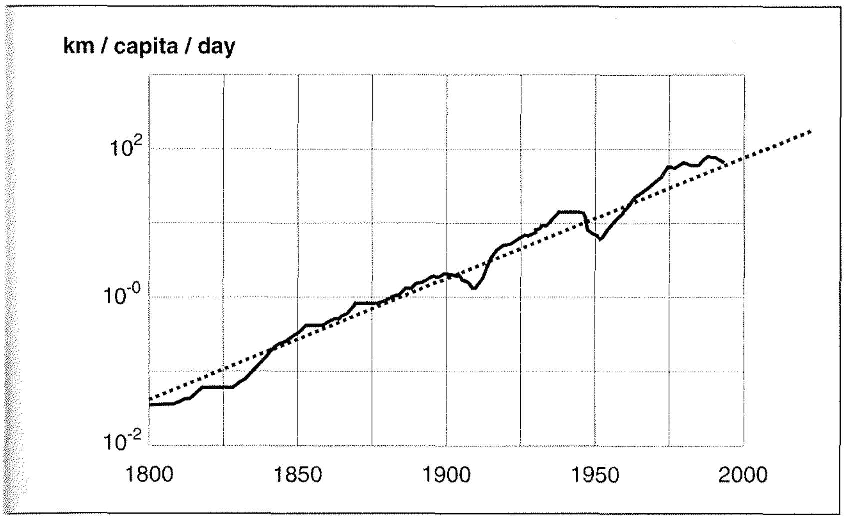

Figure 1 Growth of transport with new technology.

already well covered in standard texts. Perversely the most pressing issues globally are not non-renewable resources but renewable resources that we hold in common. Innovation has been the key to keeping the problem of non-renewable resources at bay. Yet the inevitable diffusion of innovation presents a quite different problem to buildings - the prospect of their obsolescence. This is the second aspect of buildings and sustainable development that I would like to address. Buildings ought to be one asset that we pass on to next generations which are at least as valuable as they were when we inherited them. If we insist on using long life refractory materials for construction, then we owe it to the future to ensure that they are passed on as assets not mausoleums. As the London tour guides will remind you, 2 Marsham Street will be demolished next year. Even if we recycle the rubble, it is hardly a monument to this second perspective of sustainable development.

Thus, although each building affects the sustainability of development through resource consumption, the stock as a whole has an asset

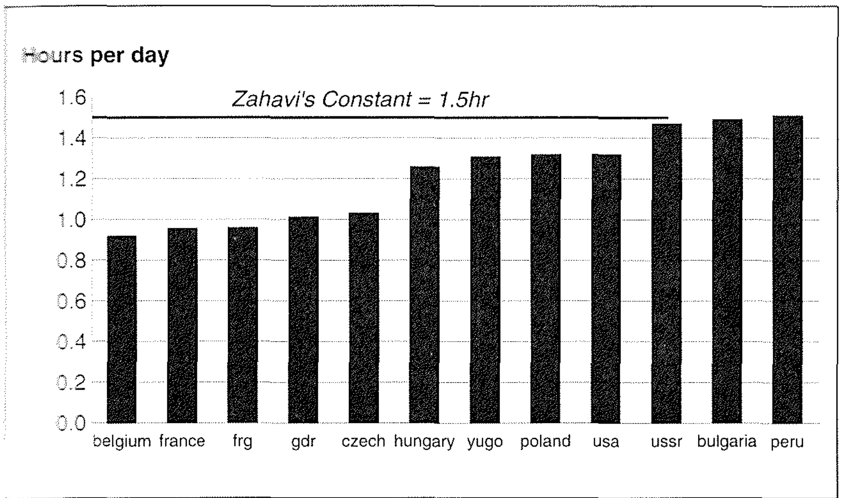

Figure 2 Approximate constancy of travel time.

value which is passed on to succeeding generations. Consider the area of sheltered space in the UK. Add to that for each household its share of shop, factory, office, school and warehouse. I suspect we find ourselves with an average floor area per household that would do a Roman Villa proud. Why do we consume so much sheltered space and why is it found where it is? What forces of innovation might make that built form in that location obsolete?

The Rural Paradigms

To illustrate my point, I would like to begin with an example remote from the normal discussion of built form - the rural building. Figure 1 is arguably the single most significant curve in the rural environment. It records data first collected by order of Napoleon on the average distance travelled per day by Frenchmen. It is a record of the growth of transport technology, as each S-shaped diffusion curve of new technology spreads through France. It begins with foot and horse. Then follow canals and railways, and the motor car. The final spurt is the Train à Grande Vitesse (TGV). This is hardly the end of the story however. In France, as in Britain, the fastest growing passenger kilometres are in air transport. You may recall that in Paul Theroux's novel of the future, *O-Zone*, personal air transport was common-place, so there may be more to come.

The lesson for the rural community is that each step in technology leads us closer towards a world market for food. Once cities relied on their surrounding countryside for food. Now cities rely on the world. For the rural community two extreme scenarios unfold.

The first might be called the Euro Disney/Thomas Hardy experience. Farms in this scenario cannot compete in the world market. They diversify through tourism, vernacular - but centrally heated - residences, with agriculture as a part-time pastoral backdrop. The second scenario is quite the reverse. Here farms are a high technology, capital intensive enterprise, world competitive and using the most advanced technology. Like any other industry, it will be keen to reduce its wastes, and keen to satisfy the requirements of the environmental protection regulator. Unlike other industrial enterprises, located some way from other services, it will be keen to recycle its by-products. The buildings that this enterprise will require are quite different from the rural paradise.

There is arguably a further scenario, where the farming enterprise has moved away towards new non-food crops for pharmaceuticals or fuels. It would be hard to imagine a farm that was producing biofuels that was not using them for its own use. At last then - the autarchic dwelling, about which the Cambridge School of Architecture dreamed in the 1970s! This exercise shows how innovations in transport may be the largest factor in defining the right type of building at a specific location.

The City

Let me now turn to the city of the future, where the effect of transport technology must be at least as great. My analysis here begins with an observation from transport theory that, rich or poor, we tend on average to spend about 10% of our waking time travelling. (Figure 2) The proposition that this fraction will be maintained in the future is reasonable. The richer we get, the longer we can afford to travel, but the higher the opportunity cost in time that it incurs. This constancy should put us on our guard in assuming that information technology will solve our problems. It may enable many to work from home, and so free up time previously spent commuting. However, that may mean these workers will simply locate themselves even further from work than before, travelling to town for the occasional critical meeting.

This constancy and the expected advance in transport technology, lead us to an explanation of the growth in city size. Arguably a pedestrian city could hardly manage a radius of much more than 5-6 miles. A dense urban city with slow transportation might manage 10 miles. A low density city with free flowing freeways could manage 20 miles. Thus as transport innovations spread through the populous, so existing cities grow, rather than new cities emerge. This is easily illustrated by the growth of London. As transport technologies were taken on board, it was able to spread and lower its density. If Paul Theroux's personal air transport really were to become a reality, finding where one city began and another stopped might prove hard.

City Density and Environment

The low density city is not without its own problems. A classic study in urban geography (Figure 3) shows that the gasoline consumption *per capita* in low density cities is significantly higher than in high density cities. This is despite the low average speed of traffic in the denser city. As a consequence, it is worse to be downwind of a low density city than a high density city of comparable size. This may be why most of the pioneering innovations on abating vehicle emissions have been applied first in the low density environment. However, the high density city is not without its problems. The same data shows that the gasoline consumption per unit area is no better, probably worse, in the high density city (Figure 4). We would thus expect local pollution in the form of noise and short-lived emissions to be higher.

Expectations are that motor vehicles, like other manufactured goods will, through the leaning curve, become cheaper compared with average wage rates. We have also seen that, at least in the medium term, raw material inputs will not be a limitation. So the traffic in the high density city will if anything become denser. Cities might then follow one of a number of possible scenarios.

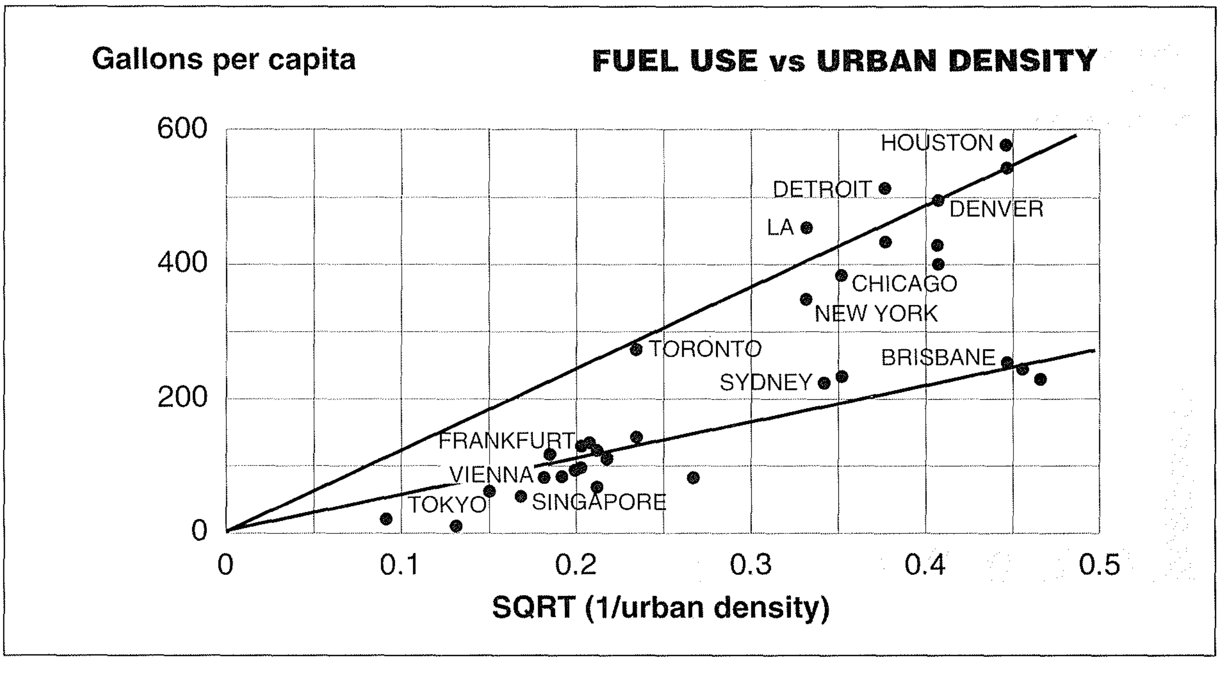

Figure 3 Fuel use in high and low density cities.

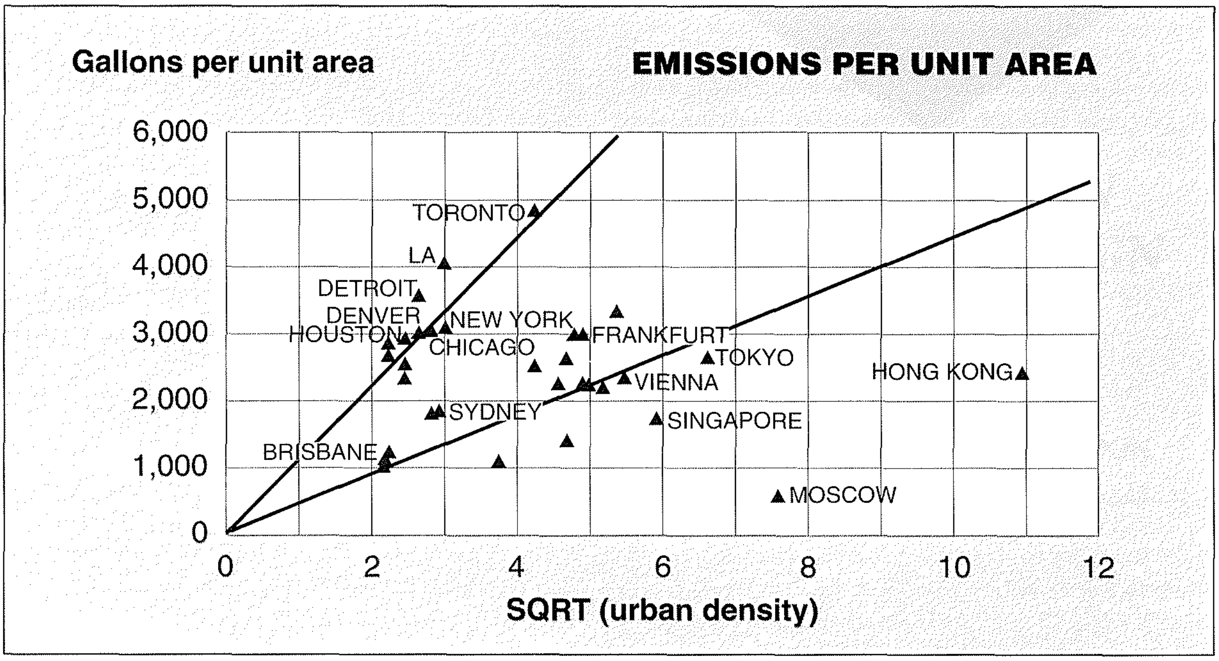

Figure 4 Fuel use per unit area for high and low density cities.

One scenario would be Euro Disney again. Already some European cities have an Old Town free of traffic, full of tourists, and full of museums and art galleries. These cities will ossify about some transport epoch. Venice perhaps is the classic example, locked in time at the great age of the canal. The real business would take place in the new low-density suburbs beyond the 12-lane Belt Way. But there may be a third scenario.

Conclusion

I have argued that buildings contribute to sustainable development in two ways. They are consumers of resources and they are assets to pass on to future generations. Innovation is playing a major role in tackling the first of these concerns. However, the course of innovation also means that transport, and hence the value and function of location, are likely to change over the lifetime of the building. The issue under most pressure is the future of the city centre.

As the scope of personal travel and of goods and services extends ever wider, we may be moving back towards the city state. Globalisation tends to induce regional specialisations and the urban centre sits at the hub of these global networks. That it may take only twice as long to fly from JFK to Heathrow as it took to get from New Jersey to JFK only serves to emphasise how the modern city becomes the regional gateway to the wider world. Not every city will wish to become a Disneyland town. Few cities will wish to become hollowed out cores, home only to the destitute. Instead, some will aim to be dynamic. Their areas of art, commerce and entertainment will need to expand and contract as opportunities and markets arise. They cannot afford ossification or decay. For a building in such a city it hardly then means much to say 'form follows function' when 'function' may vary so widely during a building's life. The function one seeks is then simply flexibility within the building shell. The idea of a design tightly optimised to first use, looks inconsistent with sustainable development in a rapidly changing world.

If these speculations are correct, it does not mean the end of building design appraisal, possibly the reverse. Rather than an automaton optimisation to a client brief, design becomes an assessment of the options to be left open, not the options to close.

The opinions expressed in this paper are those of the author alone.

Background Reading

A useful introduction to future scenarios for transport technology is to be found in *Mobility*, R RAINBOW (Shell, 1994). This was the source material for Figures 1-4.

Flexibility in Building Design

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Introduction

A range of social, architectural, engineering and environmental considerations all conspire together to influence buildings in ways which are unpredictable and unforeseen. The spaces they contain, their systems of control, the nature of building enclosures and the events that take place inside them are all closely interconnected; it is difficult to disentangle one element from another. For instance, internal divisions on a floor may influence air flow from above and temperature control at the perimeter, create barriers to communication between people, and have a fundamental impact on the use of adjoining spaces. All these problems can be solved but the in-built 'flexibility' that results may be difficult to operate, expensive to maintain and remain esoteric to those who need to understand it. As a result, the validity of the building and its systems are called into question as its continued use becomes subject to uncertainty and even chaos.

The predicament I have described has been brought about by attitudes and skills developed over the last 50 years or so. Distinct areas of expertise exist which can be applied effectively to the many separate systems of building and organisational design. These embrace technological, mechanical, electrical, behavioural and managerial skills and many others. But the separateness of these disciplines tends to cause building systems to break down at their connections. The full impact of one on another is not always appreciated because, for instance, architects neglect the continuing role of facilities managers, engineers misinterpret the needs of building users, interior designers have no knowledge of an organisation's management thinking. The list of potential disconnections is long. Together, they impede our ability to tackle and control the complexity of building in the Age of Paradox. (Figure 1) More than ever before, it is necessary now to think in terms of complex wholes rather than individual parts. For the future, the traditional barriers between professions may need to be lowered and categories of expertise re-defined; the term 'flexibility' will begin to assume a new meaning.

Analogies with Science

To develop the theme of disconnection further I am delving, first, into the world of scientific discovery. For 300 years scientists have been looking for the simplest pieces possible; they have dissected everything into modules, atoms, nuclei and quarks. But these simple particles, apparently obeying simple rules, sometimes....

"spontaneously organise themselves into complex structures like stars, galaxies, snowflakes and hurricanes - as if they were obeying a hidden yearning for organisation and order."[1] (Figure 2)

As a result, scientists' attention has been diverted away from ultimate particles towards patterns of change and what prompts them to form and

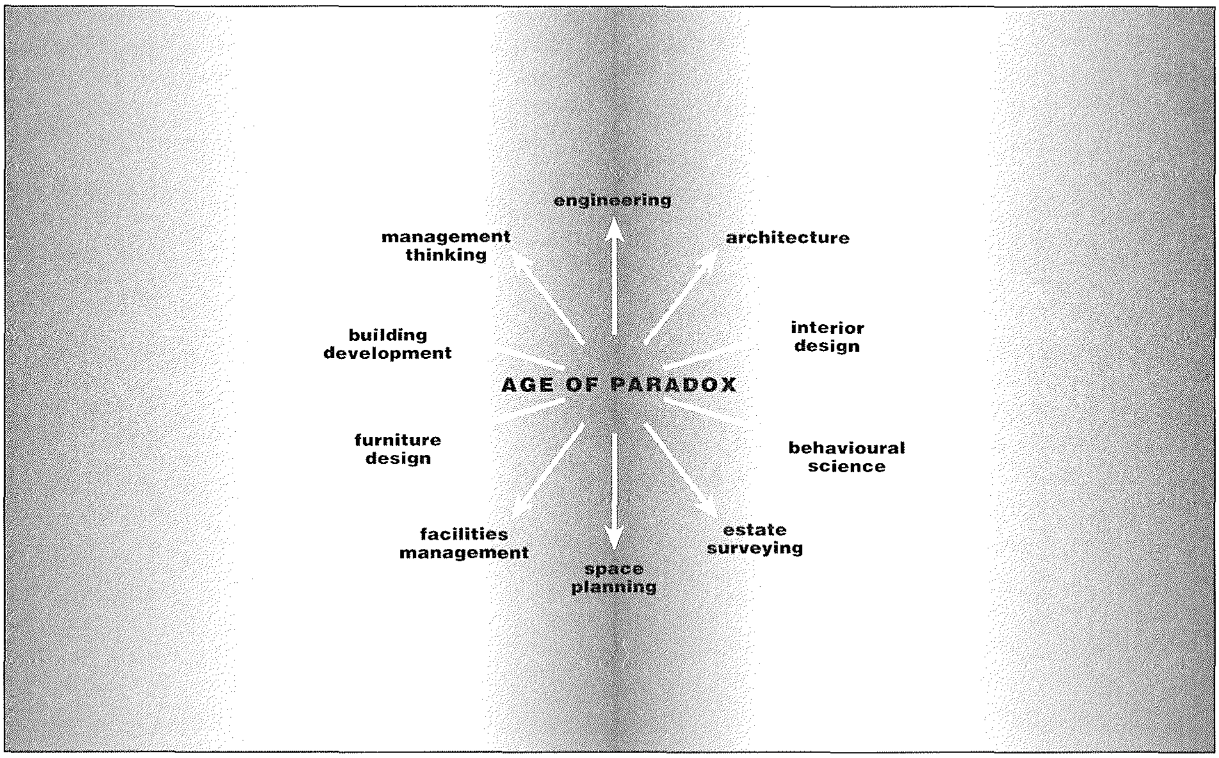

Figure 1 Disconnections exist between the many separate disciplines which influence building and organisational design.

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Figure 2 Andromeda Galaxy

dissolve. We can follow scientists into these new areas because we are familiar with them; the problems respond to spatial thinking and are less concerned in elegant equations and advanced mathematics.

The New Science is just as exact and rigorous as physics but, instead of being about simplicity, it is concerned in 'complex adaptive systems'. These range way beyond the traditional boundaries of science to include, for instance, the world economy, ant colonies, transport networks, developing embryos and cities. Complex adaptive systems have many levels of organisation. In the brain, separate groups of neurones form speech centres, the motor cortex and the visual cortex. In a similar way, a group of individual workers forms a team, a group of teams forms a department and a group of departments constitutes a company. Such systems constantly revise and re-arrange themselves in response to knowledge gained and outside influences.

Each complex adaptive system, according to John Holland,[2] is a network of 'agents' acting in parallel. In the brain, the agents are nerve cells; in organisations, agents may be individual workers; in towns, agents may be individual households. In all cases "each agent finds itself in an environment produced by its interactions with the other agents in the system." Nothing is fixed because, in complex adaptive systems, each agent is constantly reacting to what the other agent is doing.

The Architects' Dilemma

My brief excursion into the science of 'complexity' (ie. at the edge of order and chaos) highlights one of the key paradoxes of the architectural process. Of necessity, to provide finite results in the form of building enclosures, architects engage a wide spectrum of 'agents' to serve their task. The result can be the creation of an ingenious and complex adaptive system but because this occurs with often very little knowledge of, or control over, other internal adaptive systems, the building's life may be thwarted from the very beginning. The skills of even the very best architects do not always succeed in adequately predicting the future. Of course, the time differential between the outside and inside is recognised; the outer system can be expected to stay intact for 70 years or more; the inner systems engage in frequent and often fundamental change. What is inside strives to permeate the skin of the building enclosure (Figure 3) or, alternatively, shrink to insignificance as other internal adaptive systems take over. Flexibility, if this is defined as in-built flexibility, has seldom been able to cope with the extent of physical and mechanical change that constantly occurs inside buildings. In the Age of Paradox, the events that take place appear always to exceed our expectations.

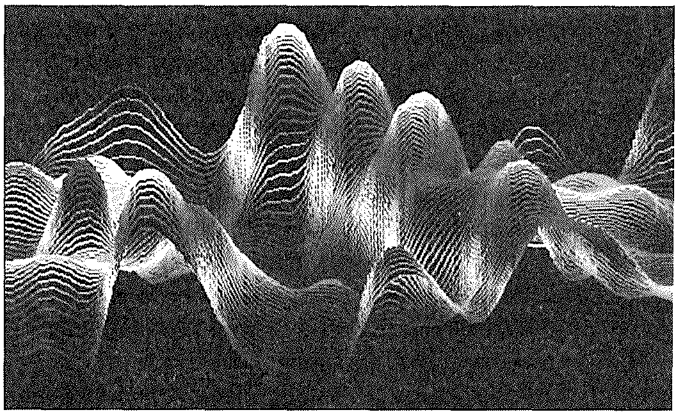

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Figure 3 Inner systems may strive to permeate the skin of a building enclosure. (DNA seen by tunnelling microscope)

Looking Back to an Age of Certainty

Our present Age of Paradox, which has introduced complexity into all aspects of building design and use, was preceded by an Age of Certainty when, apparently, architects and builders were able to produce a sense of order that could better cope with unforeseen change. The oft quoted example is the 18th century London house. (Figure 4) Apart from its initial function as a residence, it was equally able

Figure 4 18th century London houses, Charing Cross

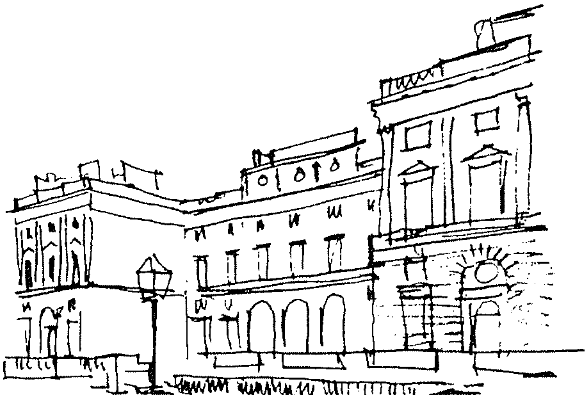

Figure 5 Somerset House in the Strand. Sir William Chambers, 1776.

to provide a base for a merchant or even a government department (although, face-to-face communications took place in coffee houses or the market place). The formula of the house persisted. Somerset House, for instance, was a multi-functional establishment containing galleries, salons, and institutes as well as a tax office. (Figure 5) In essence it was a domestic building on a grand palatial scale reflecting the style of royal palaces built elsewhere in Europe. Today, it performs much as it did 200 years ago.

The invention in the 1880s of the long distance telephone, together with the telegraph and the typewriter, shaped a new pattern of work which has persisted ever since. It enabled administrative functions to be separated from the market place or manufacturing plant and prompted the development of buildings devoted specifically to organisational activity. In Europe these early offices maintained the concept of the large house. (Figure 6) Suites of executive rooms at lower levels were linked via a grand staircase to upper floors devoted to work. But, in the USA, a new order was created which represented a negotiated compromise between commercial and environmental interests; the concept of building high could only make sense

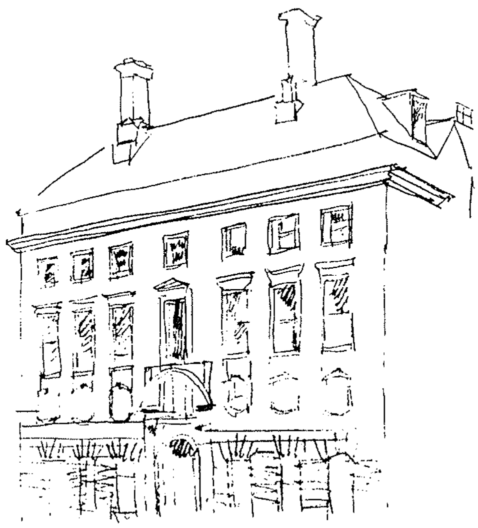

Figure 6 Hudson House, Covent Garden. Sir Edwin Lutyens, 1904.

if the substantial mass of fabric involved could be made to support correspondingly substantial areas of usable space. In Manhattan and Chicago, unlike Europe, public health regulations did not preclude the building of deep office space in which enclosed cellular offices could be located in positions without direct access to natural light and ventilation. Hence, the skyscraper was born....

"The age found its form in a new type of office building: a sort of human filing case, where occupants spent their days in the circumspect cave of paper."[3] (Figure 7)

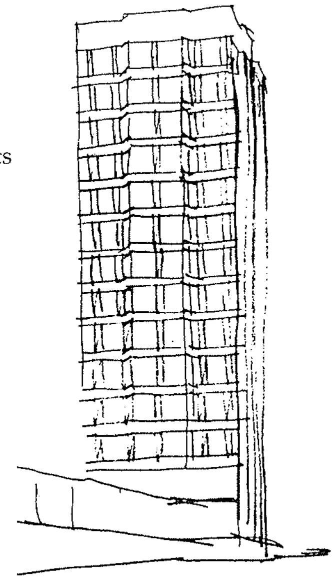

Figure 7 Reliance Building, Chicago. Burnham & Root, 1894.

In an Age of Certainty, few architects appeared to experience doubts on the validity of the buildings they were creating. Detailed knowledge of the organisational adaptive systems they were to contain was not sought nor did it feature, as a major priority, in the design process. (This was in marked contrast to the introduction of mechanical adaptive systems, including air conditioning and hydraulic lifts, which were vital, of course, to the successful development of high buildings.) It was assumed that clerical activities should be relegated to the back (or top) where they could remain unobserved by casual visitors; the front office existed primarily to impress. Office democracy had not yet arrived nor had the term 'functionalism' entered the vocabulary of architects. As a result, buildings reflected image as a first priority and their form was dictated by a combination of site conditions, building economics, and public controls.

The developments I have described took place during the last decades of the 19th century and early decades of the 20th century. Although the architects of the time were not particularly inquisitive about the needs of people occupying their buildings, they did succeed in demonstrating a remarkable degree of 'clairvoyance' in producing results which have stood the test of time. Buildings designed for one generation have proved to be perfectly valid for succeeding generations. The reason, I believe, is because flexibility, as an aim, was not so much on architects' minds; more, they were striving for a degree of 'stability' which was capable of change. This is a quality that people (ie. building users) both recognise and want. It is a paradox of our time that, by seeking more to meet peoples every need, we move further away from what they want.

Causes of Disconnection

Scientists, in examining non-linear nature (ie. aspects of nature where the whole is equal to more than the sum of its parts), have revealed that everything is connected. For example, the flap of a butterfly's wing a millimetre is one direction may change the course of a hurricane in the opposite direction, one thousand miles away. Apparently, even the most tiny movements of an adaptive system can grow, under certain circumstances, until the system's future becomes completely unpredictable - or chaotic. Something similar happens in buildings; it is evidenced by the very high 'churn' rates that can occur in which people are relocated two, three or more times a year. They may never have an opportunity to stabilise themselves in a familiar setting but, instead, suffer the stress of exponential change and continual disruption.

High rates of churn are accepted by many managements as an inevitable outcome of the pressures under which they work; they are regarded as a responsible and responsive reaction to organisational change. Another less supportive interpretation, which I share, is to regard continual physical change as a sign of failure, by the managers and designers concerned, to take a wide view and apply strategic design thinking. If something requires fixing as soon as it exists, it was probably wrong in the first place. As WG Bennis observed in his article on Changing Organisations:

"In every age there is a strain toward organisational form which will encompass and exploit the technology of the time and express its spirit".[4]

In the Age of Paradox we are still searching for that form.

I recognise, of course, the extent of the revolution that has taken place in our organisations. The undemocratic paradigms of the past have been replaced by new patterns of work; people's tasks at the workplace have been re-engineered in order that they can better provide a sense of achievement. At long last, managements are beginning to appreciate that the creation of a sense of satisfaction at work is influenced (even if it cannot be determined) by the environment in which work takes place. Generally, an over-simplified push-button idea of people's needs is being replaced by a recognition of their complex and shifting expectations. What is lacking in this process of radical change is an ability to comprehend and therefore unify the various complex adaptive systems that impact on organisational design. More often than not, we can observe that the complex adaptive systems of organisational life work against one another. They are not synchronised; as one catches up, the other moves on.

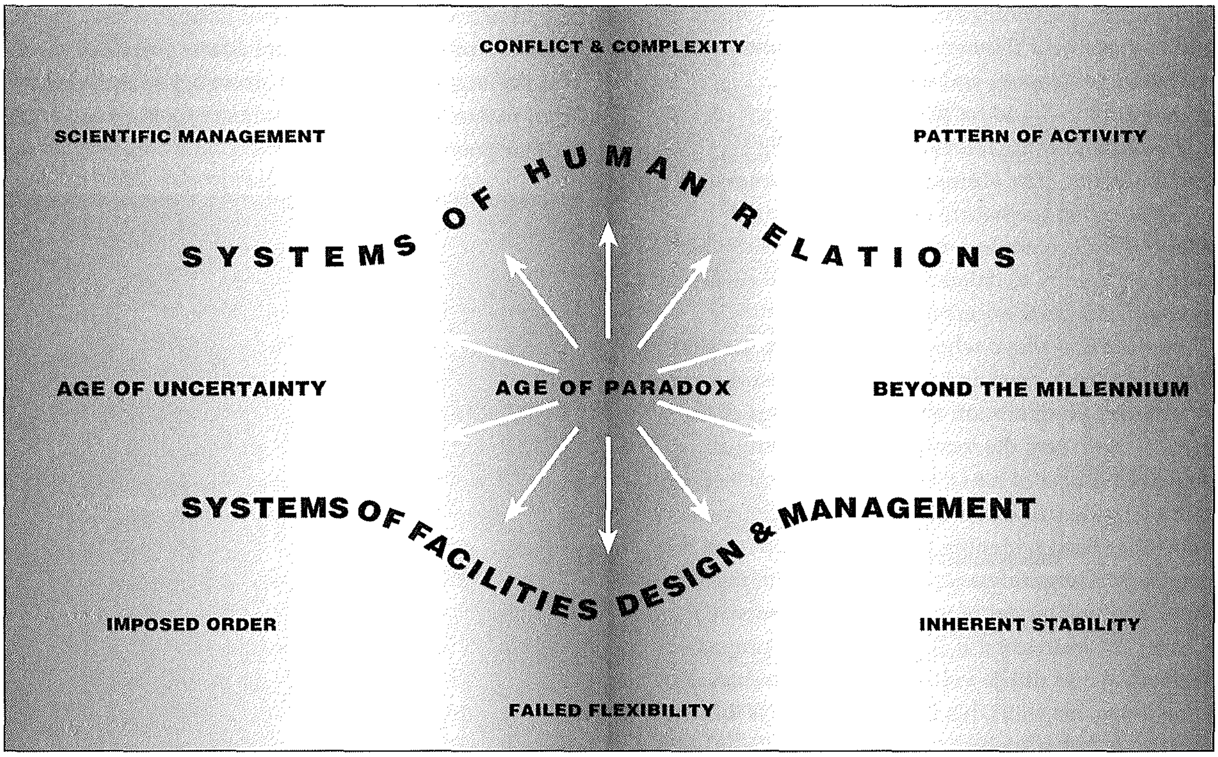

Figure 8

An example of disconnection, well known to all of us, is the Property Market. By the time it has moved to fill a perceived gap, the need for space has receded. Consequently, maximum supply occurs at times when demand is at its lowest. We accept the inevitability of this type of situation. Even the scientists of 'complexity' know that equilibrium can never be achieved; if it were, the system would be dead. But, as we begin to emerge from the Age of Paradox, it should be possible to achieve a greater degree of congruity between the various adaptive systems that act on organisational life - less novelty, more stability. To test this idea further, I am examining, in particular, two complex adaptive systems which can often be seen to working and odds with one another (see Figure 8):

- Systems of Human Relations
- Systems of Facilities Management and Design.

These two systems require different types of intelligence; analytical and interpersonal in the case of Human Relations; spatial and practical in the case of Facilities Management and Design. Maybe this explains why it is apparently so difficult for these two types of thinking to act together in unison.

The Growth of Human Relations

Caring about people as individuals, taking an interest in what influences their attitudes to work can be described broadly as 'The Human Relations' approach to management. Within the last 50 years, sociologists, psychologists, behavioural scientists and management thinkers have made immense strides in developing and defining what organisations should be striving for in terms of improved and more relevant management environments. The Human Relations movement recognises that the nature of the employment relationship is complex - an adaptive system which needs constantly to balance organisational demands against individual expectations.

It was Elton Mayo who, in the 1940s, concluded that a manager's task in organising teamwork (and stimulating co-operation amongst members of the organisation) was the most important but most neglected aspect of his or her job. Mayo opened up a chink in the principles of scientific management which has been widening ever since. As part of this process McGregor developed 'theory Y' (to replace the traditional model of management 'theory X') where "the individual is continually encouraged to develop and utilise voluntarily his capacities, his knowledge, his skills, his ingenuity in ways which contribute to the success of the enterprise."[5] The process of change, according to Argyris, was one of mutual adaptation "where the organisation modifies the individual's personality and the individual, through the informal activities, modifies the formal organisation. These modifications become part of the organisation."[6]

A total organisation, therefore, is much more than the formal organisation; Argyris regarded it as a composite of four different but inter-related sub-systems which result in four kinds of behaviour:

- the behaviour that results from the formal organisational demand
- the behaviour that results from the demands of the informal activities
- the behaviour that results from each individual's attempt to fulfil his idiosyncratic needs
- the behaviour that is the resultant of the unique patterning for each organisation of the three levels above.

For me, Argyris's grasp of the complexities of organisational life comes somewhere near the truth; certainly, it accords with the findings of my own studies into organisational activity. Although these have been undertaken with the express purpose of defining the physical forms in which change can be managed, I arrive at the same conclusions. The adaptive system of interpersonal relations in organisations may have become more complex, more individual and less and less related to clearly laid down lines of communication but, always, it operates in accordance with its own 'unique pattern'. It is this pattern which, once identified, provides the key to successful organisational design. The scientists of complexity would not be surprised at this finding; they see "order emerging spontaneously from molecular chaos and manifesting itself as a system grows".[7] (Figure 9)

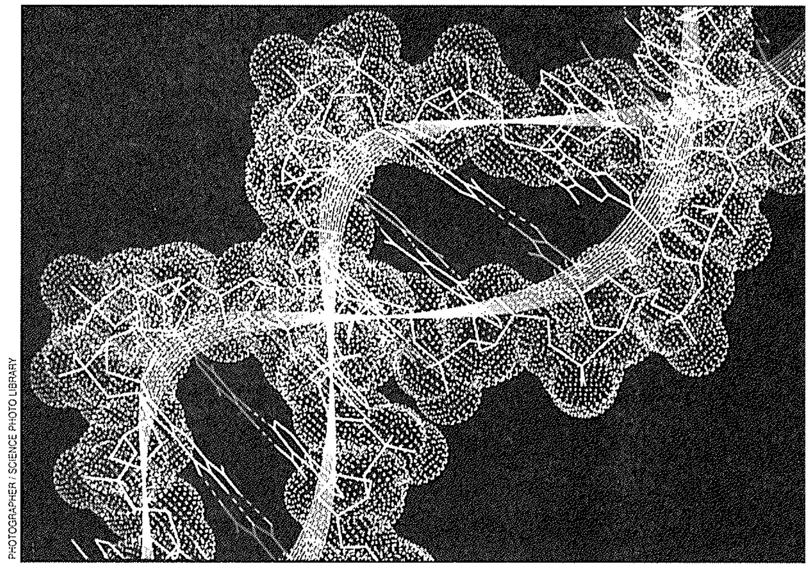

Figure 9 DNA Molecule

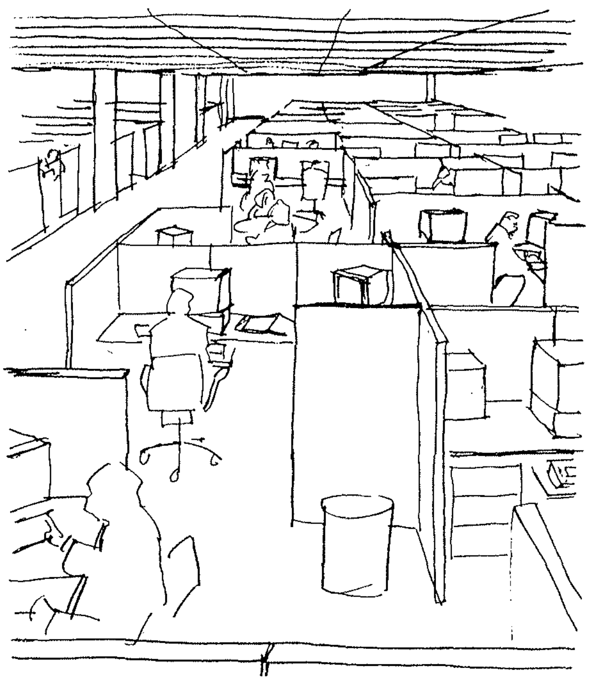

Figure 10 Typical installation of wall-to-wall screen based furniture.

A Bridge to Facilities Design and Management

The tasks involved in defining the specific adaptive system, or unique pattern, by which an organisation maintains itself and then translating this into a physical format requires a broad range of intelligence, spatial and practical as well as analytical and interpersonal. As these skills are unlikely to be found in one person (or consultancy) dialogue needs to take place, at an early stage, between management strategists and facilities managers and designers. If this does not occur, results can be hit-or-miss. Sometimes successful, by chance, but more often, installations are created in which people can be seen to be constantly struggling to make new management initiatives work in conditions which provide little appropriate physical support. (Figure 10) In my experience, installations which consist of little more than wall-to-wall screen based furniture have been a significant cause of discontent and 'churn'. Even though a degree of in-built flexibility may exist in such installations it is seldom sufficient to make up for a fundamental failure in communication at the outset of a project.

Mismatches between management aims and the buildings occupied by organisations are not solely caused by designers. The management theorists I have already referred to (Mayo, Argyris, McGregor) and many others have seldom made mention of the potential contribution of the working environment to organisational success. It is as if an early misinterpretation of the Hawthorne experiments forever coloured their thinking by consigning the environments in which people work to a low level of priority. This partly explains why the revolution in management thinking has not been reflected by an equivalent fundamental reappraisal of the workplace. For their part, designers and architects have remained content to produce buildings and interiors which are based on an outdated view of human activity in organisations; little has changed since the invention of the skyscraper. As Robert Sommer opined, as long ago as 1969:

"what is needed is a shift of temporal perspective. Just as scientists are thinking more about the future, designers must shift some of their attention away from the past (buildings that have been) and the future (Utopia) and study buildings on the narrow plane of the present and from the stand point of user behaviour."[8]

Although it is 30 years since Sommer's extortion, it still remains pertinent. Much has been achieved architecturally and in the design world in the intervening period; conditions of increased comfort and efficiency have been created at the work place; much dedicated effort has been directed towards making buildings more responsive to human need. (Figure 11) But, overall, architects and designers have not moved far towards understanding the conflicts and complexities of organisation design, nor have management theorists embraced spatial thinking in order that they can better comprehend the contribution that design can make to organisational success. However the gap is just beginning to close: "a fragile bridge has been built between design and the social sciences."[9] We now accept that there is a behavioural basis for design.

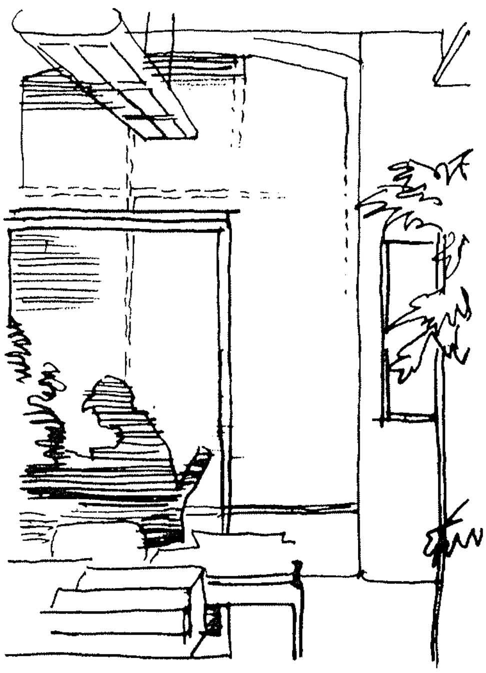

Figure 11 Workplaces responsive to human needs are a feature of this conversion of a 19th century cotton mill for CV Home Furnishings. Trickett Associates, 1990.

A Behavioural Basis for Design

A determination to uncover an organisation's 'unique pattern' requires us to tackle, head-on, the conflicts and complexities of organisational behaviour. This has been defined by Payne and Pugh as:

> "....... the study of the structures and functions of organisations and the behaviour of groups and individuals within them. It is an emerging, inter-disciplinary quasi - independent science drawing primarily as the disciplines of psychology and sociology, but also on economics, operation research and production engineering."[10]

The interconnectedness of the skills required is important; analytical and interpersonal skills need to be allied to spatial and practical skills if the results of research are to be effectively applied. Of equal significance is the stress placed on 'the behaviour of individuals and groups'. From my own work, in uncovering the determinants of behaviour in organisations, I find that it is the functioning and formation of groups that becomes a key factor. People in groups need to experience a sense of belonging so they can more easily define themselves in relation to others. They are substantially dependent upon their own work groups for obtaining an understanding of the social and technological environment in which they work.

Further, they need the help and support of fellow group members in order to carry out their tasks effectively. For this reason, the way people are arranged in groups (the physical configuration of work positions and the shared spaces between) plays a key role in enabling an organisation to establish a physical form which accurately reflects its operational aims and management philosophy.

An investigation and analysis of an organisation's unique pattern, and the way its groups are linked through communication routes, can often reveal forms which resemble those of the DNA molecule! (see Figure 9) These forms become simplified, of course, during the process of matching an organisation's pattern to a specific building. But, contrary to normal belief, this task does not have to be constrained by lack of group design options. The available vocabulary of group design is almost limitless; it extends way beyond the normal 'open' and 'cellular' extremes. Further, it influences the shape and size of building that an organisation requires. Reference elsewhere reviews the techniques of group design[11] and the skills involved in fitting groups (and the shared spaces between) into buildings.[12]

During the 1990s a drive towards an increased intensification of space use now demands the application of more sophisticated planning and management devices. As a result, the two types of adaptive system, human relations and facilities management and design, have begun to act together as never before. Group design still remains a key issue, however, whether or not it includes the provision of shared use workplaces.

More than anything else, it is the adoption of a behavioural approach to design which spans the divide between the many disconnections I have referred to earlier. It extends well beyond an analysis of user needs by establishing how buildings, and what happens inside them, can influence the frame of mind of their occupants and help instill a new set of values which have a direct impact on organisational success. The strategic importance of the behavioural approach cannot be over emphasised. It helps to ensure that the often huge cost of re-establishing an organisation in new premises can be seen to have a positive and measurable impact on productivity. Further potential outcomes are equally far-reaching; they include:

- allowing a sense of order to emerge from diversity
- encouraging informal communication at all levels in an organisation
- acting as an aid to creativity
- contributing towards people's self esteem.

It would take a close examination of case studies to fully explain the benefits gained by those few organisations that have adopted a behavioural approach to design. (British Airways and Scandinavian Airline Services come to mind, in particular.) To many, the process appears difficult because it must inevitably embrace both the social and psychological issues which now play an important part in any programme of organisational and environmental change. To tackle them successfully, they require the application of both interpersonal and spatial forms of intelligence. When these are successfully combined it becomes possible to resolve the key paradox of organisational life (as referred to earlier); an increased understanding of people's needs will enable the design process to provide what people want. A direct result will be installations which are less subject to the continual churn of physical change. Although in-built flexibility may still be required, it will act within a pattern of operation which remains inherently stable.

Beyond the Millennium

In illustrating the added value that can be obtained by causing two specific adaptive systems to act together, I have emphasised the importance of making crucial and sometimes unexpected connections. This approach applies equally to the many other complex adaptive systems which impact on building design. These include technology systems, communication methods, building enclosures, environmental control systems and many more. All need to be 'unified' in order that their benefits can be maximised. To achieve this, as has happened in the New Science, traditional categories of expertise may need to be dissolved; instead of focusing on the simple and separate pieces of organisational design, increasingly, it will become necessary to gain an understanding of complex 'wholes'. The main skill required to enter this world of discovery will be an ability to see connections (where none have existed before) often though the use of sophisticated computer simulation techniques.

Complex adaptive systems never remain fixed for long; all are in a constant state of revision and rearrangement relative to one another. In the Age of Paradox, there has been a tendency to place the burden of flexibility on just one or two systems (eg. environmental systems, facilities management and design) with the result that they break down. Beyond the Millennium, all systems must play their part, within a unified whole, in responding to development and change. This is again analogous to the new science of complexity where it is understood that no one system can be 'optimised' at the expense of others.

Turning now to the design of building enclosures (Figure 12), I have made reference to the attitudes that predominated in an Age of Certainty. Paradoxically, many buildings from this period have proved themselves well able to withstand the impact of fundamental change (see Figure 11); they now accommodate new types of technology systems, communication networks and human relation systems, etc. which could never have been imagined by their original creators. With the benefit of hindsight, it is evident that building forms in an Age of Certainty were successful in anticipating function.

Conversely, in the Age of Paradox, form has followed function with less prescient results. We are surrounded by many buildings, created in 1950s and 1960s, which must be regarded as virtually obsolete because their outward form has been identified too closely with one specific type of internal adaptive system. Buildings constructed to contain specifically Burolandschaft layouts are a prime example. In the Age of Paradox, the agents of change which work within every adaptive system have often been ignored, to disastrous effect.

In reaching beyond the Millennium, I am not advocating a return to the Age of Certainty (ie. buildings based on little knowledge of what they were to contain) but, more, a determination to uncover the connections between the many and various complex adaptive systems which underlie organisational design. In this endeavour, new interdisciplinary skills will be required to:

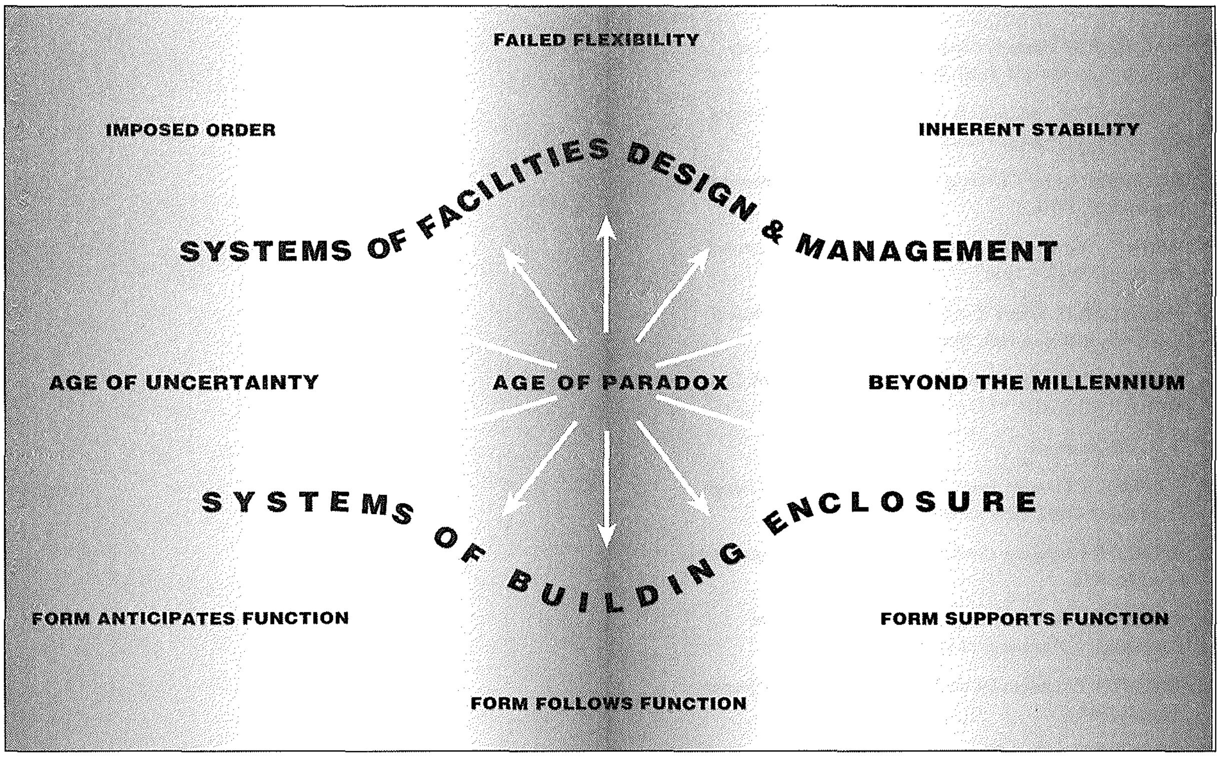

Figure 12

- uncover a pattern of operation which remains inherently stable
- provide control systems which are intelligible and accessible to users
- find building forms which support rather than follow function.

Such objectives can be met only by applying a process of 'holistic' thinking which must inevitably cut across current specialisms. To meet the challenge of building beyond the Millennium, the design process must itself become more flexible.

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DESIGN FOR MANAGEABILITY

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Introduction

Recent studies of building energy performance and of management and occupant satisfaction suggest that too many buildings deliver less than they promise. Pathological characteristics are too widespread, for example avoidable wastage of fossil fuels; poor indoor environments; chronic low-level illnesses of occupants; and low user morale. Most of these may also lead to productivity losses and absenteeism. The problems tend to reinforce each other: once standards slip they can become increasingly difficult and expensive to reverse. Since the features of the building and the culture of the occupying organisation are inter-related, it then becomes difficult to attribute direct causes.

Designing with management and use clearly in mind should help to make things easier. However, this seems to be much more easily said than done. Indeed, in striving for improved flexibility and efficiency, both designers and their clients often appear to under-estimate or ignore:

1. how systems - physical and human - can conflict with each other, thereby pulling performance levels down to the lowest-common-denominator; and
2. how uncertainty and inefficiency in systems' operation and use can readily develop through lack of attention to detail for occupants' requirements.

This paper considers how things might be improved, particularly in strategic thinking at the briefing stage about building design for use. It suggests that many problems can be traced to unmanageable complexity, a feature of modern buildings which arises from the tendency, first, to require too much of the building and its services and then too much of its management. It considers desirable attributes in buildings, postulates that designing for manageability may need to become an important criterion, and identifies new areas for research.

Much of the data referred to here is from studies in which Building Use Studies and William Bordass Associates have been involved over the past decade, including post-occupancy evaluations of offices, schools and museum buildings; building services and energy performance in a range of non-domestic buildings; and surveys of occupant comfort, ill-health and control behaviour.

Design, Occupancy and Management of Buildings

Different perspectives

A building consists of things that occur in space and time, and have a certain level of performance; see Figure 1. Although both designers and users usually try to create flexible buildings that respond well to changing requirements, their perspectives are different and often incompatible:

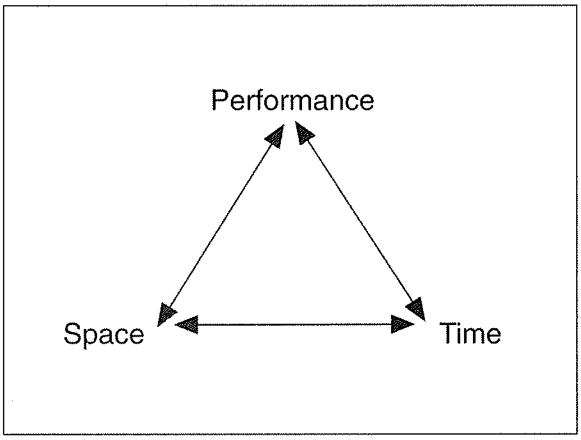

Figure 1: Different viewpoints on building performance

- The design team, in providing the artefact, are clearly most concerned with the spatial. However, they must also give the building the potential to meet changing needs over time, both from minute-to-minute (as, for example, the building services respond to changes in the weather, internal heat gains use, and occupant requirements), from day-to-day (with changes in working patterns, space use, equipment, furniture etc.), and from time-to-time (with changes in organisational structures, requirements, tenancy and even function). Figure 2a.
- Occupiers are most concerned with the time element: they want the building to support them in their activities - now! - and with as little effort as possible.[1] Figure 2b.
- General management, be it of the developers, the owners, the users, and even amongst the designers, has yet another viewpoint: the performance factors. How much will it cost per square metre to buy and to operate? What will the rental be? How many people will fit in? What heat gains can it accommodate? How much energy will it consume? Performance requirements may also be regulated by legislation and corporate or professional norms. Figure 2c.

At the design stage, problems often seem to arise when one party expects another to solve their problems completely. Flexibility is a common culprit; see Figure 3.

Design team
Performance and time factors tend to be subservient to space conditions.

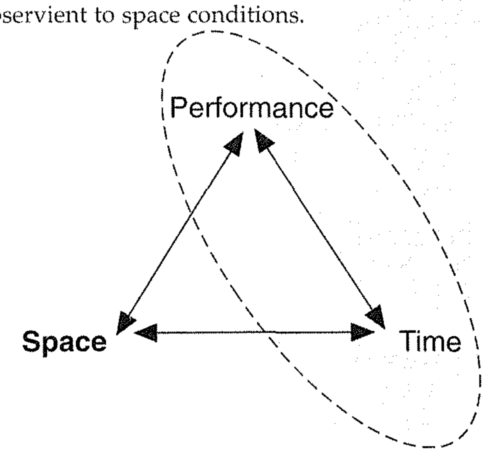

Figure 2a

Users and Occupiers
Time factors, often short-term, tend to drive space and performance considerations.

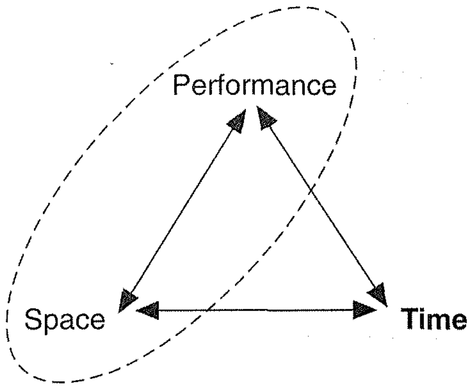

Figure 2b

Corporate management
Corporate managers tend to put performance indicators above everything else.

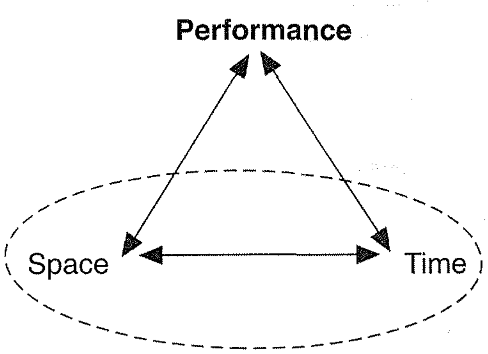

Figure 2c

At the Design Stage:

1. To avoid altering the building in use ...
2. one asks for it to be flexible.
3. Designers respond with complex systems ...
4. which in use demand management time.

In Use:

5. If not enough resources are devoted, or if response is not fast enough, failures occur ...
6. directly or indirectly affecting staff satisfaction, comfort, health and productivity.

In Use, Alternatively:

7. Enough time and effort is spent; but ...
8. the cost of looking after the complex systems intended to provide flexibility may exceed those of adapting a simpler building to meet new needs as they arise; and ...
9. the demand is relentless; and ...
10. the systems that were initially intended to provide the flexibility may themselves obstruct the change which is then found to be required!

Figure 3

A strategic diagram
Figure 4 is a diagram which has helped us and our clients to review some of the issues. Buildings can be seen as integrated systems (vertical axis), including both physical (top half) and behavioural (bottom half) elements with interfaces between them.[2] Physical systems (such as the building structure, walls and enclosed spaces, windows and ventilation systems) tend to be tightly coupled (meaning that there is relatively little slack or give between them.[3] Behavioural systems are loosely coupled (meaning that certain parts express themselves according to their own logic or interests.)[4]

The systems have attributes, on the horizontal axis:

- Context-free attributes (left hand side of Figure 1) can apply to buildings more-or-less independently of their operation. They include technical features, often passive ones, which are normally taken for granted in everyday use; and much habitual behaviour. They are very appropriate for application of standards and legislation.
- Context-dependent attributes (right-hand side), need to be tailored to suit the needs of the occupants, and generally require regular attention.

The four quadrants
The two axes divide Figure 4 into four quadrants:

A. Physical and context-free
Characteristics which are predominantly spatial, can be taken care of physically, and do not alter with operational context: for example location (except perhaps for transportable buildings); and passive features such as structural stability, fire compartmentation and insulation, which are largely 'fit and forget'. This is traditionally the main territory of designer, setting the major physical parameters for the occupier: the results in use may be regarded as anything between insuperable constraints and helpful, simplifying disciplines, depending how appropriate they are to the requirements. Ideally they should be made unnoticeable.

B. Physical and context-dependent
Here designers and occupiers meet, the occupiers having to look after the systems the designers have provided, and adapt them to ever-changing demands, e.g: equipment needs operating, servicing, adjusting and replacing; furniture needs to be moved about; and engineering systems react to changing weather and occupancy. These things need to be implemented and managed, but what this may truly entail is seldom fully considered at the design stage. Ideally they should be made usable, preferably by those most directly connected with them: it is better if you can move your own table, adjust your own thermostat and light, and for the engineer get at the item needing maintenance or adjustment without having to take lots of other things out of the way.

C. Behavioural and context-free
Things one would like to take for granted in (or at least reasonably expect from) people, and have implemented and internalised. They are ingrained in social structures, ethics and value systems, and supported by written and unwritten rules: national laws, habits, practices and expectations, overlaid by those of the occupying organisation and of the particular user groups. As a rule, designers as professionals do not share the occupiers' culture, lack understanding of their habits and priorities, and may expect them to behave in unfamiliar ways (for designers as individuals, there may be less of a behavioural gulf!) If this is really necessary, then a strategy must be carefully worked out, agreed and implemented. Better still if what you want fits the way people already do things, if it is intuitively obvious, and can be made habitual.

D. Behavioural and context-dependent
All is going well and something breaks down, or a telephone call changes everything! This is an area of risk, but of freedom and of opportunity too. Most

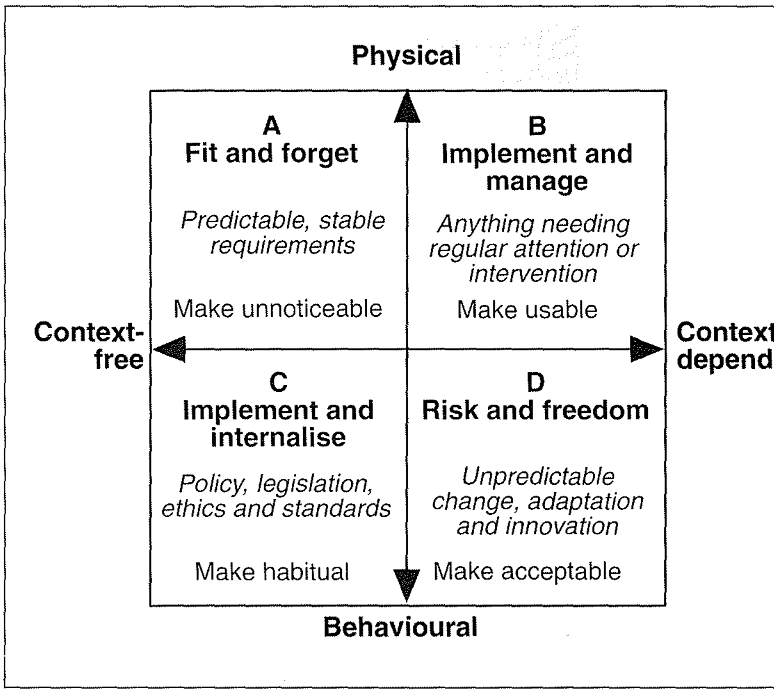

Figure 4

hazards can be reduced by a combination of physical, behavioural and managerial measures in the other three quadrants, together with risk management procedures, but if these are taken too far the result may be over-regulated, over-bureaucratic, and poorly adaptable either to change or to the real needs of individuals. Many cannot be entirely eliminated, at least at sensible cost (spending too much on reducing one kind of risk can divert funds from better and more cost-effective measures) and without unreasonable restrictions on freedom: instead they need to be made acceptable. Risks also have a nasty habit of being shunted around: people in safer cars kill more pedestrians and cyclists,[5] or force them off the road!

Trapping the fantasies
Designers tend to inhabit the left-hand side of Figure 4, users, the right-hand side. Many problems seem to occur because people either put things in the wrong quadrant, or fail to evaluate interactions between features and quadrants. Naturally clients want to avoid potential problems in use by referring them to the designers. Designers, in turn, often offer solutions which pretend to be in the top left of the diagram; but the leakage back into other quadrants, and the true implications for occupiers, is seldom reviewed carefully: it is assumed that the occupants will do whatever is necessary to make the solution work. In developing the solution, occupant behaviour is often stereotyped or ignored,[6] and if things go wrong later the usual defence is that the problems could not have been foreseen and that the occupiers are not behaving in the way that the design assumed and required.

As buildings become more complex, designer and user perspectives are more likely to 'fight' each other.[7] The rapid growth of the facilities management profession can be seen as partly a response to the need to cope with the consequent conflicts and inefficiencies, and the insights it is generating can now begin to be fed back upstream. Clients often misunderstand or ignore the spatial, technical, cost and legislative constraints within which designers must operate, and it is easy for everyone to conspire in fantasies that solutions are 'fit and forget', while 'fit and manage the consequences' (top left and right of Figure 4) would be more like it.

Many difficulties in practice can be traced to the quest for 'flexibility' and subsequent problems with the 'solutions', for example as outlined in Figure 3. In practice, it might have been better to start off with something simpler, which made fewer routine demands of management, even though it might require more substantial ad hoc intervention from time to time - which could itself be made easier with the right sort of design. At present, however, there seems to be a general tendency to try to force as much as possible into Quadrant A, whether it belongs there or not, some symptoms being over-reliance on technology, burgeoning legislation (designed in part to deal with technological overkill), more standards and codes to be met, and less scope for discretion in design and management.

A Way Forward?

Introduction

If we expect too much of the building in the hope of reducing risk or making things easier for its management, the consequent demands of a different kind upon management may restrict opportunities for appropriate and effective compromises, and in turn reduce overall performance. This trend could become self-perpetuating as designers, managers and legislators continue to seek technological solutions to what should more properly be considered as human management problems, and which in turn make buildings harder to manage effectively, and less easy to change.

Instead we consider that more attention should be given to understanding outcomes of human behaviour in real contexts, especially:

- in risky, abnormal or dangerous circumstances;
- when individual actions are further constrained by group behaviours, including how individuals and groups respond to sub-optimal internal environmental conditions;
- change, flexibility, adaptability and responsiveness of conditions to new situations;
- effects on behaviour and decision-making of changing work tasks;
- usability of control interfaces.

All these fall properly in the right-hand part of Figure 4, and all are seldom given due weight.

Improving performance in use

Figure 5 summarises eight fundamental Attributes of buildings and their management which studies have shown to benefit performance in use, and which could be used in strategic briefs for new or remodelled buildings. They will be discussed in turn in the eight sections below. Supporting evidence can be found in the references: we must apologise for about one-third of these being our own, but these in turn do also refer to the wider literature!

1. Optimise relationships between physical and human systems over their lifetimes.
2. Keep resource inputs and undesirable effects to the necessary minimum.
3. Are simple but capable of upgrading, avoiding unnecessary complexity.
4. Are economical of time in operation.
5. Respond rapidly to change.
6. Have sufficient management resources to deal with both routine requirements and unpredictable consequences of physical or behavioural complexity.
7. Are comfortable and safe most of the time, but use properties 5 and 6 if difficulties occur.
8. Try to avoid introducing failure pathways.

Figure 5

ATTRIBUTE 1

Optimise relationships between physical and human systems over their lifetimes

Buildings and their occupying organisations are recognisably complex systems, with many levels of interaction and feedback between sub-systems. However, many are designed, built and occupied as if they were independent systems with simple causality. It is commonplace to hear designers plead for their specialism (lighting, security, furniture and so on) to receive priority in the design process. This way they can avoid or minimise constraints deliberately or unwittingly imposed by others, and perhaps pass on some of their own for good measure!

True integration, with attention to detail and avoidance of unnecessary conflicts, comes through a well-developed briefing process which does not compromise specialists' roles. Later in the building's life, the brief should become the yardstick for post-occupancy surveys which objectively test whether it was met - and whether it was relevant! The information may then be fed into new building briefs, closing the quality improvement loop. The now extensive literature on 'total quality' offers many suggestions for building managers. For instance, techniques used in small-scale product development seem particularly appropriate to use at the larger building-system level.[8]

For building and environmental services, it is important that the point of control is as close as possible to the appropriate point of need. Anything else will require access to management resources: which is at best wasteful, and usually means that an undesirable state becomes the default state because it is the most convenient.[9]

ATTRIBUTE 2

Keep resource inputs and undesirable effects to the necessary minimum

Buildings are undergoing a demand-side revolution, of which the rapid growth of the facilities management profession is an important part. Emphasis on systematic building evaluation techniques is increasing, in an attempt to give potential occupiers a clearer understanding of strengths and weaknesses in advance of committing themselves to development, lease or purchase. Good buildings match demand and supply, while keeping 'just-in-case' provision to a necessary minimum. From the somewhat extravagant 1980s - both in appearance, specification and over-provision (for occupancy, structural loadings and in particular cooling loads) - one now hears calls for 'no frills', 'lean and mean', and more recently 'lean and fit' buildings. However, whether the economies have been made in the right places has yet to be demonstrated!

With wider understanding of building performance - through investment, costs in use, technical features and human factors - clients are more aware of the questions to ask their design teams. Faced with an informed client, and more focus on problem definition, designers must respond with better predictions of what their buildings will deliver. That architects and engineers have less influence over briefs and strategic agendas for buildings is not necessarily a bad thing: potentially more attention to needs and requirements will permit better problem definition in the building brief, to which designers can then give a better response.

For day-to-day running, the resource inputs include manpower, technology, space, materials, management and energy. While economies are being sought in all six, this can be done in the context of adding value rather than penny-pinching, and under good management virtuous circles are possible. The results are encapsulated in phrases like "environmental sense makes business sense".

In user surveys we see a microcosm of this. For example, buildings which worked best for human comfort and satisfaction were also energy efficient[10] probably because a good match of demand and supply was achieved through more effective building procurement and management, careful performance monitoring, attention to users' complaints and relatively rapid feedback loops and well-defined diagnostics. This was helped along by robust, well-designed, user-friendly systems, effective cleaning and maintenance, and efficient energy management all involve active monitoring of systems' performance. The cleaning or the energy saving may not be most important part of these activities, but the monitoring and the culture which causes it all to happen.[11] Interestingly, the three best buildings from the users' point of view happened to be pre-lets: while not statistically significant this suggests that the occupiers, while able to influence the buildings, were less distracted by the mechanics of having to build them, and could concentrate more on what they really needed from them as users.

ATTRIBUTE 3

Simple but capable of upgrading, avoiding unnecessary complexity

This is a development of Attribute 2. The desire for (or promise of) 'flexibility' often leads to complex solutions which are reliant on energy-dependent technologies such as air-conditioning. However, in practice the flexibility may not be as great as was initially hoped, as can be seen by all the nearly new materials which end up on the skip when many air-conditioned offices are fitted out.

Almost invariably, when buildings are altered to suit new requirements, the altered space will be more densely occupied and accommodate a wider range of activities, for example, in higher education which needs to change uses from daytime to evening and from termtime to vacation; or in converting offices from cellular to open plan.

The best buildings are able to accommodate higher densities and more functions operating simultaneously. However, in recent solutions one has fears about more rapid obsolescence. An alternative route may sometimes be to provide simpler, but potentially adaptable, buildings which are easily altered as needs change. If properly thought-through, this can potentially reduce both initial and in-use costs. 'Mixed-mode' services concepts, which allow natural ventilation and mechanical systems to work together, are examples of this.[12]

However, designers and clients seeking flexibility, or energy efficiency, may unwittingly add to complexity and the management resource requirement and hence sow the seeds of failure - and new ideas (including mixed-mode) could be as prone to this as the old ones. For example, the 1994, Energy Efficient Best Practice Programme, *Technical review of Office Case Studies and Related Information* notes that:

'complex energy systems may not be operated as the designers intended, and saved heating and cooling energy may turn up instead as parasitic losses from pumps, fans and unforeseen control problems'. It goes on to say that 'the greatest savings nationally are likely to come from simple applications of available technology in a manner which integrates architectural, engineering and user requirements, and provides control and management systems to suit.'[13]

ATTRIBUTE 4

Economical of time in operation

While buildings operate over time as well as in space, far more attention has been given to performance in relation to spatial variables. As a result, space and time systems are often poorly integrated and physical solutions are often proposed where operational approaches might have been better, and sometimes vice versa. In future, more thought should be given to the way buildings work dynamically, especially to overcoming inefficiencies of space or time (efficient use of space is not necessarily good: sometimes what looks like waste space may be useful redundancy which saves time in operation and may be cheaper to build - or to retain - and to service). Understanding time involves not just considering gluts and famines of occupancy, but also how habits, attitudes and behaviours influence the way systems really work.

The best buildings keep the time wasted by occupants moving about to a necessary minimum. The point is closely related to response times (Attribute 5) - the faster a need is met, the better. This applies not just to more obvious facilities such as say the location of meeting rooms or toilets, but to activities such as photocopying, where there may be major inefficiencies in queuing, machine downtime and travel time to the machine location, and to the ease with which the building may be altered. Economy of time in fact unites many of the Attributes in Figure 5. A simple rule is to make 'the bad difficult and the good easy', which means comprehensible devices correctly located, easily operated, and configured to give rapid response while avoiding unnecessary waste.

ATTRIBUTE 5

Respond rapidly to change

Speed of response is widely discussed in management science[14] but rarely in the building literature. However, the faster a building (meaning the whole system, human as well as physical) can respond to requests for change from occupants, the better people like it and the more productive they say they are.[15] Response time applies in obvious ways in lifts answering calls, or computer systems responding to a log-in request. (J Neilsen says four seconds is the tolerance threshold!)[16] More emphasis is now being placed on the speed with which furniture systems can be reconfigured, and possible cost savings by much more efficient relocation logistics.

Management which reacts promptly to occupants' complaints is appreciated, even where the source problem cannot be completely solved. Surveys of comfort and occupant satisfaction,[17] reveal more positive and appreciative occupant perceptions where quick response is the norm - whether this is provided by physical control systems such as adjustable blinds or manually-adjustable thermostats, or by building management support services, or combinations of the two. One reason why, when surveyed occupants say that they like the conditions in naturally-ventilated buildings more than one would anticipate from the monitored values, is that openable windows give fast response and intuitively obvious control, even though they may not always deliver optimal or even reasonable conditions.

Rapid response is most commonly found in buildings which have enough management resources to deal with problems when they arise. Good management will set up self-reinforcing virtuous circles of causation which consistently 'deliver' quality and responsiveness. However, most buildings are victims of vicious circles which can become increasingly expensive to halt or reverse as they spiral into decline,[18] as with vandalism which tends to escalate unless an environment is cared for, with immediate repainting or repairs.[19]

Technical systems also need to give rapid response to failures, see also Attribute 8. While automatic alarms are usually provided for critical faults like fires and boiler lockouts, chronic faults which affect efficiency but not service frequently persist for long periods. Examples include:

- wasteful operation of heating and air-conditioning systems, sometimes even running continuously;
- malfunctions of energy-saving systems, like heat recovery, free cooling and night ventilation.

ATTRIBUTE 6

Sufficient management resources to deal with both routine requirements and unpredictable consequences of physical or behavioural complexity

As often as not, the true manpower requirements of running buildings are under-estimated or ignored altogether by designers and by senior management, forcing many buildings into vicious circles from move-in day. Budgets are also soft targets for cutbacks, partly because line managers do not have convincing data with which to defend themselves against attack from above (for example, MH Smith[20] and B Williams[21] suggest that - as a rule of thumb - expenditure on energy and on building services maintenance should be similar). But much can be done in good briefing and design to reduce the management task by making things less complex and more self-managing.

Early work on sick building syndrome (SBS) in UK offices led many, including the authors, to regard SBS as primarily a design problem (with the main explanatory variables being physical features such as type of ventilation system or depth of space). As understanding grew, it became clearer[22] that problems usually surfaced where the building's demands for management and maintenance were well in excess of the resources provided.

In general, management and maintenance leaves a great deal to be desired, either from knock-on effects of chronic long-term underfunding (as in many British schools for instance); through bad habits and practices (including poor selection and supervision of outside contractors); and because the building's demands were too great for the resources available - often a result of wishful thinking at the design stage.

ATTRIBUTE 7

Are comfortable and safe for most of the time, but use Attributes 5 and 6 if difficulties occur

One of the best kept secrets of work on thermal comfort is that alleviating discomfort is just as important for occupant satisfaction as providing comfortable conditions in the first place,[23] and that people can exploit opportunities to adapt themselves and the internal environment to meet their needs.[24] Occupant dissatisfaction with the indoor environment is directly related to occupants' perceived productivity[25] - with a stronger link between dissatisfied staff and lost productivity than between satisfied staff and better productivity. On this basis, it may be better to give building occupants more capability to fine tune their environment than to rely upon fully automated systems which in theory can deliver better conditions but may not be perceived as doing so.[26]

Designers often assume that comfort can be achieved solely by systems designed to "keep the measured variables within the required tolerances"

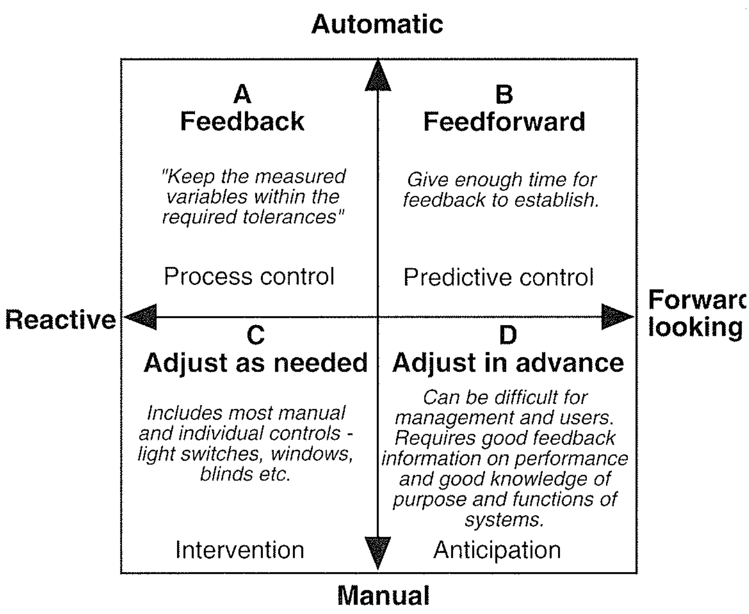

Figure 6

and leave out the other features. However, to provide both comfort and energy efficiency the best buildings require all four features shown in each quadrant of Figure 6. They need automatic control (top half of diagram) plus manual control (bottom half) and if possible should anticipate likely change (right half), and not just operate in response mode (left half). However, gratuitously adding more controls may introduce conflicts between different sub-systems and increase complexity beyond manageable bounds.

User control is also important because people are often better than pre-programmed systems at dealing with unusual or unpredictable situations - which are also likely to increase as space use is intensified. For example, open-plan offices trade off the greater personal controllability normally found in cellular spaces for greater inter-personal communication in the open areas. However the productivity gains from better communication may not always outweigh the productivity losses caused by more distracting, less controllable environments, which are frequently perceived as less comfortable too.

Like airline pilots who normally fly under autopilot but take control in difficult, unusual or emergency circumstances, building users need the capacity to make adjustments; and their tolerance of conditions increases as perceived control rises. For example, users seem to accept 'poorer' conditions in naturally-ventilated than in air-conditioned buildings.[27] Similar considerations apply in the arena of safety and health, and especially in the rapidly-growing subject of risk assessment. Figure 7,[28] briefly illustrates some of the considerations. (See also Attribute 8 and C Perrow, *Normal Accidents: Living with High-risk Technologies.*[29])

Unfortunately, some engineering and energy-saving systems may create rather than alleviate discomfort. As a general rule it appears that:

- manual systems should operate perceptibly and give immediate response, if not by performing the intended function then at least by giving a click or lighting an indicator;
- automatic systems should operate imperceptibly: if not, whatever they do is sure to be wrong for some occupants.

Automatic control of lighting and blinds are common offenders here:[30] the blinds close either just as you are enjoying the sun or long after you have become fed up with it; the lights come on when you enter the room whether you think you need them or not; and other people's lights flashing annoy you. Automatically-controlled windows in new 'green' buildings may create similar problems. For such systems, individual user over-rides are not costly luxuries, they are essential.

Failure to consider the ways in which human errors can affect technological systems
Example: Obscure and difficult to operate Building Management Systems resulting in energy wastage and discomfort.

Over-confidence in current scientific knowledge
Example: Failure to take unproven scientific evidence seriously or develop precautionary strategies (eg global warming).

Failure to appreciate how technological systems function as a whole
Example: Overlooking importance of control interfaces in buildings, especially manual controls.

Slowness in detecting chronic, cumulative effects
Example: Building-related sickness

Failure to anticipate human response to safety measures
Example: Windsor Castle fire where emergency telephones were not seen by those wishing to raise the alarm.

Failure to anticipate common-mode failures, which simultaneously afflict systems which are designed to be independent.
Example: Failure of innocuous window components like friction hinges in naturally-ventilated offices simultaneously affecting noise, ventilation and heating performance.

Figure 7: Risk estimation considerations.
Source: Adapted from B Fischhoff, 'Risk: a guide to controversy' (see Reference 28)

ATTRIBUTE 8
Avoid introducing failure pathways
Few buildings fail catastrophically in a technical sense. Many more fail economically, functionally, aesthetically or socially and exhibit chronic problems of one kind or another which often persist for the lifetime of the building. With hindsight, some of these once latent faults seem blatantly obvious, but they can be hard to detect beforehand unless thorough briefing and design management disciplines are in place, plus appropriate testing of solutions where practicable. With risk analysis techniques, which help prevent accidents in complex and dangerous systems like nuclear power plants,[31] one can now target problem areas and put prevention strategies in place early in the design process. For example, in a naturally-ventilated building, the window is one a crucial building element, so it is imperative that its components should operate reasonably effectively and in sympathy with associated systems, or apparently trivial difficulties or oversights can be very costly in the long term.

Buildings too often default in performance to undesirable states which are extremely hard to alter. For example, many run with all their lights on all day because the first person who arrives in the morning in the half-light of dawn will switch all the lights on (at the gang switch near the door). Maybe they have no option, maybe the switching is incomprehensible, or maybe they just want to 'cheer the place up'. As successive people arrive, it becomes harder and harder to switch any lights off because of the difficulty of agreeing amongst everyone that this should happen. The building will thus tend to run 'lights on' by default, whatever the daylight conditions outside. The combination of habit, poor control design, and the difficulty of making small-scale 'trivial' decisions in groups leads to unnecessary inefficiency and sub-optimal working environments. Here, lack of integration between spatial factors and time factors (location of light switches, times of arrival) leads to buildings running 'just-in-case' - that is, inefficiently and insensitively to true demand. Automatic daylight-linked controls are not the complete answer to this problem. Human and automatic systems need to be sensitively combined.[32]

A review of case studies[33] found that office energy use depended more on the detailed design, commissioning, control, operation and management than on the technical features adopted. Human management was at least as important as technology in securing good energy performance, particularly in the air-conditioned buildings which had more potential for wastage. We are now finding that the more complex designs being developed in an attempt to avoid air-conditioning are often similarly afflicted,[34] and that much of the energy waste previously attributed to air conditioning can be laid at the door of unmanageable (or at least unmanaged) complexity! Typical energy-related failures include:

- Default to ON.
  Systems operating unnecessarily.
- Tail-wags-the-dog.
  Large systems operate inefficiently to meet small demands.
- Antagonistic operation.
  eg: heating fighting cooling.
- Embedded system failure.
  Breakdown or faulty operation of systems designed to save energy not detected because comfort and service are not sufficiently affected.
- Parasitic losses.
  Excessive energy consumption by items intended to save energy but not directly involved in service delivery (for example heat recovery pumps).

Conclusion

We have explored a range of issues which affect building performance in practice, often through the inter-relationship of space- and time-dependent variables, and of design and management. Many of these have received less attention in briefing, design and research than we think they deserve. We have begun to use them ourselves in briefing and design reviews, with positive responses, particularly from clients who can envisage integrating their buildings more closely with their business needs; and from designers who have simplified their proposals, reviewed their usability and considered how potential operational failures might be avoided or trapped.

However, each of the eight Attributes could merit a research programme of its own, or at least some changes in the emphasis of ongoing research. In some areas we feel that solutions are close: indeed many answers may already be available in related areas like management studies, risk analysis and ergonomics. However, their applicability to buildings has not yet been clearly considered.

If there is a single conclusion from the work to date it is: avoid unnecessary complexity and design for manageability. While what this means exactly requires more study, provisionally we suggest that:

- The fewer demands a building makes on management services, the better.
- Passive is better than active. Make sure that things which are designed to operate in the background do so properly.
- Things which needs changing or looking after should be usable, preferably by those who are most directly concerned with them. Responses should be rapid and understandable.
- Simple is better than complex, but when complexity is necessary try to package and isolate it wherever possible, and provide simple interfaces.
- Cater where possible for people's preference ranges rather than averages or norms. Try to foresee risky situations and consider how people may compensate.
- Potential failure paths should be identified and if possible avoided; if not, appropriate indicators should be monitored to help identify, and deal with, incipient problems.
- Try to assess risk cost-effectively, so that resources are spent realistically on avoiding the costliest and most risky events.
- Beware unsubstantiated promises of 'flexibility' which may bring unforeseen management costs. Recognise that all situations are subject to constraints, which will reveal themselves sooner or later.
- Remember that designers are not users, although they often think they are![35]

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SPACE INTENSIFICATION AND DIVERSIFICATION

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Introduction

This paper was originally prepared in 1994 as a working document for the *Vision 2000* study, undertaken by National Power plc. It examines how space use is changing in the United Kingdom building stock in the light of socio-economic and technical changes, some of which appear paradoxical. Implications for buildings in different sectors, such as housing, office and retail, are examined, and brief conclusions offered.

Definitions

Intensification is where existing, refurbished and newly created built space is used for more activities, which may be carried out over longer periods of time and/or at higher densities than in the past. Diversification is where activities are spread over a greater number of spaces in a larger number of geographical locations than before.

Intensification and diversification (I-D) are both are features of the same underlying processes of social and economic change. They are leading to:

- more highly-serviced spaces both for living and working;
- more prolonged use of space over time, with buildings occupied for longer periods during the day;
- much greater use of communications infrastructures;
- increasing demand for faster and more reliable transportation;
- wider geographical spread of organisations and social networks.

However, there is no single trend or vector: buildings in different sectors are affected to varying degrees. In the office sector, for instance, organisations with a well-developed knowledge of information technology are much more likely to both intensify (by introducing address-free working) and diversify (with remote-access working). Those not taking full advantage of information technology may intensify into a single headquarters site (in the search for reduced occupancy costs) but fail to take advantage of diversification.

The ability of organisations to exploit opportunities offered by intensification - diversification will often be determined by behavioural, managerial and social factors, not just technological ones. Especially important will be the degree to which people share common assumptions: the more they do, the more they will be able to work remotely. For example, at the beginning of complex, multi-professional projects, people may have to meet frequently and intensively to thrash out the basic rules and approach. As the rule set is agreed and matures, people will need to meet less and will tend to work more by themselves.[1] Similarly, younger staff who do not fully understand the culture and *modus operandi* will be less likely to work away from the office. This will also lead to a greater proportion of young staff based in the office, with older staff having more locational options.

Organisations which have potential for diversification (such as soft drinks manufacturers, where production plant is relatively indifferent to location) can over-centralise, in the mistaken belief that economies of scale can be found in one large plant.

In the domestic sector, diversification by office-based organisations may lead to greater use of the home for office work, but this may be countered by people carrying out more activities outside the home (as with eating out, for example) so that the home tends to be used as a base.

Effects of intensification on occupant densities of buildings vary with more equipment and supporting space and services. At any time occupant densities may be in fact lower. However, with increased occupancy hours and greater throughput of people, a given building may support more people. Diversification of more people spending more time outside the intensified building may increase the use of other spaces - homes and hotels, for example, which may consequently expand to cater for the demand, again lowering densities.

Minimising cost and adding value

The economic process underlying spatial decision-making has been concisely expressed as 'minimising cost and adding value',[2] although the neatness of the phrase sacrifices some of the complexity of the dynamics involved (see later section on Dynamics). Most spatial decision-making - geographical, planning and architectural - involves variations on themes of cost and value.[3]

Cost minimisation produces clustering through economies of scale, especially taking advantage of reduced transport costs; however, it can also send work long distances away when premises and labour costs are lower elsewhere and where information can be moved about easily and cheaply. This is one example amongst many others of paradoxical counter-trends which are found in spatial processes. But people seek building types and/or locations which trade-off least costs against added value, often resulting in countryside or greenfield locations on the urban fringe. This operates within existing social, technical and cost constraints: in particular, accessibility. The process has been a prominent feature of twentieth century spatial change - witness suburban expansion in America in the 1920s and 1930s. Outcomes are seldom optimal because costs and benefits fall upon different people at different times. For example, each wave of suburban expansion at the city periphery lowers amenity values enjoyed by the previous phase of settlement.

The intensification-diversification (I-D) process is often unstable, because of positive feedback loops built into it. Cost minimising activities carry side effects which result in the transfer of disbenefits to others, thereby ultimately reducing, rather than adding, value. The distribution of these externality effects which result from cost minimising activity is a fundamental feature of the process of spatial and environmental change. Its most recent manifestations are Nimby (not in my backyard) and Banana (build absolutely nothing anywhere near anyone). Negative effects become more obvious once environmental carrying capacities reach their upper limits, as with tourism pressures or the destructive effects of pollution. Usually, the ultimate consequences of spatial decisions are not understood at the outset, as with the location of nuclear power plants, for example. Once made, spatial decisions have considerable geographical inertia, and can be difficult or impossible to undo.

Simplistic cost-minimising objectives seemingly drive an increasing number of spatial decisions, which are often taken with short-term profits and higher productivity as prime motives. At the same time, activities like building procurement, design and management are all becoming more complicated and seem to be affecting more people. Two types of complexity, one arising from spatial activities (that is, spatial densities, interactions, adjacencies and combinations of existing activities) and the other from increasing uncertainty about future actions are involved.

Complexity

Building users usually want multi-functional spaces which respond positively and quickly to their changing requirements. These preferences apply as much to constantly occurring, high-frequency decisions with small-scale effects (such as when people switch on the lights or adjust temperatures) as to low-frequency decisions with large-scale effects (perhaps made once every 20 years when an organisation may want to refurbish its building or move to a new one on another site). Nowadays, moves are often made to accelerate a change in culture, and not necessarily because the buildings themselves are technically outmoded.

Faced with this, designers have created buildings which they perceive to be both more spatially diverse and more responsive. The term 'flexibility' is often applied both by designer and client to indicate a desire for improved responsiveness to changing but uncertain needs. Flexibility implies the capability to accommodate higher spatial densities and cope with greater uncertainty. Often, buildings designed this way will be more automated or 'intelligent' than previously, in the belief that adding automation (which often involves taking direct control away from many of the occupants) will achieve more spatial diversity, greater responsiveness and less uncertainty.

However, many modern buildings fail to meet these expectations. Recent research evidence from office buildings suggests that in some buildings with greater complexity the environment is sometimes less responsive, harder and more costly to manage and disliked by the occupants.[4] As designers are faced with increased uncertainty (through proliferation of technological choice, among other factors), their strategies also tend to embrace 'normal', predictable, operating conditions whose parameters are easier to define (legislation and standards often prescribe them). Buildings prescribed in this way also seem easier to automate, which often means that too much control is inappropriately taken away from the occupier and user and placed under automatic supervision.

These circumstances lead designers increasingly towards assuming:

a) that they can work to a normal 'envelope' of physical and behavioural performance criteria, quantitatively defined and largely context-free (as for thermal comfort standards, for instance);

b) that buildings will usually stay within this envelope in use; and

c) that the mechanical systems should operate to keep conditions within the required tolerance envelope.[5]

These assumptions and judgements are now more frequently assisted by mathematical models and simulations which test out various scenarios of use. Relentless intensification of use, though, can have opposite effects. It can drive the actual performance of buildings to move outside the designed-for envelope. When this happens, the physical, human and management systems are often not responsive enough to ensure that the building copes properly with needs.

Intensification also increases the chances that discrete functions will conflict with each other's performance. This may help to explain why so few buildings seem to achieve in use the performance standards which were predicted for them, and this is one reason why buildings seem to be more uncomfortable and unhealthy for their occupants. Many open-plan office spaces, for instance, quickly become hotter, dirtier and noisier, and reach a lowest common denominator of performance (in which people compromise and accept lower standards because they are not prepared to give time and effort towards reaching reasonable solutions). Once a building reaches this state, it is extraordinarily difficult to change it for the better, which is one reason why organisations move and attempt to start again from a 'higher' base.

Rather than design for average requirements, strategies will increasingly be employed which respond to thresholds of change, so that buildings and spaces within them are able to switch from one state to another in response to demand. These thresholds apply to individuals (who, triggered by discomfort, may need to alter heating, lighting and ventilation settings, for instance) or to groups (who may want to reconfigure quickly their workstations or production processes) or to larger-scale changes in building use over time, where a space may need to be rapidly changed to serve a different purpose. The potential for modal switching is becoming an increasingly important feature of modern buildings, and is one of the responses to intensification.

Dynamics

The intensification-diversification process has nine constituents, A - I in the list below. Stages A and B are about minimising costs and adding value, as discussed above; stages C - I are about the emergent dynamics, including feedback loops and their consequences.

A. Minimise cost

B. Add value

C. Hidden negative interaction effects of A on B (value subtracted through excessive external costs)

D. Legislation to stabilise or prevent C

E. Negative effects of D on A (where legislation is perceived to increase cost, therefore increasing pressure to reduce costs of D)

F. Increasing spatial complexity (in part response to uncontrolled A)

G. Increasing strategic awareness to increase responsiveness to cope with increasingly uncertain change (in part a combined response to both B (quality criteria) and A (management cost)

H. Hidden negative interaction effects of F on G (less responsiveness possible with increased spatial complexity)

I. Positive interaction effect of G on F (producing 'simpler' and more robust design strategies as a response to increasing complexity and higher management costs).

The extent to which people participate in this process depends on their respective roles. To some managers or clients, for example, stage A (minimise costs) will be all that matters; they will go no further. Developers may have a strategy which stresses B to the marketplace, while pursuing profit maximisation for themselves and their investors. Increasingly, building legislation is forcing all participants in the process to consider stages C, D and E as well (although enlightened developers are also realising the market potential of buildings which work well for C, D and E, and are exploring I [7]). Managers in touch with the consequences of poor coordination between design decisions and user requirements are more aware of F and G, and in rare cases, understand H well enough to insist on design strategies which also go as far as stage I.

In future, as knowledge of building performance and its social and environmental consequences increases, more buildings will reach stages F,G,H and I, but increasingly driven by criteria set by management. For example, there is increasing

What do you think will be the next 'big one', the next huge success, in the software world?

Bill Gates: "Group productivity, advanced mail stuff - a lot of opportunity there ... In this client/server thing, the idea of seeing corporate data graphically, being able to browse around it very easily, and have it sort of remember what stuff you like to see and make it easy to call up. That whole way of seeing your corporate data - nobody's really done very well with that. That's a big area. Some people call it database front end, but that's just because they are using an old label on a new thing." September 1990.[6]

"In ten year's time, in most successful businesses, the workers will truly 'own' the means of production because those means will be in their own heads and at their fingertips ...Large parts of organisations could ultimately become a collection of project teams, harnessing the intellectual assets around a task or an assignment, rather as a consultancy company or advertising agency does now."

Charles Handy[8]

evidence to show that organisations with clear-cut missions which are resolutely carried through in everyday management practice are more likely to have buildings which are comfortable, healthy and energy-efficient. These organisations insist on rapid response in the total building system (including the management systems), even if they have to by-pass the design or consultant teams to achieve it. Some will be happy to 'drive' complex solutions but most will insist on simplicity and manageability. This is more likely to happen where tenants can 'take ownership' of some operational features of the building, and this seems to happen best in buildings which are let to them in advance of fit-out.[9]

Changing demand

The intensification-diversification process both helps promote new technological developments and, in turn, is affected by changing social and technological requirements. Some of the most prominent of these are listed below, and covered in more detail in subsequent sections.

Client/server networks
Rapidly increasing demand for information technology, with broader communications bandwidths (for multi-channel graphics, voice and video) and uncongested communications gateways leads to more advanced client/server computer network relationships based on advanced document management,[10] with wide-area and wide-bandwith networking becoming much more important.

Working groups
Working groups and project teams are increasingly becoming the organisational focus in all kinds of working contexts - commercial as well as industrial, short term and long term.[11] The tendency, especially in offices, is still to plan for the individual or the department, leaving the workgroup as barren ground.[12] This will change as individual needs are better understood and the department become less important organisationally.

Demand sensitive use of space
Use of space is now much more context-dependent and demand sensitive. This leads to more rapid reconfiguring and switching between changing uses and different states. It emphasises the different requirements of space/services supply and user demand in buildings, the interfaces between them and different materials cycles inherent in site, fabric and services (which also have major implications for waste avoidance).

Energy Consumption by final user

	1960	*1992*
Domestic	29%	29%
Industry	42%	25%
Transport	17%	32%
Other final users	12%	14%

Based on table 7, Digest of UK Energy Statistics, 1993

Consumption of space by different modes of transport, occupancy and speed

Mode of transport	*Speed (km/h)*	*Space (m^2/person)*
Pedestrian	5	0.8
Cyclist	10	3.0
Car (fully occupied)	10	6.2
Car (fully occupied)	40	20.0
Car (1 person)	10	18.7
Car (1 person)	40	60.0
Bus (full)	10	3.1
Bus (1/3 full)	10	9.4
Bus (full)	30	9.4
Bus (1/3 full)	30	28.1
Light rail (full)	30	2.2
Light rail (1/3 full)	30	6.9

Source: J Whitelegg[13]

Unhindered access
Unhindered access to transportation infrastructure is more important with increased intensification. As activities intensify, they also become more segregated, leading to greater accessibility being required on demand. However, with improving electronic communications and pressure to reduce environmental impact of motorised transport, many of these movements will be over shorter distances, or irregular, or replaced by more rapid and cheaper information transfer.

This may renew interest in optimum sizes for cities, perhaps leading to existing large agglomerations, such as London, dividing into smaller units (based on, say, Westminster, Croydon, Hammersmith, Lewisham, Stratford and Islington/Camden). The geographic extent of these places may possibly be defined by tramway/metro systems (as is now happening in Manchester and Sheffield, and in the near future in Croydon, Nottingham, Glasgow and Solent).

Security
Greater physical security will be required, both in buildings and information systems. Rapid changes have taken place in this respect in recent years, with, for example, displacement behaviours caused by increased use of closed-circuit television and neighbourhood watch schemes especially interesting.

Organisational cores
Organisations are increasingly concentrating on spaces occupied by their core business functions, which tend to be more highly serviced and specialised, and more consistent with their mission or image. However, building services may ultimately become simpler. The non-core businesses shed will create new opportunities for other organisations, for redundant staff and for new businesses.

Redundancy
Non-essential space, especially space which is poorly used or costly to maintain, will be released, leading to a greater proportion of stock which is under-used or obsolete. Demolitions are likely to increase, and there will be more strategic thinking on redevelopment and re-use.

Cost of time
Time dependency, time management and the cost of time increasingly affects locational and spatial decisions. High labour cost activities are intensifying and agglomerating; low cost and non-locationally critical activities will increasingly diversify and disperse, and the old economies of scale will be less appropriate.

Coupling
There is more 'tighter coupling' (that is, increased connectivity between and inter-dependency) of human and physical systems, which leads to increased likelihood of system breakdown or failure and greater attention to risk management. This is a marked trend, with more and more buildings failing because of inappropriate integration between physical and management systems.

Theoretical capacity
When all spaces are completely full at all times, but allowing for cleaning, etc - obviously never met, even in hospital wards where the target is often for 100 per cent bed occupancy;

Design or system capacity
The capacity at which the building and its occupying organisation was designed to run.

Effective capacity
Often a reduction from the design capacity to reflect typical operating conditions.

Utilisation
The actual level of use (sometimes also called load factor), which would normally be less than the effective capacity, but when exceeded create bottlenecks.

Bottlenecks
Where utilisation is greater than effective capacity). Output (utilisation) divided by input (design capacity), and utilisation divided by effective capacity, are two measures of the efficiency or yield.

Yield of the system
Measuring yield begs the question of how much extra capacity (or 'redundancy') the system needs in order to function properly. Redundancy is used in the same sense as in information theory to measure the extra information that needs to be carried by a message in order that it can be efficiently and economically decoded. The Bible, for instance, has been estimated to be 41.3 per cent redundant.[14]

Client/server dynamics

Intensification-diversification is most clearly seen in client/server arrangements in information technology networks. The 'server' machine is usually a central store and management system for data and software. These data are distributed (in the form of electronic mail or data files, for instance) to 'clients' over a local network (usually within a building) or a wide-area network (which can be anywhere in the world).

Server machines intensify the use of space because they require security, back-up and specialist technical support. They must also be well-managed with stable, reliable and constantly accessible communication pathways.

Client machines may be located in the same office, or anywhere that has reliable and economical communications pathways to the server system. Client machines thus have the potential for spatial diversification. Activities which are information-hungry, such as libraries, banking, media and insurance, have the potential for rapid intensification-diversification. Offices in these sectors, for instance, will become more like mail, meeting and message centres (with the server intensively serviced); libraries will become nodes and local delivery points in global communication systems. Access to systems will increasingly be made via communications services using Integrated Services Digital Network (ISDN) and equivalent facilities.[15]

Until these systems are stable and proven, many buildings will operate concurrently, with client workstations retained within buildings alongside servers as well as using 'traditional' computing or filing arrangements. Increasingly, client workstations will move to remote locations once the cost effectiveness, reliability and usefulness of networks have been proven. Server locations will be in buildings which are intensively serviced and managed, secure, and operate for 24 hours a day. Client locations will be less-intensively serviced, lower cost, less secure (security will still be important but not critical) and often operating on demand.

Organisations will be increasingly identified with their high-cost, server addresses, but far more organisations will use virtual arrangements with a headquarters address front-end and dispersed working for the majority of staff. These arrangements will increasingly highlight those differences between buildings and spaces which are critical to organisational effectiveness, and those which are not. This will lead to smaller organisations and space shedding (see also below under core business and redundant space).

Building types and sectors especially prone to intensification-diversification will be:

- offices (especially in high technology and IT industries);
- higher and further education (especially for mature or part-time students or professional staff involved with continuing professional development);
- libraries;
- media industries;
- some retailing and banking operations (mail order and automatic teller functions).

Industry will not be immune, especially where the necessary components, supplies and information can be sent to local production units.

Working groups and project teams

Whereas server locations and client locations are increasingly differentiated, groups of 'clients' will come closer together. As foreseen by Gates, Handy and others,[16] working groups are more important. Buildings increasingly serve the needs of groups and teams, which are in constant change and flux. There is a greater distinction between buildings and spaces which serve the needs of teams or multiple functions, and those that serve individual needs and single functions, such as requirements for privacy and concentration.

The sizes and dynamic form of working groups differ from one building type to another and between different organisations. However, there will be basic similarities. For example, in higher education, seminar groups of 12 people were common 15 years ago, but are now often over 20 in size. These groups still involve *many* students to *one* teacher relationships. With the increasing use of IT, it will be increasingly possible to take the teaching to the student and tempting to reduce labour costs through so doing.

In offices, groups of 4 - 6 appear to be optimal for many tasks (although the best group size varies between different organisations). In hospital wards, groups of 26 patients are common, although there is increasing potential for just-in-time health care and patient hotels which reduce the need for wards. All such groups will have to be accommodated satisfactorily, at the same time as keeping levels of space utilisation as high as possible.[17]

The focus on the working group is a radical change from past practice. It has been common, for instance in offices, to base space planning calculations on room densities using numbers of individuals, or perhaps individuals aggregated in

Time Use in a Typical Week: by Employment, Status and Sex, Great Britain 1992-1993

	Full time employees	
Weekly hours spent on:	*Male*	*Female*
Employment and travel (to and from work)	47.1	42.2
Essential cooking, shopping and housework	13.0	25.5
Essential childcare, personal hygiene and other shopping	13.2	20.0
Sleep (assumes average of 7 hours sleep per night)	49.0	49.0
Free time	45.7	36.8
Free time per weekday (1990-91 in brackets)	5.0 (4.5)	3.3 (3.0)
Free time per weekend day (1990-91 in brackets)	12.1 (10.3)	10.3 (8.2)

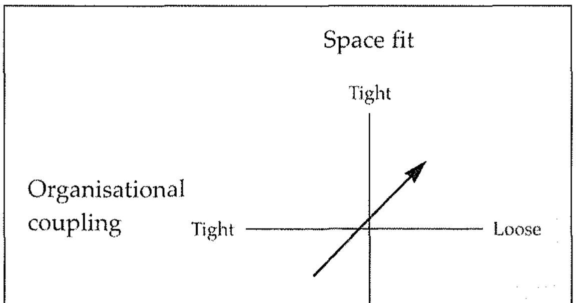
Source: Social Trends Table 10.2 1992

departments. Findings from Stanhope plc[18] point to measured densities in offices being 20-30 per cent lower than design densities. This may be the result of working groups eventually requiring more space pro rata than individuals, many people being out of the office for extended periods and some individuals occupying more than one workstation, for instance. Surprisingly, it is still rare to find published studies of the needs of working groups in offices, higher education and health buildings.

Demand-sensitive space and services

Organisations are becoming more aware of the cost consequences of building strategies based on 'supply-side' criteria.[19] Increasing interest in demand management is not only being stimulated by awareness of the global consequences of profligacy in energy use, but also as a design strategy for coping with the management and cost consequences of unnecessary complexity.[20]

Careful demand management (a symptom of which is rapid response to users' complaints), is associated with higher quality buildings and better occupant performance.[21] There are many



Organisations are becoming more loosely coupled (less hierarchic), but are fitting into tighter spaces hence the vector of change shown here by the arrow.

components to demand in buildings, not least of which are the different requirements of individuals, groups, departments, visitors and occupants (across many building types) and the ways these requirements complement and conflict with each other. Buildings which are sensitive to demand: a) respond to abnormal requirements much faster and b) are capable of rapid switching between uses. This means that greater understanding will develop of baseload provision (for human comfort, energy supply and so on) and of how to adapt buildings and spaces quickly, cheaply and easily for exceptional demands beyond basic requirements.

Buildings which are capable of switching quickly between supply-led and demand-led states will often be intrinsically more useful and efficient. Thus modal switching over time will be increasingly important, and will complement increasing interest in mixed-mode servicing strategies. Demand modes are likely to be increasingly linked to other cycles. It has been suggested, for example, that long-lasting building components would be linked to the mineral cycle, whereas short-lasting components would be part of the renewable cycle.[22]

Access to infrastructure

As space use intensifies and diversifies, so the demand for transportation and communications infrastructure continues to rise. Regular patterns of day-to-day commuting are seemingly in decline, but the 24-hour rush is more likely. Space intensification fuels this process both for physical accessibility and also for accessibility via communications channels.

Whereas the proportion of time that people spend on transportation appears to be stable, increases in efficiency and speed mean that transportation systems consume much more space than they have in the past.[23] It is likely that mature information technology will reduce the demand for some physical communications, as information can travel rather than people and goods.

Yield management techniques (see later under *redundancy*) are part of the intensification process, but they also make organisations increasingly reliant on efficient transportation and communications infrastructures, thereby increasing the risk that the system may fail (see later under *Coupling*).

Core business

Driven by cost and productivity imperatives amongst others, many types of organisation have been actively reviewing space usage and increasingly regarding it as a normal (rather than exceptional) part of their planning and review processes. 'Space productivity' is a term heard more frequently in the speculative office market, for example, and is thought by some to be crucial to the medium-term future of the UK property market.[24] Similar thinking has pervaded the retail, banking, insurance, health and to some extent educational sectors in recent years, leading to widespread downsizing or at least rationalisation strategies, affecting both numbers of employees and amounts of space.

Outcomes are likely to be:

a) further specialisation and intensification;

b) release of non-essential floorspace and land;

c) focus on core activities of main businesses, especially where these involve highly specialised and intensively serviced space;

d) development of design missions compatible with organisational missions (to create closer interaction between management systems and physical systems);

e) greater emphasis on long-term strategic planning of space and property;

f) insistence by occupiers on higher quality and value for money in buildings that are owned or leased; and

g) more partnerships between occupiers, landlords and service providers, especially in the use of highly specialised space.

The divide between highly-serviced, specialised, secure space and less-specialised space will increase. The function of less-specialised space is becoming increasingly problematical especially:

a) where it can be provided at lower cost locally, and

b) where it is embedded in another building types (student housing on campus and office accommodation in hospitals, for instance).

Organisations are regularly reviewing the pros and cons of contracting services out to the local marketplace or keeping them in house. They are much more adept at evaluating and costing the risks involved in these decisions, and in maximising yield from marginal cashflows and available capital. More attention is given to revenue expenditures, especially on long-term maintenance. Future maintenance liabilities may lead to large-scale disposals of properties which are marginal to the core business.

Non-essential space and redundancy

The activities described above are leading to more realistic assessments of the value of space and its attributes. Techniques aimed at increasing utilisation and stripping out redundant or under-utilised spaces are becoming commonplace. These have been used for many years by, for instance, airlines to maximise income from trade-offs in price/occupancy ratios of seats. Yield management techniques are now found in many types of buildings (leisure centres, theatres, cinemas and schools are examples), and their use is spreading quickly.

They include the following.

- Booking systems (for rooms and seats).
- Space charging (for demand management).
- Address-free working (to increase occupancy).
- Building evaluation and benchmarking (of suitability for purpose).
- Building performance measures (of performance in use, especially cost, energy efficiency and comfort).
- Timetabling and scheduling.
- Greater investment in facilities management.
- Operations research (OR) techniques [for avoiding bottlenecks (eg. lift management), capacity planning and queuing].
- Transportation algorithms (for optimised routing).
- Inventory management [increasingly related to Just-in-time (JIT) methods].

Yield and operations management has also introduced new terminology.

In universities, which have recently been subjected to increased space intensification, the reduction of redundancy has created the linked problem of lack of decant space - a typical space planning dilemma for many organisations, so increased utilisation is not necessarily the best strategy. Spaces are often under-utilised because they are used as 'buffering' to simplify management and to protect individuals or groups against perceived inefficiencies or threats from others – hence the tendency to 'defend' territories rather than behave co-operatively or altruistically.

Some organisations require relatively high levels of redundancy, usually because the systems operating within them are both complex and 'loosely coupled'. Building Use Studies estimates that higher educational buildings usually operate at 30-35 per cent utilisation (which equals 65-70 per cent redundancy) and are often still perceived to be full!

Yield management techniques, along with the family of value engineering methods, are increasingly exposing the extent to which systems are redundant, and raise the question of which of two strategies should be employed:

Tight fit	Spaces designed around processes.
Loose fit	Spaces designed to accommodate a range of uses and processes.

"... The machines in the (Ford, Michigan) factory are flexible enough to build the (twelve) different engine models with just minor adjustments ... The trick to this capability has been the redesign and simplification of the new engines to reduce 25 per cent of the parts and keep about 350 of the remaining parts in common. "[25]

Redundancy in space comes in three forms.

Useful	Extra spatial or volumetric capacity or adjustability which gives inherent flexibility and adaptability (such as floor-to-floor heights which enable additional building services or a mezzanine floor to be added, if required).
Generous	Where the organisation prefers to be generous rather than intensify its space management requirements.
Superfluous	Extra space or building elements which serve no really useful function.

Intensification could well result in less useful redundancy within buildings, as nice-to-have features are removed on cost grounds, leading to growing obsolescence of whole or parts of buildings. At present, vacant or obsolete floorspace appears to be increasing. For example, The Open University's study of Bury St Edmunds, Tamworth and Manchester found that on average 12.5 per cent of non-domestic floorspace was vacant.[26] It is not known what proportions of this vacant space are likely to be re-usable or obsolete.

Vacant space is especially apparent in building types where potentially conflicting functions co-exist alongside each other. For example, many high streets have ground floors in use as retail premises, but the living accommodation above is unoccupied[27] and with modern just-in-time distribution techniques has ceased to be useful as storage.

University campuses and hospital estates often have a small proportion (say 10 per cent of the usable space) devoted to highly specialised functions (such as laboratories), but have many buildings which are either under-utilised (such as large halls and sometimes student accommodation if it is not attractive to conference or holiday uses when not otherwise occupied) or marginal (such as boathouses, gazebos and stables left over from when the site was once a large house with outbuildings). Increasingly, marginal buildings are coming under scrutiny. For some their only valuable function in the future may be aesthetic, as desirable landscape elements, for instance.

Diversification, on the other hand, increases demand for change of use. More farm buildings, for instance, are vestigial, in use as homes or holiday accommodation, rather than for agricultural purposes. Some of these homes will also incorporate an office, perhaps networked to a file server or e-mail gateway in another location, and be thought of as telecottages.

Intensification of office space goes together with diversification of this type. It is increasingly common to find offices where staff come in and find a place that suits them, log on to the file server and work from there. They may have a locker or cabinet for personal belongings. The advantages are that less space is needed, and that people can log into their working files from wherever they wish. The central office is intensified in use, but uses are also diversified at remote or temporary locations.

In time, the common information technology infrastructure required for different uses may make it possible to switch spaces between uses relatively quickly. In higher education, for example, it is possible to have teaching rooms cabled for 10-20 computer workstations equipped with a local file server which can be rapidly changed over into office or conference accommodation.

Organisations which have seasonal demand (conferences in the summer and teaching and administration in the rest of the year, or seasonal product launches) may seek out this potential for switching. This will lead designers to think much harder about where they put the value-added (that is, where they locate in the building needed but costly redundancy).

These considerations will lead to buildings with some or all of these features:

- spatial zones sized according to characteristically dominant patterns of user groups;
- use zones more closely matched with control zones for lighting, heating, cooling, ventilation, noise, physical security and disturbance;
- both use and control zones capable of rapid and logical switching between types of use and in accordance with seasonal or other external conditions;
- linking of different parts of the building system to different resource cycles (the longer-lasting fabric will be treated differently from the interior, for instance, so that different management strategies can be applied to them) with emphasis on separation of waste streams;
- greater separation of complex elements and components from simple elements, with greater emphasis on the function and performance of the building, especially the fabric;[28]
- hence simple, but adaptable spaces for all but the most complex environments, with additional equipment and services added as necessary;
- greater separation of the total building system (human as well as physical) into 'supply-side' and 'demand-side' elements with much more focus on the latter, especially with respect to energy management and human comfort;
- a corresponding emphasis on interfaces, especially control devices.

Buildings with these characteristics can rapidly adopt different internal states and respond to changing demand. Occasionally, state-switching will be very rapid, requiring flexible technological solutions. Often, simple and easy adaptability will be sufficient. Recent research has shown that office buildings which are more responsive to demand are also likely to be energy efficient, comfortable, healthy and clean.[29]

Time dependency

The cost of building occupants' time is becoming a more important consideration. Staff salaries are by far the most expensive part of most organisations' costs - in offices the proportion may be upwards of 75 per cent of annual costs, and in schools even higher, perhaps 80 per cent. Using people's time effectively is an important consideration, especially where time is spent wastefully or work is carried out in sub-optimal conditions. The 'productivity of space' - the ability of buildings to accommodate functional requirements efficiently - is a term gaining wider currency.[30]

Although statistics on this topic may be unreliable, free time has increased appreciably for both men and women between 1990 and 1992. People who are 'time poor', that is those working long hours, but also relatively wealthy, have different behaviour patterns. They tend to time shifting activities, through the use, for example of video recorders, so that they displace activities and try to use time more efficiently. They may also be more hurried and tend to carry out more than one activity at a time. Time-poor people consume more space, both because they travel greater distances (although they do not necessarily spend more time on travel) and because they are more likely to have more than one place of work and more than one home. Additional space consumed travelling at higher speeds must not be forgotten, as this is one of the environmentally most serious consequences of intensification-diversification as currently practiced, where the physical communications infrastructure carries too much of the burden of dispersal and the electronic infrastructure as yet too little.

Coupling

Systems have varying degrees of 'coupling'[31] - the extent to which elements within them are connected together. Buildings are systems which have the peculiar property of being relatively tightly coupled in some respects - their structure and fabric, for instance - but loosely-coupled in most others. HA Simon called them 'nearly decomposable systems' to describe this property! For example, interconnectedness of some components is critical to structural stability and weathertightness, but the number of components which are connected together in this way are a small proportion of the total building system.[32]

The trend, however, has been for buildings as total systems to become more tightly coupled. This comes about for several reasons.

1) In the engineering sense because of greater automation, and attempts (not always successful) at greater integration of services systems through, for instance, building management systems.

2) In order to occupy spaces at higher carrying capacities, greater inputs of management resources are required (cleaning and repair of wear and tear, for instance). Organising these inputs effectively means that space use must be programmed and timetabled more rigorously, which increases dependencies of one part of the system on another. Some of the consequences are that:

   - More interactions and dependencies increase risk of failures. Buildings are only rarely subject to catastrophic failures such as structural collapse. There are, however, frequent small-scale failures, many of which go unnoticed or unrepaired. Collectively, adverse effects of failures can be greater than the sum of their parts and their consequences can be hard to correct, especially in complex, poorly designed and badly-managed buildings. Although this has never been measured, the number of small-scale failures may be increasing, leading to more widespread discomfort and inefficiency.
   - People have traditionally resolved complexity in their lives by behaving habitually (Michael Young uses the phrase 'habit: the flywheel of society' which aptly catches this property[33]). Increased complexity makes habitual behaviour less likely because of increased likelihood of conflicts and disturbances to the daily pattern, thus increasing inefficiency and adding even more complexity.

Positive feedback loops like this contribute to an increasingly hyperactive society, the personal costs of which are measured in stress and breakdowns. Consequences include more retreats and longer holidays, and greater segregation of lives in both space (holiday resorts and tourism) and time (longer holidays). Increasingly, the costs and inefficiencies of this system, in both human and environmental terms, will mean that relaxation and leisure time will be merged with work, so that there will be less distinction between work time and leisure time, and people will have far more control over the use of their own time.[34]

Effects

This section covers some of the foreseeable effects of the I-D process on building types and sectors.

Housing
Although the number of households is expected to increase in the UK, average household sizes are will continue to decline. Average space per household (90 square metres per household in 1991) is likely to stay constant or to rise slightly, both of which will increase the space per person.

Intensification of use of offices and educational buildings will mean that more knowledge-based work will be based at home during the day, but the home may be used less during the early evening and weekends with the trend towards more outdoor activities, increased eating out and less television watching continuing. This may spread occupancy of the home over a longer period, reduce commuting distances but increase use of heat, light and power. This will dampen demand peaks, but raise baseloads, especially for equipment like faxes, modems, computer central processing units (CPUs), time clocks, answerphones and security systems which are left running continuously to service home working.

Offices
Increasing intensification of use of the home will depend on the costs of use of the car, penetration of information technology based on wide-area networking, and changes in employers' attitudes. A further significant factor will be the productivity of key individuals, and the need to provide them with tailor-made facilities and uninterrupted periods of time to carry out key tasks. As time becomes scarcer and more expensive, more people will be conscious of organising their time effectively, which will mean phasing workloads - many meetings in one place on one given day, concentrated work in another, for instance.

This produces:

- Offices created primarily for client and workgroup meetings, for technical support of remote tasks for highly-specialised activities and for ad hoc project teams.
- Decline in informal and serendipitous workplace-related meeting places (lunch and coffee places, for instance), disappearance of the formal lunch break and coffee break, but possible increase in local facilities for homeworking and *ad hoc* meetings (see also hotels). There are possible contradictions here. One of the main constraints against homeworking may be that individuals, in spite of higher productivity, become more invisible in their organisation, thereby affecting their career chances. This may force people back to headquarters.
- Step-change improvements in information processing and data transfer services for offices (especially company databases and file management systems).
- Greater emphasis on costs, especially the opportunity costs of wasted or inefficiently-used time. Activities which are tiring or environmentally damaging will be avoided where possible (this applies especially to commuting and unnecessary travel). It may become fashionable not to travel.
- Smaller, more secure, offices, with mixes of open plan and cellular spaces using natural ventilation, where possible, and mixed-mode where not, with full air conditioning rarer.
- Greater attention to logistics planning, including diary management, timetabling and travel arrangements for work, family and leisure.

Retail
Retail floorspace development has passed through a period of intensification especially in shopping mall and superstore construction. This market is now approaching saturation, and schemes are either being abandoned (for example, Tesco, Plymouth) or increasingly opposed on social and environmental grounds. The Department of the Environment is also opposing more out-of-town shopping, although many planning applications. It is possible that different retail development strategies will emerge in the near future. Increased diversification is likely to lead to renewed interest in the revival of local, independent retailers in town and city centres.

In the past thirty years, the average time spent on shopping in Britain has doubled, from 20 minutes a day to 40. It is claimed[35] that this is not just because there is more to buy, but because retailers have been pushing distribution costs onto their customers. With Sunday trading (which releases more time for shopping), this pattern will probably remain until a point when true social and environmental costs of car-based transport are more widely known and treated more as a cost to the individual than a benefit.

Possible scenarios are:

- new mixes of retail, service and location types emerging to service foci such as airports, railway termini, supermarkets at ports and borders, schools, universities, hospitals and garages);

- new retail developments with smaller, low-cost, intensively-serviced, lightweight, modular, pre-fabricated and short-lasting buildings: for example, Forte (Happy Eater), BP/Shell forecourts;
- local convenience shopping based on freshfood and fastfood outlets (combined butchers/bakers/greengrocers/fishmongers) to serve people increasingly based at home for daily requirements. A revival in home cooking may be prompted by food poisoning and health scares (formally notified cases of food poisoning have increased four-fold in Britain between 1981 and 1992[36]);
- development in town and city centres, serving daily, weekly and seasonal needs. Some revival in local and village shops serving daily needs;
- growth in mail order, teleshopping, on-line access and data delivery, electronic mail and delivery services with local franchises.

Patterns of shopping will divide more clearly between regular daily convenience demand (necessity shopping prompted by increase use of the home) and weekend and seasonal (leisure) demand from sub-regional or tourist markets.

Entertainment/sports

With increased distribution of large bandwidth optical fibre cables to homes and satellite channels, along with integrated computer/television/audio systems, there will be an inevitable focus on entertainment in the home, though not necessarily any extra demand for domestic floorspace. This trend will be countered to some extent by increased interest in 'live' spectator or audience entertainment either in theatre, cinema or sport performances or in 'social' viewing of performances transmitted by television (as with sports viewing in pubs, for instance).

Although leisure, pubs and clubs, and sports and recreation accounts for 7.7 per cent of current floorspace (and there are other uses embedded in hotels), changes in this sector will probably be only marginal, thus no large-scale effects will be seen. Possibly, the major influence of the entertainment/leisure sector will be promoting the penetration of e-mail, on-line services (such as remote banking, mail order and databases) and other computer-based services into the home. In many homes, they will have been first introduced for entertainment purposes.

Hotels

As business use increasingly diversifies and constraints on individual's use of time become tighter, hotels, conference centres, resorts, schools, universities, leisure centres and restaurants will become increasingly used as short-term meeting places. These locations will be used for intensive half-day or day-long training and staff development sessions, or for project team work. As organisations cut space back to core business requirements, they will be more likely to hire conference facilities in hotels for occasional requirements, rather than carry the (under-utilised) space overhead themselves. Hotels and conference centres will quickly come to understand the importance of providing seamless connectivity with office computer networks (these facilities have been notoriously lacking) so that ready access can be had with base or headquarters. These trends will probably create more well-defined differences between hotel types (luxury, holiday, business/conference, business/travel, family and so on).

Hotels will be innovators in space management and utilisation techniques, developing charging schemes similar to those used by airlines to ensure that rooms and other facilities are kept at maximum occupancy. This will lead to more innovations in use within particular market niches. Hotels and offices will become more similar as building types. Other organisations, such as hospitals and universities, will utilise hotels to a much greater extent (patient hotels for short term patient care, and hotels attached to business schools, for example). There will be greater diversification of the hotel industry into these markets.

Health

The health sector in the UK has been undergoing management changes similar to those which are now affecting education (see next section). Current thinking[37] emphasises:

- disposal of surplus land;
- increasing utilisation of poorly utilised or under-utilised building stock;
- reducing maintenance backlogs (estimated at up to £2,000m.);
- emphasising the advantages of refurbishment of the existing stock rather than unnecessary new building;
- improving strategic thinking about property planning and recognising the role of estate planning in the management of change.

These are characteristic intensification-diversification trends. Hospitals are trying to cut back to core. They are examining the role and cost of perceived non-essential activities, such as research laboratories (which could be shared with, say, the nearest university or pharmaceutical company) and accommodation for nurses. It is likely that hospitals will increasingly cut back to highly specialised, technologically and professionally intensive spaces (such as renal units, operating theatres, casualty units and intensive care) and move other activities, such as patient outcare, off-site. Many hospital sites now have significant traffic bottlenecks created by large visitor populations. It is becoming increasingly necessary to move excessive traffic-generating activities off-site to locations which are closer to the people they serve.

In future, hospital 'core buildings' will be highly-serviced, specialised and technically complex, although many other buildings will become less complex as medical technologies become more packaged. Simpler buildings (such as wards or outpatient departments) will be increasingly spatially separated and managed differently.

Education

The I-D process is now being accelerated in education in schools (assisted by devolved management of schools introduced in the UK in 1989-91) and in higher education (with the strategic space requirements of the funding councils, which require that all universities produce a strategic property plan).

Trends include:

- increased security provision;
- use of buildings over longer periods of time;
- emphasis on making better use of under-utilised space, especially general teaching space;
- questionable viability of specialist laboratory space for small groups;
- increased likelihood of distance-learning in higher education;
- growing influence of information technology, especially multi-media;
- growing awareness of role as service providers, competition between establishments, and growing emphasis on image and presentation;
- fashion for mission statements.

These are leading to:

- growing similarities between different types of space and their servicing requirements;
- more rapid changeovers between uses, and increased rental and hiring of facilities;
- higher occupant densities of teaching spaces;
- increased wear and tear on facilities, leading to greater emphasis on management and repair;
- less space per person;
- closer matching between space provision and functions;
- more zoning, and growing consciousness of the need to efficiently mothball space not in use.

Factories and warehouses

Factories are the second highest users of floorspace next to housing - just under 10 per cent of the total (housing accounts for 63 per cent). Freeman[38] distinguishes:

- shifts towards information-intensive rather than energy- and materials-intensive products and processes which favour designs which economise on materials, energy and moving parts which utilise electronics, bringing about shifts in product mixes and in relationships between manufacturing and services, as well as a transformation of the production process;
- changes from inflexible, dedicated mass-production systems towards more flexible systems capable of manufacturing a diverse range of products as efficiently as a single product, which have consequences for the rapid evolution of product design and products and for 'economies of scope' in production lines;
- changes in the pattern of business organisation, involving integration of office and plant, of design, production and marketing, closer communication links between assembly plant and suppliers, manufacturers and distributors, permitting a faster response to demand conditions, better stock control and a wider range of inputs into the design and development process.[39]

These changes emphasise the redesign process, with products and commodities progressively simplified in the number of parts they have and the length of the assembly process. Value engineering is at the heart of this approach, examining parts of processes which add cost but not value, and trying to remove them or make them contribute more effectively.

The implications are that:

- large parts of factory buildings will become more similar to other building types such as laboratories and offices, a trend which has been clear in the electronics industry for some time;
- production systems in factories will be much more sensitive to changes in demand, making them 'rapid-response' environments where the building is fitted around the process equipment and needs of the supervising staff (sometimes they will need to be less intensively serviced, but

frequently processes requiring special services will have these services integral to the process);

- factories will be much more automated;
- they will probably be smaller;
- production processes will be more tightly coupled with human, organisational, utilities and transportation infrastructures;
- demand for floorspace will be lower, but
- energy costs (because of increased use of technology) will stay about the same with a trend away from fossil fuel to electricity for many requirements;
- warehouses will again become smaller and more localised for industrial and retail purposes, although storage for agricultural and mineral products may increasingly intensify in trans-national depots.

Conclusion

Intensification and diversification have been identified as constant features of spatial change. There is a dynamic interplay between spatial clustering and higher densities, on the one hand, and dispersion and lower densities, on the other. They often appear as alternatives or opposites, but they are frequently complementary.

Minimising cost and adding value are also a fundamental part of spatial decision-making. Again, they are alternatives or opposites in some contexts and complementary in others.

Recently, sustainability considerations have been and will become of increasing importance as attitudes change and environmental legislation bites (although sustainability has always been a part of non-intensive agricultural and economic systems).

How will these processes affect buildings in the UK in the foreseeable future? The key will be the extent to which thinking about cost, value and sustainability become congruent and part of the same decision-making and resources system.

There is evidence that this is happening, first through the global influence of management science methods which have revolutionised the understanding of cost and value in manufacturing and service industries (especially with value engineering techniques), and secondly between cost, value and sustainability in the influence of environmental thinking. Although these are often still separate 'systems' driven by different motives and agendas, they have potentially important common links, the most important of which is avoiding waste.

Avoiding or minimising waste is common to value engineering methods (cutting out unnecessary costs without reducing perceived value) and to sustainable strategies (especially through conserving non-renewable resources and minimising pollution). As the economic and social value of these approaches becomes fully appreciated, there is likely to be a major change in attitudes towards waste avoidance in the near future. This will 'drive' increased emphasis on total cost and value (for individuals, organisations, investors, developers and wider social and environmental costs and benefits).

When this occurs, it will rapidly accelerate many of the change processes talked about in this paper. In particular it will:

- reduce unnecessary physical movement, shifting a far greater proportion to information and communication highways;
- rapidly accelerate I-D in the sectors best suited to it - offices especially (but the tendency for commentators to telegraph office trends onto other building types may exaggerate its importance);
- stress local and 'federal' structures;
- rapidly improve efficiency across systems;
- focus on life cycles;
- encourage 'mode-switching' and rapid state changes;
- make many building types much more similar in form and servicing, thereby reducing the number of generic types;
- increase use of buildings over time, thereby improving total occupancy.

Total systems thinking will become the norm so that the consequences of actions in one area can be understood in their effects on others.[40]

A critical part of this process is the improvement in feedback and monitoring techniques across a wide range of disciplines, but especially in complex, cross-disciplinary areas like buildings where the consequences of actions in one area have not been fully appreciated in their effects on others. For example, there is little evidence available on the costs and benefits (to investors, developers and occupants) of re-using historic buildings as opposed to new build.

Systems thinking and total cost accounting is also likely to lead to more emphasis on life cycles. This involves understanding inter-relationships between cycling processes and their inputs and outputs, such as for energy, hydrology, nutrients, minerals, ecology, and social and economic cycles. Buildings are complex, dynamic systems which play a (sometimes significant) part in many natural and artificial cycles and systems. With increasing emphasis on true costs and rapid-switching between different demand states, it becomes much more important to understand how different states of buildings intervene in different systems. For example, the building fabric is usually long-lasting, and part of a long-term cultural cycle as well as the physical, economic and construction cycles which produced it. The building interior is altered much more frequently, and is part of another set of cycles, concerned with day-to-day use. Systems dynamics and life cycle thinking is likely to contribute to increased concern about the costs and value of the existing building stock.

Minimising and avoiding waste emphasises efficiency gains in processes and highlight the value, costs and benefits of the existing building stock. This will lead to more consideration of redundant stock, obsolescence, demolitions and disposals. This is a much neglected area and is likely to be the locus of much activity in the near future.

All these features of buildings and the building stock are outcomes of wider socio-economic and technical changes, but disguised because of the inertia that exists in the present stock and its relatively slow rate of change over time. Several management writers refer to the Age of Paradox to try to explain some of the contradictions.

Among the paradoxes are:

Competitiveness	...	Sustainability
Productivity	...	Employment
Rigor	...	Humanity
Health and Safety	...	Risk and freedom
Protection	...	Dependency
Cost effectiveness	...	Durability
Durability	...	Redundancy[41]

Paradoxes in buildings include:

Sustainability	...	Marketability
Durability	...	Redundancy
Redundancy	...	Lifespan
Standards of provision	...	Occupants' perceptions
Automation	...	Obfuscation
Flexibility	...	Complexity
Technology	...	Manageability
Energy efficiency	...	Energy dependency
Intensification	...	Diversification[42]

This paper has dealt with only the last. Like some of the others, I-D is not just a modern phenomenon but circumstances are being changed because of an important juxtaposition of events which is radically new. Systems based on cost, value and sustainability have common features: fuelled by the new ability to move information about quickly and in vast quantities, they are beginning to act in conjunction, rather than 'fighting' each other in what is perceived as a paradoxical way. This has changed the rules about buildings and settlements, and the consequences will be clear to see in the next generation of buildings.

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