# Flexibility and Adaptability in Buildings: the "killer" variables


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## Introduction

Flexibility, and its running mate adaptability, are now commonplace in the vocabulary of briefing, building design and building management. With the future perceived as increasingly uncertain, and buildings - especially the more complex ones - carrying higher risks, and possibly also of dubious long-term value, clients increasingly insist on flexibility as an essential ingredient. In response, designers are more likely to say that their buildings will indeed be flexible and can of course cope with the vicissitudes of change. But are modern buildings more flexible, and how well are they able to cope with the expected? Our scope includes:

- the physical adaptability of buildings;
- how the property market offers a suitable range of building stock;
- the adaptability of the occupants in "fitting in".

We deal with the crucial things (the "killer variables" of the title) that prevent flexibility and adaptability being properly present. We are interested in the extent to which buildings are always going to be inflexible or poorly adaptable in one way or another, given that social and technical change is ever-present and to some extent unpredictable. We want to know whether buildings are becoming more or less flexible. What are designers doing right, and are there things which could make things even better? Can managers and users help? We try to make our conclusions as relevant as possible to designers, clients and managers without bypassing some of the definitional and theoretical preliminaries.

## Definitions

Flexibility means that changes can be made quickly and with relatively little effort or cost ("It will do anything you want"). Adaptability offers greater potential for larger-scale changes over longer periods, without cutting off crucial options or making things unnecessarily costly or complicated ("You can change it to suit you"). In offices, for instance, adaptability is more likely to be associated with major changes in occupancy, usage or services; flexibility with the layout of workstations and ancillary user areas, which may be constantly altered or adjusted.

Flexibility is thus more about short-term, often potentially reversible, changes of relatively low magnitude; adaptability with in-built potential for larger-scale changes of greater magnitude in the longer term. A rope has flexibility within limits set by its length, tensile strength etc. Its adaptability is a property of how many ways it can be knotted, and, crucially, our knowledge of how to tie knots and which knots to use safely in which circumstances (Figure 1 and Reference 1). Adaptability thus involves additional knowledge of context, purpose and application which may not be obvious at first sight.

Some definitions of adaptability emphasise how performance requirements constantly change over time, with inevitable mismatches created between the supply of space and the demand for it. In this perspective, adaptability becomes the manageability of the mismatch [References 2 and 3] - the easier it is to tune, the more adaptable the building becomes.

Flexibility and adaptability can also be placed within a wider framework(see Figure 2). Here lack of flexibility and adaptability are two types of (usually unwanted) risks which are the bedfellows of two others - catastrophic ("acute") events like structural failure or capacity grid-lock (short duration, high magnitude and low frequency), or insidious ("chronic") events (long duration, low magnitude, high frequency) like inadequacy of heating and ventilation plant, maintenance defects and unending ill-effects on occupants' well-being like summertime over-heating, glare and noise.

**Examples**

Buildings can be:

- very flexible but costly to support, and/or difficult to adapt (eg, the "Hotel" Office, The Hague, Reference 4, see Figure 3);
- adaptable but not very flexible, like Victorian houses, or possibly buildings like British Airways Compass Centre [Reference 5, Figure 4] which was originally intended as a shell-and-core office but has been fitted out as a crew reporting and aviation crisis centre as well as offices);
- neither flexible nor adaptable (for example, older laboratories, especially those purpose-built for physics and chemistry in the 1950s and 1960s with many permanent fixtures. More recent designs try to tackle these problems, see Reference 6);
- both flexible and adaptable, eg the CLASP system, used in schools and universities in the UK from 1960 (but which has other drawbacks like noise, thermal performance and, originally, fire safety); and the example given by Brand - Building 20 at MIT [Reference 7. Figure 5]).

Developments which have demonstrably benefited from a learning curve by becoming more flexible and adaptable are rare; often, instead, the more recent buildings have become increasingly specialised and less adaptable (although they may be flexible!). The mixed-use development at Milton Park, Abingdon, UK, featured in the television version of *How Buildings Learn* (but not the book) is an exception. This has examples of cheap, robust ex-military buildings (still in service after 80 years for uses varying from vehicle servicing to bio-technology) plus several generations of their more modern counterparts. In some instances, companies have moved from older to newer, giving insight into flexibility/adaptability issues as they grow and evolve [Reference 8]. In hindsight, the designs have afforded less adaptability than could have been offered. In some of the earlier ex-military buildings used as bioscience laboratories, the ratio of building value to equipment value has been 1:20! But even here, where the developer has gone to some lengths to learn lessons from the buildings in use, organisations have less adaptability than expected.

**The myth of self-managing flexibility**

Often, it is all too easy to put a gloss on flexibility / adaptability issues and forget the downsides. We obviously need more flexible buildings, otherwise they may not meet occupier needs and may quickly become obsolete, but:

- Will they be too complicated?
- Will the occupants like them?
- Will they require too much routine effort?
- Can they anticipate the unforeseeable?

Evidence from studies of buildings in use [eg Reference 9] show that flexibility / adaptability are inextricably linked with building technology and its manageability. How well a building functions (for eg energy efficiency and comfort) seems to be more about technology-management interactions than design alone. Figure 6 summarises our concerns. From the data we have so far, the best performing buildings are either Type A or Type D: that is briefed, designed, constructed, used and managed with an "up-front" mandate on technological complexity and manageability. The best buildings have either:

- realistic assessments of their technological complexity and find appropriate levels of management and maintenance skills to cope with the inevitable consequences (eg Tanfield House [Reference 10], One Bridewell Street [Reference 11]);

or

- minimised technological impacts, by making things simple and self-managing where reasonably possible (eg Woodhouse Medical Centre [Reference 12]. Elizabeth Fry Building [Reference 13]. As technological side effects are usually also environmental impacts [References 14 and 15], this makes environmental sense as well.

Unfortunately, many buildings (our data are mainly from Britain, but this applies worldwide) are Type C, that is barely coping with the consequences of technology-driven complexity, usually without adequate management resources to do it. Unmanageable complexity is the bugbear. Often systems are sold as “flexible” and “fit-and-forget”, by implication, seemingly requiring no extra inputs. In reality, management resources are limited. Supposedly flexible systems can become obstacles to adaptability, for example, where “flexible” servicing systems are so congested and pervasive that it is difficult to alter them or insert additions without major surgery.

Therefore it is prudent to:

- avoid fantasies and wish lists (eg leading future occupants to think that automation in the new building will be the answer to everything, or parking problems in areas where nobody sees them (eg leaving detailed design of lighting controls to the contractor));
- not rely too much on performance specifications (as Alex Gordon said: “Do not be surprised if you get a rubber tube with a clamp on the end when you wanted a tap.”);
- do not expect more of the building than it can reasonably be expected to deliver (eg over-optimistic modelling of energy performance at concept design stage);
- make sure the right people “own” the problems (eg don’t expect the managing agent to program the system to meet the changing needs of individual tenants);
- seek robust, generic solutions (see the “safe territory” area of Figure 7);
- consider adaptability (long-term adaptability may be a better and most cost-effective way of meeting unforeseeable future changes than quick-fix flexibility);
- have contingency planning strategies (especially important during periods of volatile technical and environmental change when shifts in one critical parameter can lead to cascading effects elsewhere - eg potential to switch from air conditioning to mixed-mode or natural ventilation);
- try to minimise downside risks (especially with the performance of obviously critical systems like air-tightness of the building fabric (often leaky in the UK, creating unwanted comfort and other side-effects) or window design in naturally ventilated buildings [see References 16, 17]).

Figure 7 summarises some of the side effects as they commonly occur in offices. Two vicious circles result.

1. *Complexity trumps manageability*: To avoid altering the building in use, one asks for it to be flexible. Designers respond with over-complex systems which in use demand management time. If not enough resources are devoted, or if response is not fast enough, failures occur directly or indirectly affecting staff satisfaction, comfort, health and productivity.
2. *Disease claims to be the cure:* Enough time and effort is spent on managing the systems but the cost of looking after systems intended to provide flexibility may exceed those of adapting a simpler building to meet new needs as they arise. As demand is relentless, so systems originally intended to be flexible may even obstruct the change that is required, and may prove very ineffective indeed as they begin to become obsolete.

**Leaving elbow room**

Flexibility is one way of dealing with uncertainty and the vagaries of change, but often unpredictable changes defeat flexibility strategies. Some of the more notorious occurred in the UK in the 1980s when the perceived need for extra cabling and air-conditioning - driven by sales-inflamed scares about accommodating new technical equipment and the unthinking adaptation of buzzwords and quantified but poorly-researched standards by letting agents - led to gross over-capacity of heating, cooling and ventilation plant [Reference 18] and fewer degrees of freedom with floor-to-ceiling heights (because of raised floors and ceiling voids). Added complexity of plant, ducts and controls with less available volume for air created many nasty side effects for occupants as well [Reference 19].

Successful flexibility / adaptability strategies anticipate how contextual factors change over time.

However, the reverse is one of the reasons why US building strategies are copied worldwide [Reference 20]: globalisation involves destroying context in order to achieve uniformity of product and a form of market flexibility. Its advantages in terms of appropriateness, use value and long-term adaptability and environmental responsibility are more questionable. This has economic advantages - standardisation being one - but ultimately produces cultural and environmental revenge effects which are unsustainable.

From a flexibility / adaptability standpoint the crucial question is always where to locate the needed, but seemingly (but not not necessarily) costly, redundancy. Is redundancy best located in the structural fabric (to guarantee structural integrity and weather-tightness), building services (to cope with all conceivable demand fluctuations), extra space (to accommodate growth and change), lower densities (to give managers and occupants more degrees of freedom) or what? Using the minimum number of non-negotiable criteria (see conclusions to Reference 21), we are looking for systems which successfully meet demand, given different requirement profiles for users, managers, owners, developers and designers within contexts in constant flux.

This implies strategies which go further than fit-and-forget technologism or short-termism. We have found Figure 9 useful here. The diagram has physical / behavioural and context-free / context-dependent axes, giving equal weight and importance to all four quadrants.

Four distinct strategies are implied:

1. make invisible (those things which are supposed to work only in the background, with hardly any intervention);
2. make usable (things needing regular attention and/or interaction);
3. make habitual (formal and informal rules which help with safe, comfortable and smooth running);
4. make acceptable (things which are not prescribed and covered by the rules, but allow scope for individuality, innovation and change).

Buildings which are properly flexible and/or adaptable will have included consideration of provision for all four somewhere in the briefing, design and operations thinking, raising issues such as usability, innovation, habit (ie cultural norms in the organisation and user etiquette), safety, security, risk, value and uncertainty.

However, the modern tendency is to push as many things as possible into Quadrant A - seek "fit and forget" - and leave the consequences of leakage back out into the other three quadrants for someone else to worry about. Unfortunately for us all, side-effects cannot be forgotten even if they are not immediately foreseeable or includable in cost-benefit equations or risk-value payoff calculations. Examples of some of the consequences are given in Figure 8.

**Dependencies and interactions**

The temptation to use technology as a get-out-of-jail-free card is often irresistible to designers and managers when faced with problems requiring quick answers. But buildings are interdependent systems with many hierarchic layers, a property which introduces dependencies and interactions, often unwanted, hidden or unforeseen. The shell-scenery-set diagram introduced in the 1970s [eg Reference 23] neatly summarises the hierarchic nature of buildings and their sub-systems and can be helpful in separating variables and developing adaptability strategies. However, in the wrong hands such layering can actually inhibit strategic integration. Our expanded version is in Figure 10. Systems at the top of the list - site, strategy, shell - tend to set constraints for things lower down (services are determined to some extent by the shell, for instance). Things at the top also tend to be longer lasting - centuries in the case of some sites; minutes for the position of things on desks. The diagram has many virtues, not least of which to emphasise Russian-doll-like complexity (with systems apparently nesting inside each other) and the time frequencies of changes. The implication is that things at the bottom are easier to change than those at the top - more flexible, and perhaps more adaptable. However, this is not necessarily so: a transportable building can be moved to another site, shells and structures can be adapted or replaced; and sometimes, for instance, arrangements can be impossible to change because of their interlocking nature!

Modern businesses are increasingly demanding much greater flexibility throughout the hierarchy, trying to give themselves greater degrees of freedom. Some of the symptoms are:

- rental lease periods reduced from 25 years to 5 years or even less;
- the rapid rise of businesses such as Regus [Reference 24] which offer high quality, very short term, office accommodation for rent in major cities around the world, and growing investor interest in fully-serviced suites for temporary or long-term occupancy;
- more stress on property and estate strategies;
- renewed interest in briefing, and further consolidation of business and design targets.

Strategies based on shell-and-core or space guidelines for space planning are no longer sufficient. Space plans must not cut off options for new layouts. Potential for moving cores if necessary may even be required.

Flexibility at one level does not guarantee flexibility elsewhere - often the reverse. For example, buildings which are designed around their space plans often introduce onerous constraints. A fixed furniture system may offer occupants no options to fine-tune their seating position and furniture so that they can try to mitigate adverse effects of eg glare or low winter sun. Any changes may have to be carried out by the facilities managers. In one instance, external consultants had to be called in every time the furniture needed to be moved! It is usually better to avoid dependency of this sort - occupants are capable of making these minor changes for themselves, they are happier and problems and costs for managers are avoided. However, the trend is towards greater dependence, not less. Occupants are increasingly having control and adjustment options taken away from them. This, in turn, places a higher burden on the technical and management systems that are supposed to provide these services - and makes them more vulnerable as well. This is why occupants say they are less comfortable in buildings which relatively good internal environmental conditions have less perceived control options (in the jargon, fewer "adaptive opportunities") [Reference 25].

The hierarchy means that, unless the design is well-integrated, unresolved constraints occurring at one level can easily pass to the next levels down without being properly resolved [Reference 26].

In Britain, commercial and professional pressures have tended to divide and rule so that integration between architects and engineers can be minimal sometimes, even in so-called "integrated" design practices. Parts of the design can easily fall in the gaps between areas of professional responsibility (no-one "owns" the problem). Some of these turn out to be crucial for occupants' welfare, eg the stability of the indoor environment and opportunities to change conditions quickly when required. Anecdotal evidence from Scandanavia and the Netherlands [Reference 27] indicates that under global market pressures their previously better-integrated design cultures may be taking this course as well.

Key considerations are:

- Develop clear strategies for flexibility and adaptability and keep them under review.
- Identify risky constraints at each level of the hierarchy and explicitly flag them up for designers or managers, making sure that they are fully "owned".
- Unless there are circumstances which require specialised optimisation, do not allow any one to dominate the others eg the space plan, or "optimising the irrelevant" servicing considerations [eg Reference 27].
- Allow for changes at any level, including those that may be seemingly unthinkable, like the shell and structure but don't get carried away - robust simplicity is also most important, but do not forget that many parts of the building may be appropriately permanent.
- Flexibility can be hindered if options are restricted higher up the hierarchy. This than can specially vexing for certain types of building services, for example, building cores obstructing the best routes for ducts or adaptability thwarted by lack of consideration of site constraints. For more detailed treatment, see Reference 28.

**Different standpoints**

Flexibility and adaptability in buildings take on different meanings depending on your standpoint. Users and occupants often want short-term flexibility, answering specific local needs as fast as possible. Facility managers may be more concerned about occupant control and speedy and cost-effective changes in furniture layouts. Designer may think about possible image changes, and certainly issues like capacity, turnover, space fit, densities and layout types. Corporate managers may be more concerned with how easily they can sell the building if they no longer need it. All of them will want their needs to be met reasonably quickly, with as little fuss and cost as possible. For any of them, it makes sense to bring the action as close to the point of demand as possible. The problem, though, is that requirements conflict and it is not obvious:

- what the needs are, especially in the future when contexts may subtly change;
- where priorities lie;
- where risks are greatest.

Specialised buildings tend to become obsolete fastest, but there are still many spectacular examples of unlikely function changes inside seemingly specialised structures, particularly if they have become respected parts of the landscape (for example, Figure 11, Reference 7).

Does the designer:

- play safe with industry norms (eg Reference 29);
- ;- opt for more generic, context-free approaches, gambling on accelerating trends towards convergence of function (eg offices and laboratories becoming more similar);
- take a longer term view, attempting to combine this with emphasis on lower environmental impacts;
- place greater faith in promising new technology (eg Doxford Photovoltaic building, Figure 12) while gambling that accommodating new constraints (the photovoltaic wall) does not compromise other considerations (such as office layouts forms);
- fit suitable strategies to prevailing circumstances, perhaps giving priorities to costs in use, manageability, occupants' needs, and taking a more pronounced "demand" side perspective?

Our view is that attention to the demand side, minimising environmental impact and carefully reviewing the extent to which generic solutions are appropriate will yield effective results. Greater account must be taken of needs - and resolving conflicts between them. This implies more emphasis on:

- brieftaking;
- future business and organisational scenarios;
- social, economic and technical changes in the background;

all of which give further colour to demand.

**Bringing action closer to need**

Bringing action as close as possible to perceived need while minimising the need for vigilance at other levels is usually the main objective when tackling flexibility-adaptability. At lower levels of the building hierarchy this can be obvious. For instance, when you switch on a light (action) you want the response to give you the result you require (need). The faster the need is met by the action, the better. Any extra thought required (if the switches operation is unclear), involvement of others (eg ringing a helpdesk) or delay in response adds unnecessary complexity, inefficiency and cost. When action does not meet need, the system is often said to be inflexible or inefficient. When it is difficult to change, it has poor adaptability.

However, things are not so straightforward as you go higher up the building hierarchy. Lags between demand and supply (the demand for space may not be in the same place as spare capacity), geographical inertia (the tendency for organisations to stay rooted to a familiar area) and longevity (only about one per cent of, for instance, the UK building stock is renewed every year) all conspire to create mismatches and inefficiencies. These inequalities drive fluctuations in property markets, giving them their peculiar character [Reference 30]. With individual buildings, it is unusual to find a perfect "fit" between preferences and the facilities provided - buildings which in the eyes of their occupants, owners, managers and designers are "just right". But "good enough" is usually sufficient (satisficing rather than optimising). Beyond this, if the building lacks adaptability it may be replaced or abandoned.

In this section, we deal with just two of the levels - shell and services - trying to incorporate flexibility-adaptability criteria in a brief for a building intended to be energy efficient, with good occupant characteristics for perceived comfort, health and productivity, and enduring investment value. The example is a hybrid from several projects and could be utilised as an office, or for other functions such as health care, education, research and development, laboratories and light industrial use.

*Shell*

Given locational and site constraints, how would the building shell and fabric fit flexibility and adaptability criteria? We are aiming for a "future-proof" fabric with passive energy design features plus built-in standard low-energy services plus potential to add and change supplementary services centrally or locally to suit tenant's needs. Security, loading, reception and own-entrance requirements may he high on the tenant's priority list. These are some of the considerations.

- Sensible plan and section (see Figure 13), with a depth of 12-15m, double height - allowing for mezzanine floors to be added, with plant in and on the roof and plenty of opportunities to open up walls and roof for extra capacity, or introduction of bulky, complex or valuable plant and equipment.
- Good insulation and airtightness, giving stable internal comfort conditions as well as lower energy demand.
- High thermal capacity to help provide thermal stability and minimise the need for supplementary heating and cooling.
- Minimised use of lifts.
- Good daylight with glare control.
- Unwanted solar gains minimised and useful solar gains employed.
- Effective natural ventilation as the default, with options for further mechanical ventilation, cooling and humidification, if necessary, or, if air-conditioned, options to reverse ventilation to mixed-mode or natural at a later stage (for example, The Body Shop Headquarters, Littlehampton, UK was originally designed as an air-conditioned building, but was subsequently constructed with natural ventilation as the default to suit the requirements of the initial occupiers; [Reference 34] with a contingency plan to upgrade to air conditioning if necessary).
- Simple, clear routes for people, supplies and services which can unite different types of space, with elbow room for additions and alterations, and interchangeability between different types of space, particularly at borders. Perimeter space should not be squandered, especially with respect to view, natural light and ventilation and plug-in services.
- Various options for plant location, with easy but secure access for maintenance.

Specialised buildings tend to become obsolete faster. Many activities are now converging into office-like space (eg electronic, biological and software research and development) and/or big sheds, with specialised areas. This suggests a three-way space needs classification into:

1. *Generic office-like*, with natural light and ventilation available..
2. *Generic big shed*.
3. *Special*.

Organisations may run in to severe flexibility-adaptability problems if they attempt to run these together into single buildings - or clusters - which attempt all three at once, and do not have a well-defined strategy to manage them over their life. For example, university colleges bring together residential, laboratory, teaching and library accommodation in building clusters at relatively small scales - perhaps 400-600 occupants altogether. This has the advantage of encouraging communities of scholars but the disadvantage of sometimes making buildings extremely inflexible, especially when strong territorial allegiances develop over time (eg Reference 31).

The implications for future strategy are;

- Minimise highly specialised space, for most purposes less than 20 per cent of total floorspace is normally required (but disregard this if this benchmark is meaningless for your particular situation).
- Keep boundaries clear, so that unmanageable complexity is not "spread about", but at the same time consider strategies which allow these boundaries to be moved.
- Have an idea of what complex space actually means. Many organisations - especially corporations with technology as their core business - think that they must have highly-serviced, air-conditioned space because it is intrinsically more flexible. As we have argued earlier, in the wrong circumstances this can seriously impair business strategies, because the costs of this type of flexibility can be onerous, eventually making it extremely inflexible!

Shell constraints usually pre-determine the types of services that are needed (for example, buildings with depths greater than about 15 metres across from wall to wall will require some mechanical ventilation). Deeper spaces preclude the use of natural ventilation and some mixed-mode options as well. Standard briefs such as Reference 29 emphasise 18 metre office depths because these work well for integrating planning, lighting and space planning grids which in turn helps optimise lettable to gross space ratios and developer's profits. However, extra depth requires more costly support and management and frequently produces occupant productivity or environmental backlashes. There is the danger of the space-planning tail wagging the dog.

If we are looking for strategies which help achieve user value, environmental value and investment value, the balance may well change It makes much more long-term sense to create buildings which are less dependent on organisations' immediate needs and resources, especially if useful and robust longer-term strategies can be developed.

*Services*

Given that generic shells theoretically have most flexibility and adaptability potential, adaptable designs try to make generic spaces work with the simplest forms of servicing. The trick with engineering services is deciding the appropriate level of background engineering and the extent of the specialist requirement. Too often, the quest for flexibility leads to too much specialised engineering unnecessarily embedded in the background system, thereby creating dependencies which can be costly to manage, and to actions difficult to change owing to the congestion they have already created.

The servicing levels are:

- *passive* (good use of natural light and air);
- *background engineering* (making reasonable base provision);
- *specialised engineering* to suit special needs.

Some of the considerations for services are:

*Standard*

- Efficient heating, often with separate hot water.
- Efficient light sources.
- Controllable natural ventilation.
- Background mechanical ventilation with heat recovery.
- Effective, user-friendly controls.

*"Stretched"*

- Boost capacity locally.
- Manage fabric heat storage.
- Manage equipment locations.

*Extra*

- Additional ventilation and cooling.
- Extra central, zone and local plant.

Some of these are also incorporated in Figure 14 where the general principle of bringing action as close as possible to the points of need also prevails. This means:

- a spine or circuit with network or web-type topologies rather than hub-spoke arrangements, which gives more opportunities to deliver capacity to localised of high (or low) demand;
- quick but secure access to the services spine for maintenance staff, allowing more rapid servicing when things go wrong;
- modular plant, effectively controlled to match supply to demand;

- minimising movement of conditioned air and recirculating water, so that eg. usage of electricity-guzzling fans and pumps is as low as possible;
- using systems which default to off or highly-efficient tickover when demand is low;
- having enough degrees of freedom to switch between energy supplies if price-cost-emission considerations change;
- taking advantage of ambient sources of diurnal fluctuations to maintain good conditioning with minimum requirements for purchased energy..

## Conclusions and contradictions

Without being too theoretical or technical, what are the main lessons to be learned from this - the “killer variables” of the title. Seven emerge, but sometimes they contradict each other!

### 1 *What do you really need to change?*

More uncertainty in the world leads to demands for more flexibility: but how much is really required, and where? Can simpler, more generic, but adaptable building types which get some basic things right actually prove liberating, not constricting? Is it best to adapt the building, to adapt to the building, or to change the building? Flexibility of movement within a diverse and fluid property market could make up for some of the shortcomings of individual buildings in a more static market. And how can we make better adaptive use of the buildings we have already got, a significant portion of which (particularly from the 1950s to the 1970s) are now unloved, but not always owing to a lack of potential, but a lack of imagination, fashionability and market value?

### 2 *Know your timescales*

We define flexibility as primarily about short-term changes and adaptability about less frequent but often more dramatic ones. Try not to confuse the two: while ideally they are complementary, in practice they can easily conflict. For example, it is not unusual for air conditioning distribution systems installed to improve flexibility but also physically obstruct adaptations one would like to make.

### 3 *Hidden costs*

Flexible concepts for buildings often provide fewer physical obstacles, particularly to any space plan which fits within the boundary conditions. However, the downside is often much higher dependency on technical and management infrastructures that anybody had anticipated. In addition, the technology has often proved to be less flexible and more prone to obsolescence than one had thought, viz the amount of nearly-new materials and equipment which are often scrapped when an office is fitted-out or refurbished.

### 4 *Dependency cultures*

Flexibility concepts (e.g: deep plans), equipment (e.g. interlocked serviced furniture) and technologies (e.g. automated internal environments) can deprive occupants of the ability to make even small adjustments, causing them to be disgruntled, make more demands upon management, or both. The costs of this in terms of the degree to which the quality of the building needs at be improved, together with management and the expensive support services required are often ignored, or at best badly underestimated. But if these demands are not met, occupant dissatisfaction and lost productivity will result.

### 5 *Hierarchical layering*

The strategic layering of a building (shell, services, scenery etc.) helps to avoid unwanted rigidity by minimising interlocks between elements with different functions or with different timescales for maintenance, alteration and replacement. However, by excessive reductionism, and the splitting of activities into single issues dealt with by narrow specialists, it can also get in the way of holistic design and strategic integration. This in turn can destroy context, reduce added value, and increase the loads a building imposes on the environment through unnecessarily wasteful consumption of fuels and materials.

### 6 *Generic buildings: tonic or tragedy?*

Will we benefit most from more standardised solutions or from rich and chaotic diversity? We see hope in reducing the number of unnecessary variables and seeking out more generic solutions which aim to satisfy better the needs of investors, occupants and the environment. How in practice will this differ from the North American reductionist, standardised approach which tends to destroy context and create widely-accepted, competitive, but often far from optimal, industry standards?

### 7 *If in doubt, leave it out*

The essence of adaptability is to invest in the outset in the things you are really going to need, and to leave to others the option of adding (or subtracting) things you are not sure about. Of course, this is not easily done in a changing world, but nevertheless it is usually possible to reach some sort of verdict.

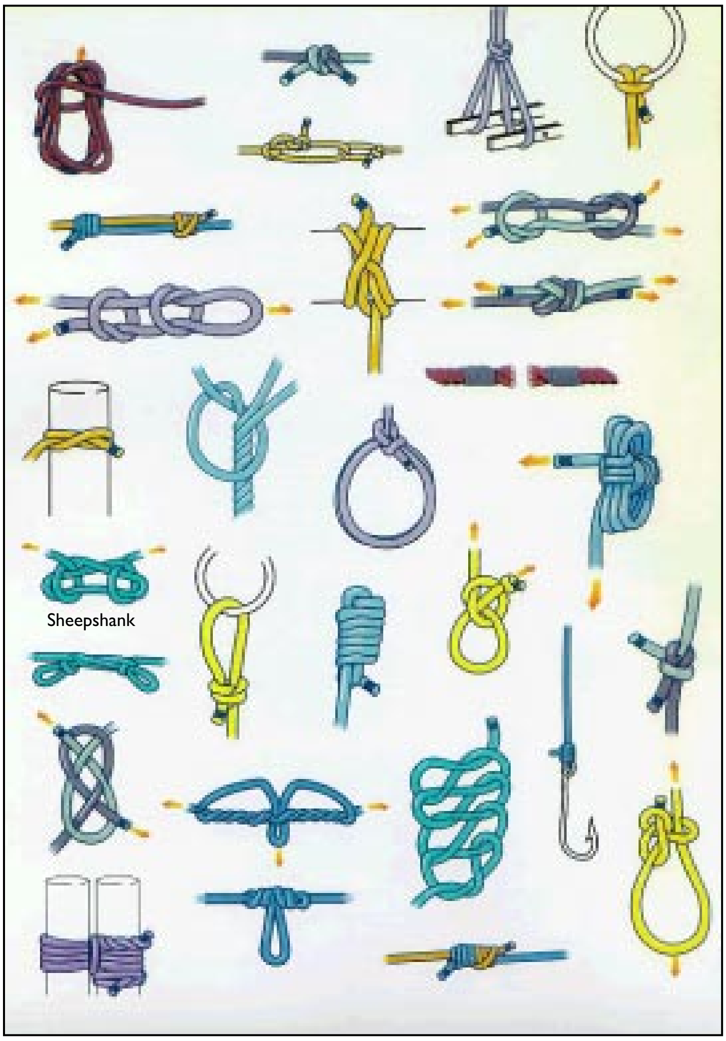
Agendas for the future will include:

- Briefs which are explicit about need, and try to make hidden assumptions crystal clear for all concerned.
- Adaptable envelopes and structures, at least in parts of the building which can benefit.
- Building shells which are better at selectively moderating the external climate.
- Intrinsically-efficient building services which adopt "gentle engineering" principles and good controls to fine-tune the environment efficiently, only to the extent needed.
- Where necessary, "plug and play" supplementary components which can easily be obtained, installed, and relocated to alter building services provision and capacity.
- More rounded understanding of future scenarios, especially from the perspective of businesses and their progress, and the social, technical and environmental constraints most likely to affect businesses, buildings and their locations.

So what to do?

- Consider all types of risks and constraints affecting buildings, not just the obvious or fashionable ones - acute and chronic, short term and long term - and work on all of them.
- Take a demand-side perspective which starts with revealed needs and preferences especially within the immediate context of business and organisational requirements - and work towards more abstract supply-side issues, rather than the other way round as has tended to be the case.
- Think of potential downsides and their consequences, emphasising the thresholds where action meets the point of need (eg the trigger points when people become uncomfortable and decide to do something about it).
- Adopt a perspective which treats constraints in a positive way, so that potential bugs become features. Most great designs - especially the most usable - are like this, apparently making insuperable constraints disappear altogether. Of course, they never do; both potential and constraints have been turned to human advantage - the essence of human adaptability and the hallmark of progress.

**Figure 1 Types of knot - literal examples of flexibility and adaptability**




**Source: Reference 1** Rope is obviously flexible and useful within governing parameters such as length and tensile strength. Its adaptability comes through how knots are applied and utilised.

Some knots, such as the sheepshank, are non-intuitive. The sheepshank allows a weak point in a rope to be bridged, but only works properly when under tension. So when climbing down a cliff on a rope it is possible to tie a sheepshank in the top end, cut through the rope (at a point between the "ears" of the sheep) while you are still attached to the rope, climb down, shake the rope free when you have reached the bottom, and retain the majority of the rope!! (p 64 "Sheepshank secrets").

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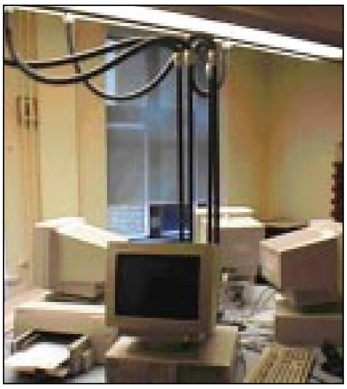
**Figure 2 Types of event affecting buildings**

| | Duration: Shorter | Duration: Longer |
|---|---|---|
| **High magnitude / low frequency** | Potentially catastrophic, eg. Structural failure, gridlock congestion. "Acute" | (Lack of) Adaptability |
| **Low magnitude / high frequency** | (Lack of) Flexibility | Insidious, eg. Inefficient technology, occupant ill-health. "Chronic" |

**Source: Authors**

**Figure 3**



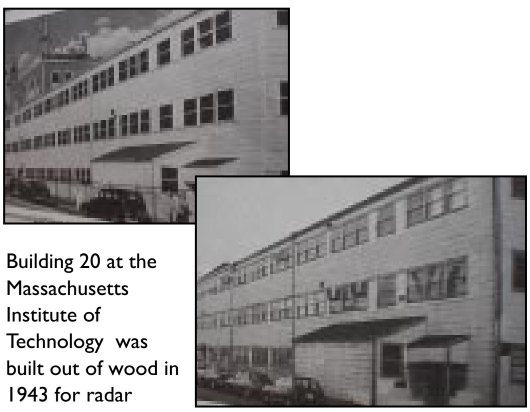
The Hotel Office in the Hague [Reference 4] has high flexibility created by the innovative services distribution and furniture designed to have minimal impact on the fabric, but the restrictions of the historic (1909) building mean that adaptability is poor.

**Figure 4 Compass Centre**

**Source:**

AL original photograph

**Figure 5**



Building 20 at the Massachusetts Institute of Technology was built out of wood in 1943 for radar development. It was still in use in 1993- although scheduled for demolition - when Stewart Brand last saw it. Photos (1945, top; 1990, bottom) from How Buildings Learn [Reference 7, Page 26].
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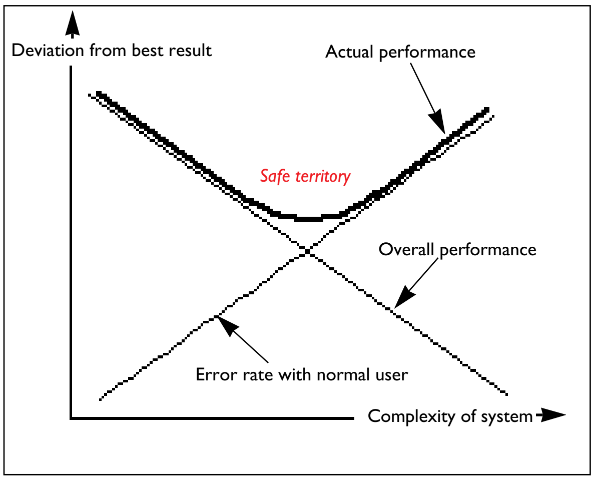
**Figure 6 Technology-management interactions**

Source: Authors

| | | Technological complexity: Higher | Technological complexity: Lower |
|---|---|---|---|
| Management input | Higher | Effective but often costly<br>*Type A* | Rare<br>*Type B* |
| | Lower | Risky with performance penalties<br>*Type C* | Effective, but small scale and restricted uses<br>*Type D* |

**Figure 7**




**Source: Jake Chapman from Reference 22**

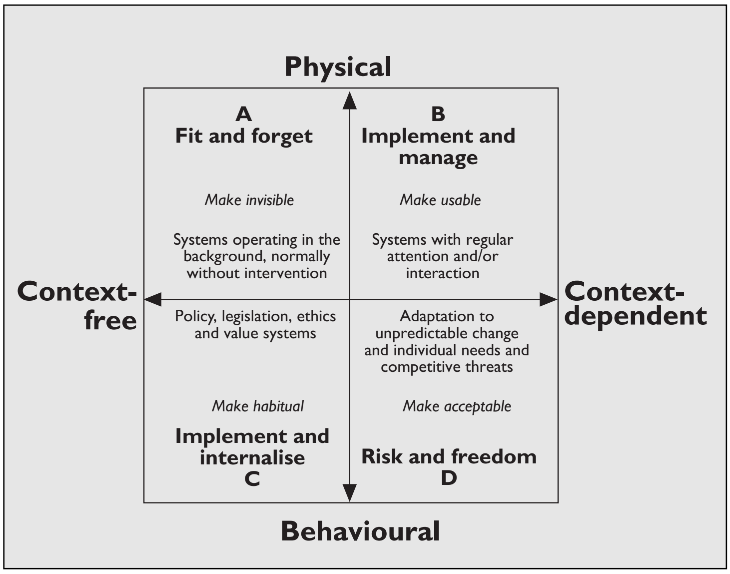
This diagram has been adapted by the authors from the original (it was first used in a discussion of energy performance). As systems become more complex (bottom axis) their performance normally improves (that is, their deviation from the best possible result (vertical axis) lessens). However, normal users make more mistakes as complexity increases. So it is often best to opt for the “safe territory” where a compromise is reached between performance and usability. For example, naturally-ventilated buildings often provide sub-optimal (but still satisfactory) comfort conditions (their “deviation from best result” is high). Air conditioning usually gives a better performance in theory (a lower deviation), but is often much less satisfactory in practice because of manageability-usability snags.

**Figure 8 Examples of revenge effects**

| Measure | Intended consequence | Revenge effect | Possible solution | Comments |
|---|---|---|---|---|
| **GENERAL:** | | | | |
| Improve comfort provision and energy efficiency | Automated windows, blinds, lights etc. can be controlled to provide optimum conditions. | Reduced occupant tolerance. Increased dependence on management. More complaints. | Include occupant over-ride facilities. | Imposition of automatic control can be very irritating. Try not to sacrifice adaptive opportunity. |
| Increase technology to provide added "flexibility" | Less management input necessary to make alterations from time to time. | More management input to look after the additional systems. Still requires some alterations too. | More realism. Better integration between physical and human systems. | Careful discussion of brief and design options to avoid fantasies. |
| Increased BEMS control | Better control and management information provided. | More load for operator, who may not be fully familiar. Local interventions more difficult. | Don't over-centralise. Allow for local decisions on over-rides etc.. | Particularly important to have local over-rides in mult-tenanted buildings. |
| Outsourced facilities management and BEMS operation. | Professional service. Leaves occupiers to concentrate on their core business. | Business requirements for environmental services not so well understood, so systems run generously, wasting energy. | Tighter contractual requirements or retain in-house control of operation. | Third parties often not on site out-of-hours when anomalies tend to occur. Don't outsource the feedback loop! |
| **LIGHTING:** | | | | |
| Occupancy-sensed lighting in offices | Lights switched off when people absent. | Lights switch on unnecessarily when occupant does not need it, or for passers-by. | Include manual ON switches, except where lighting is required for safety or convenience. | Also include manual OFF switches if possible. Control lighting of circulation routes separately. |
| Occupancy-sensed lighting in meeting rooms. | Lights come on only when required. | Can't switch lights off for slide presentations etc. | Include local over-ride switches. | Local manual control plus absence sensing only may be preferable. |
| Automatically dimmed lighting | Reduces artificial illuminance level when daylight is sufficient. | Increases artificial illuminance level when daylight fades. | Bring on at a low but reasonable level. Try to leave adjustments to increase brightness to the occupants. | Constant illuminance may also bring dissatisfaction owing to eye adaptation. Photocells sometimes confused by reflections. |
| Local switching of lighting | Greater responsiveness to need | Difficult to switch off lights left on inadvertently. | Absence sensing or "last out-lights out" facility at the exit. | The switch at the entrance should only activate circulation and safety lighting. |
| High intensity discharge lighting | Efficient point source. | Run for extended hours owing to extended run-up and particularly restrike times. | Use instant restrike ballasts or substitute fluorescent lighting. | Compact fluorescent fittings can also take some time to run up to reasonable brightness. |
| Lighting to suit VDUs | Reflected glare minimised. | Dreary-looking environment. | Added wall-washing etc. | Uplighting also worked well. |
| **HVAC SYSTEMS:** | | | | |
| Displacement ventilation | Reduces cooling loads | Increases air tempering loads | Heat recovery | Minimise parasitic losses and avoid recovering unwanted heat. |
| Generous provision of cooling capacity | Deals with possible increases in internal gains. | Oversized systems can operate inefficiently and may cause discomfort. | Contingency planning, or systems which work effectively and efficiently at low capacity. | Needs care in design and management. |
| Full fresh air systems | Improves air quality | Increases heating loads and makes humidification likely. | Avoid over-ventilation and consider heat recovery, including latent. | Cleanliness may be more important. Don't operate ventilation just to provide heating or cooling. |

**Source: Bill Bordass and Adrian Leaman Reference 9**

**Figure 9**




**Source: Authors**
In our experience, buildings which work well have addressed each of these four quadrants somewhere in their briefing, design and management systems - formally, or informally as part of the organisational culture. Physical and behavioural issues are treated equally (too often, undue faith is placed in technical and physical systems at the expense of human) and changing contexts are not forgotten (too often standardised "solutions" are applied irrespective of context). Adaptability, as the bottom right quadrat shows, is also risky - but it allows freedom for innovation and change. This implies an organisational culture which can tolerate mistakes made in well-meaning attempts to cope with change.

**Figure 10 Ten levels of adaptation**

**Adaptation?**

Site
Strategy
Shell
Structure
Skin
Services
Space plan
Scenery
Sets
Stuff

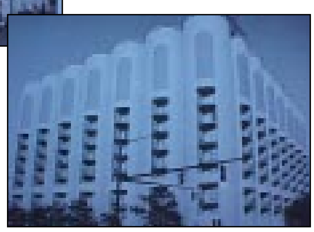
**Source: Adapted from S. Brand [Reference 7] after Duffy F, Cave C. and Worthington J [Reference 23]**

The original "shell-scenery-set" diagram by Frank Duffy and John Worthington was first published in 1972 and has since been reproduced countless times. This is a revision of the version used by Brand, to give ten levels altogether.

Severe problems with flexibility and adaptability can result if:

- systems are dependent on levels higher up the hierarchy which are beyond effective management or control (eg modular furniture which does not dovetail with the services systems);
- constraints are "passed" down the hierarchy without being properly dealt with at the appropriate level (eg human comfort problems resulting from lack of air-tightness in the building shell;
- the time dimension is oversimplified (eg assuming that the "scenery" (the basic fit-out) will outlast services);
- any one level dominates any other (eg if the space plan becomes too important).

**Figure 11 Grain silo conversion**



**Source: Stewart Brand, Reference 7, page 105**

Monumental grain silos of the Quaker Oats Company in Akron, Ohio before and after conversion to a hotel.
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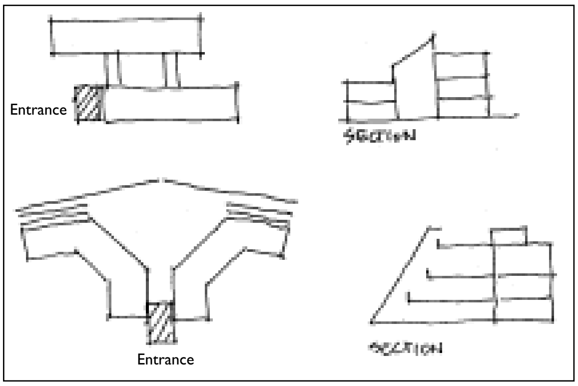
**Figure 12 Solar Offices for Doxford International showing constraints introduced by photovoltaic array**

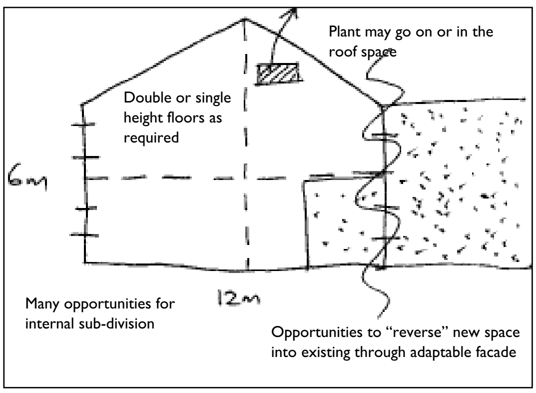



**Source: David Lloyd-Jones**

The Solar Offices for Doxford International in Sunderland UK utilise a photovoltaic array. Optimum conditions for PV power generation usually conflict with normal arrangements for passive design. Studies for a low energy building of 4,500 m² on the Doxford site suggested a 2-3 floor building of limited depth (15m maximum, encouraging cross ventilation and good internal light levels) with a clear floor-to-ceiling height of 3m. The layout had two east-west aligned blocks (minimising exposure of windows to low sun angles) with north-south links enclosing an atrium (top,).

The introduction of the substantial PV array profoundly changed the layout and form (bottom). The atrium was retained, along with limited floor depth and generous floor-to-ceiling. However, the office space was completely reconfigured with a change from the parallel east-west arrangement to a splayed V layout. The atrium is now located in the centre and at the extreme ends of the floors. Floors are now stepped back successively. This allows the inclined facade to be propped against the wings and to enclose the open side of the atrium. The inclined solar wall of 70m length and 1,000 m² area can then be accommodated, providing an estimated one third to one half of the electricity demand.

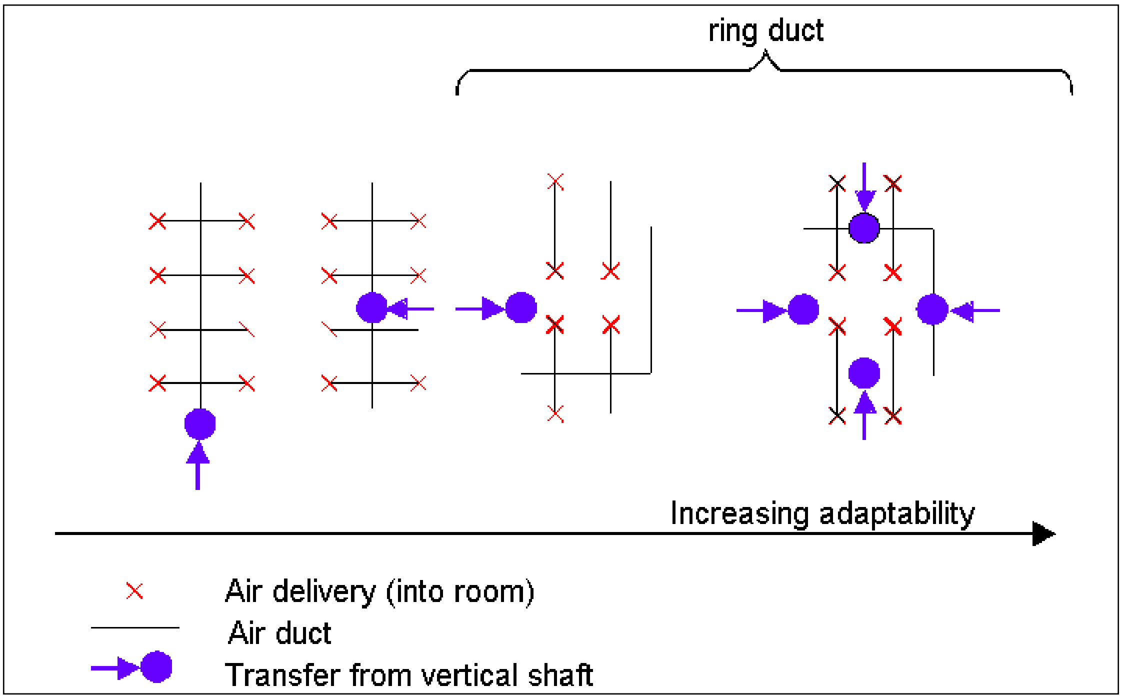
**Figure 13 Sensible plan and section**




**Source:** Interpreted by AL from Delft seminar

TO BE DEVELOPED FURTHER

**Figure 14 Services adaptability**




**Source: Paul Rutten References 36, 37 and personal communication.**

This is an example of how adaptability in services distribution systems increases with the introduction of ring topologies. Hub-and-spoke arrangements are much less adaptable.

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