The 2005 World Sustainable Building Conference,
Tokyo, 27-29 September 2005 (SB05Tokyo)

UNDERSTANDING HOW BUILDINGS EVOLVE

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Keywords: adaptability, flexibility, post occupancy evaluation, long life buildings, recycling, reuse.

Abstract

"The architect's work is intended to live on into the distant future. He sets the stage for a long, slow moving performance which must be adaptable enough to accommodate unforeseen improvisations" (Rasmussen)

Think how much life has changed over the last 10, 20 50 or 100 years. Our, values, morals, and indeed everyday activities are constantly changing, and yet the buildings that accommodate our lives are expected to cope with these changes as they happen. When we experience buildings, often we are experiencing the result of decisions taken long ago and for long forgotten reasons, so, in effect, the activities of architects today are all about designing the future. It is commonly said that the built environment reflects a society's hopes and aspirations, but it must also reflect a society's future. Just as a chameleon changes colour to adapt to its surroundings so buildings need to be designed to adapt to change and evolve over time.

"*If a building doesn't support change and reuse, you have only an illusion of sustainability. You may have excellent building orientation and other energy-saving systems, but the building must also be able to be flexible to meet a change in curriculum."* (Croxton).

The construction sites of today are building the infrastructure of the future which is likely to serve us for many years to come. Designers are making judgements and predictions about the way buildings will be used over long periods. Yet as British architect, Cedric Price, used to say, the more you try to see into the future, the more you are likely to be wrong. So what are we doing to look at the impact of time on buildings and make sure that today's designs are robust and able to accommodate the changes they are likely to encounter?

This paper discusses the importance of understanding how buildings evolve, and how this can enrich architectural design and building quality. The underlying premise is that architectural education and practice generally does not provide the feedback loops necessary for architects to understand building evolution over time, or to develop a balanced appreciation of the long term qualities of building designs. Thus, alternative "feedback loops" are necessary. Secondly, breaking the barrier between the building construction phase and the building operation and maintenance phase of a building's life, and extending the involvement of the design team into the operations phase will benefit the way the building can evolve and accommodate change.

The concept of the "*Fit Building*" - fit for the people that use it, fit for its purpose, fit for the planet, and, in particular, fit for the future is presents a context for building designers to increase awareness of issues that are important to users and society over the life of the building.

1. Introduction

For most of society, and in particular for clients of the construction industry, the building is usually merely a "means" to something else and not an "end" in itself. For the client, the building is a means for carrying out their business, or a way to provide a home for their family, and it needs to accommodate changes in that activity over time. But for the design team, and in particular for the architect, under pressure from clients and media to produce iconic or "wow" buildings, the building is the "end product", and most architects like to think of their buildings as finished products, which have been perfected, and should remain unchanged. Architects imagine that their designs are ideal solutions to design problems which will endure and will not need to be altered or refined. Thus, buildings are rarely designed to accommodate significant change and development over their life, and there is little guidance about how to design to allow buildings to evolve.

Louis Sullivan's dictum to architects that "form follows function" has inspired several generations of architects and is still influential today. But how often do we know all the functions that a building will fulfil during its life at the time when it is being designed? Architect, Bernard Tschumi, points out that:

'In no way can architecture today claim permanence of meaning. Churches are turned into movie houses, banks into yuppie restaurants, hat factories into artist studios, subway tunnels into nightclubs, and sometimes nightclubs into churches. The supposed relationship between function and form ("form follows function") is forever condemned the day function becomes almost as transient as those magazine and mass media images in which architecture now appears as such a fashionable object.' (Tschumi)

Just like human beings, buildings need to be allowed to develop over time, to mature, grow and evolve, otherwise they often deteriorate. In *The Ethical Architect*, Spector argues that architecture gains meaning and value through use. This implies some accommodation of change over time as users and their needs alter. In *How Buildings Learn* Brand talks about "blue jeans buildings" – buildings that age honestly and elegantly over time. This requires acceptance of buildings as evolving entities where the design and construction phase is just the start of a long process over the life of the building. Yet this is alien to the current ways in which buildings are procured in most countries.

Nevertheless, some architects have at least in principle accepted this challenge. Dutch architect, Herman Hertzberger, argues that:

"The point is to arrive at an architecture that, when users decide to put it to different uses than the one originally envisaged by the architect, does not get upset and consequently loose its identity. Architecture should offer an incentive to its users to influence it wherever possible, not merely to reinforce its identity but more especially to enhance and affirm the identity of its users."

And English architect Richard Rogers states that:

"One of the things which we are searching for is a form of architecture which, unlike classical architecture, is not perfect and finite upon completion....We are looking for an architecture rather like some music and poetry which can actually be changed by the users, an architecture of improvisation."

2. Evolution of buildings

We forget that design problems do not stay constant over time and the requirements placed on a building throughout its life will change and evolve. For example, the typical Georgian terraced house type may have originally been a family house, but this building type has since been used for many other functions during its lifetime such as apartments or offices. In that time, many new technologies for heating, lighting, plumbing, drainage, communications, insulation, glazing, etc., have been incorporated, as well as countless changes in layout, decorative fashions, furniture, etc. There are also many examples of conversions from office block to residential and back. Similarly, with most other buildings, even enduring types such as churches or municipal buildings, new or changing uses constantly place new demands on them, which create a necessity for them to adapt over time. Those buildings that can evolve in an effective manner are likely to last while others are prematurely replaced if they cannot encompass change. Some of this change may be minor and involve only the users in small adaptations such as changing furniture layouts, while others may lead to major renovations or adaptations involving professionals.

Building designers need to recognise this dimension of time and how it affects their proposals, recognizing that a building is likely to undergo many changes over its lifetime. Designers can begin to learn about how time affects buildings by studying existing buildings and how users experience and adapt them over time. Feedback about building performance can help to develop an appreciation (and possibly a respectful attitude) by the designer of the ongoing life of the building where the designer may have little control. Analysis of how buildings are used, how they function, and how users wish to change them can provide designers with an insight and respect for the effects of time, and their designs may become more durable and capable of being adapted for changing requirements.

2.1 Obsolescence

A building or product can become obsolete for a variety of reasons:

- A loss of *fitness* is a failure of the building or product to work effectively. Such technological obsolescence is generally reached when replacement occurs due to a technical failure that cannot be fixed.
- A loss of *function* is due to the influence of technical change. Many ageing but functioning products are replaced with new models due to the development of a technically superior alternative. Some products are upgradable and this reduces the pressure to replace them.
- A loss of *function* can also occur due to changing needs. Obsolescence is reached when a building or product can no longer accommodate the functions it was designed for due to changing practices.
- Many products are replaced for reasons of *fashion*. Social obsolescence is reached when the desires of society dictate replacement. These are often for reasons of superficial changes in appearance.
- Legal obsolescence is reached when legislative requirements necessitate replacement.
- Economic obsolescence is reached at the point when the product or building is no longer the least cost alternative.

The point at which a building becomes obsolete usually arises when the building cannot respond to the users requirements, and this may be due to legal, social and economic change. Most buildings do not reach technological obsolescence. They are replaced due to changing needs and fashions, or for economic reasons. Thus, technical solutions are not sufficient to deal with building obsolescence. Designers must consider how to ensure that the building can accommodate change in such a way that social or economic obsolescence is not reached.

2.2 Concept of hierarchical layering

Duffy has introduced the concept of a series of 4 hierarchical layers that compose the building - *Shell, Services, Scenery and Set*. Each layer has its own timescale for maintenance and replacement. This concept has been expanded by Brand into a more comprehensive set of layers, where the layers at the top of the list set constraints for layers below (Figure 1). Thus, *Services* are affected to some extent by the *Structure* and *Skin*, while the *Stuff* is constrained by the *Space Plan*. The top layers also tend to be longer lasting (possibly centuries) while the lowest layer of Stuff may last only minutes or hours. This tends to suggests that the lower layers need to be more flexible and more easy to change than the layers above.

Site	Geographic setting of building	Eternal
Structure	The loadbearing elements including foundations	30 to 300 years
Skin	The exterior surfaces providing the weather protecting layer	20 years
Services	The working guts of the building – HVAC, electrical, plumbing, sprinklers,etc	7 - 15 years
Space Plan	The interior layout – internal partitions, doors, etc.	3 – 30 years
Stuff	Furniture, equipment, personal positions of occupants	Daily

Figure 1 Hierarchical layering of building systems (after Brand).

3. Adaptable buildings

Adaptable building is a concept that incorporates, at the design and construction stage, the ability to make future changes easily and with minimum expense, to meet the evolving needs of its occupants. Adaptability means designing a building to allow the hierarchical layers to change, each in their own timescale. Incorporating adaptability into a building during initial construction saves time, money and inconvenience when changes are needed or desired later in the life of the building. Investigations of the technical issues that need to be addressed to create adaptable buildings that can evolve over time suggest the following:

- Optimise structural grids to allow changing uses of space. Use simple structural grids with clear support lines.
- Allow some redundancy so that additions and changes to the building can be accommodated. Over-design structural capacity to allow for other uses and extending the structure.
- Separate structure and cladding to allow independent alteration and replacement.

- Separate services into clearly accessible locations to allow easy change and upgrade.
- Loose fit – allow some redundancy to accommodate future addition.
- Higher floor to ceiling heights – office use requires greater ceiling heights than residential.
- Design Foundations to allow some additional capacity.
- Finishes should be integrated in ways that facilitate easy upgrade and replacement and that do not provide difficulties for access to other components.
- Simplicity often aids future change – independence of systems allows changes where necessary.
- Provide sufficient space for machinery needed for renovation, addition and dismantling.
- Prefabricated components can be assembled on site and can be disassembled for reuse/recycling.
- Avoid irreversible processes. Reversible mechanical fixings rather than wet fixings - bolts and screws - can usually be removed, adhesives and cement often cannot.
- Wet construction such as in situ concrete or plastering cannot be reused and are difficult to recycle or change.
- Avoid complex composite materials that are difficult to separate. This includes some treatments and finishes applied on site.
- Incorporate each component so that it can easily be removed and recycled when obsolete.

The principles of theatre construction require constant change and may be an appropriate model for allowing change in buildings particularly offices and retail spaces which are regularly remodelled. Services such as lighting, heating and power are provided from backstage, allowing the front stage to be restyled constantly with minimum time and impact.

4. Initiatives to help buildings evolve

The above list provides some suggested technical characteristics of an adaptable building, However, the main obstacles for increasing product life, of whole buildings and individual components are often not technical, as an OECD report on long life of components concluded: "*from a technical point of view there is no question that longer-lived appliance could be made*" (OECD). More important are the cultural and economic pressures that generate a throw-away mentality so prevalent in society today. Extending the useful life of buildings and components requires such cultural pressures to be overcome, and designers to consider issues such as adaptability, flexibility, component replacement, ease of maintenance, options for upgrade, and dismantling at the outset of the design process.

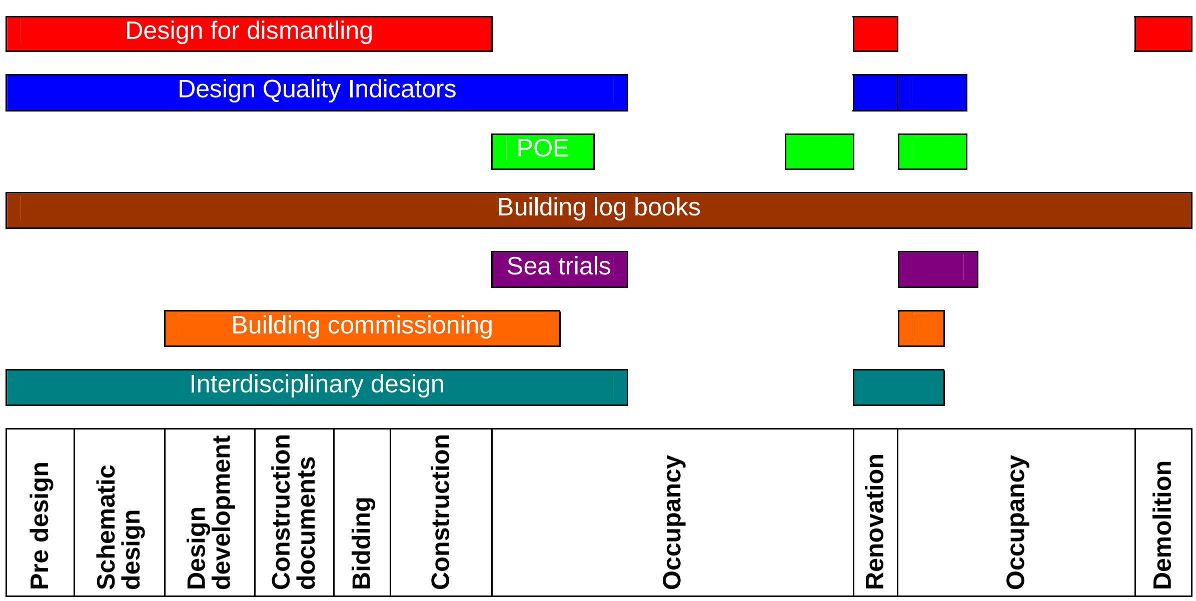

Figure 2 Feedback initiatives that are relevant at various stages of the building lifecycle.

Any initiatives that extend the involvement of designers beyond the procurement phase and into the operating phase of the building help establish feedback loops that inform the way the building will evolve. This can help establish a culture of continuous learning, and improvement that are informed by observing how buildings are used and function after completion. In recent years, greater interest in building performance and building life cycles has led to a number of initiatives that are applicable at various stages of the procurement process to improve how buildings work throughout their life, how they evolve, and how we can improve the process of delivering buildings by learning from existing buildings (Figure 2). These are leading to a greater appreciation by the design team of the building performance over time and establishing feedback systems. The following is a short review of some of these initiatives.

4.1 Interdisciplinary design

A feature of the complexity of modern buildings is that many fragmented design professions shape the environment, and it is often their concerns and priorities that are given precedence over those of the users, or of the society and community as a whole. The diversification in design, construction expertise and education has created a conventional building procurement process with confrontational structures and barriers between areas of expertise, which is often underpinned by mistrust, reducing the likelihood of effective team working. Addressing the agenda of sustainability and in particular issues of time requires a more effective dialogue between all participants involved in the production of buildings, and with occupants.

The integrated design process (IDP) is based on the well-proven observation that changes and improvements in the building design are relatively easy to make at the beginning of the design process, but become increasingly difficult, expensive and even disruptive as the process unfolds. IDP encourages a collective responsibility and leads to sharing of information and a greater understanding by all of how the building works. If goals of adaptability are set at the start of the design process, IDP creates a far more conducive environment to meet such goals. Working closely with users and other designers can lead to an appreciation of the importance of communication; between clients, design team and potential users, and the need for collaborating with the design team at all stages.

One of the key findings of the Probe studies (Bordass) carried out in the UK is "*the need for more strategic briefing, greater clarity of discussion, and the assessment of the options and solutions for usability, robustness and manageability".* By increasing awareness of long term needs and building functioning problems IDP can develop an appreciation of the importance of the briefing (programming) stages of a project and allocation of responsibilities, so that clear goals are set which include long term building evolution. This requires clear objectives which can be used to assess the design at various stages.

4.2 Ongoing building commissioning and building "Sea Trials"

It has been argued by Bordass and others that buildings should no longer be seen as practically complete when they are physically complete and it may no longer be practical to expect them to be completely trouble free at the day of handover. Perhaps it is time to accept that complex buildings require an initial settling in period before they function at full efficiency. In a world of changing customer requirements, rapid innovation, and sophisticated information and control systems, these systems need fine-tuning, and suppliers, designers and users need to work together to improve performance over the life of the building. A strategy is needed particularly for the first years of occupancy to ensure a smooth transition from construction to operation, and to ensure that the necessary information is available for future change and evolution of the building as needs evolve. Just as important, the strategy should ensure that the designers and contractors get the necessary feedback on the performance of the building so that they can learn the lessons of the project for future benefit. Without this, designers will continue to repeat the same mistakes from the past due to a lack of knowledge about how their buildings are functioning. Sir Andrew Derbyshire has argued that "…*the architect who believes that his work is done as soon as the building is finished must be made to look as ridiculous as the scientist who believes that his experiment is complete as soon as he has assembled the apparatus*".

Although commissioning of HVAC services is in theory a requirement in most buildings, the reality is that full and effective commissioning of HVAC rarely occurs, and many buildings go through their life with poorly functioning systems. Furthermore, with more complex and innovative cladding systems and the desire to achieve well insulated and airtight building envelopes there is an increasing need for building envelopes, and indeed whole buildings, to be properly "commissioned". Lemieux amongst other has advocated building envelope commissioning, particularly for green or innovative buildings. They claim that many performance problems that occur in green buildings are linked to poorly performing building envelopes and could be avoided by proper commissioning procedures. The process of commissioning an envelope often involves consideration of durability, replacement and long term performance issues, and allows problems to be anticipated and eliminated prior to construction. Additionally, it allows the links between HVAC and envelope performance to be explored.

Others have gone further and suggested the need for building "Sea Trials" or post completion test runs for a complex building, where the design team are involved in running the building for the first period of operation. For example, Cambridge University and design firm RMJM have developed "*Soft Landings*", a follow-through procedure which focuses on aftercare and feedback in the first few months and years of occupancy. Another UK study considered what is needed to be planned for in the first year of occupancy to ensure a smoother transition from construction into operation and to prepare for any necessary follow up activities such as technical, occupant and energy surveys. The main outcome was a building manager's checklist *(*Jaunzens).

4.3 Building log books

Currently most buildings have bulky and inaccessible O&M manuals that few people use. Clients then complain because they do not have the information they need to know to operate them successfully. When you buy a car you get a simple handbook and somewhere to log the maintenance history. In the same way there is a need to set down, in simple terms, how a building is meant to work and to log performance, maintenance and change. Recent changes to the Building Regulations in England & Wales (DETR) introduced requirements for "Building Log Books" in new and refurbished buildings which are intended to provide the building owner or occupier:

"… with details of installed building services plant and controls, their method of operation and maintenance, and other details that collectively enable energy consumption to be monitored and controlled".(DETR)

The log book should be an easily accessible focal-point of current information for all those working in the building that summarises the philosophy, energy performance, maintenance performance, occupancy and alterations to the building and its services. It has four main functions (CIBSE):

1. Summary of building - information about the building including the original design, commissioning and handover details and information on its management and performance, including the designers estimates of building energy consumption.
2. Key reference point - single document in which key building energy information is kept.
3. Source of information and training - key source of information for the daily management or operation of the building and for carrying out work on the building. Also relevant to new maintenance/facilities management staff and contractors and consultants.
4. Dynamic document - it is a place to log building performance and operation, and changes to the building.

Building log books can improve understanding of buildings amongst the staff working in the building, those running the building and external contractors or consultants that are new to the building. They can help prevent random alterations to buildings that might damage the overall design intent and could save time in searching for key information. Log books also provide a clear mechanism for monitoring building energy, water and other performance to highlight potential wastage (Jones).

4.4 Post Occupancy Evaluations - business benefits or better buildings

Post occupancy evaluation (POE) has been defined as "*examination of the effectiveness for human users of occupied design environments"* (Zimmerman). It generally involves some form of surveys of building occupants and may also include some measurement of environmental conditions and assessment of energy and water use. Normally, POEs are carried out a year or two after building completion, but also increasingly prior to major changes in the building to identify problems and inform the refurbishment process. As clients and governments today become more interested in the performance of their buildings for reasons of sustainability, efficiency and workplace productivity, POE feedback mechanisms provide the opportunity for quality control in the more repetitive projects, as a necessary part of hypothesis-testing in innovative ones, and to increase awareness of chronic problems and changing requirements in buildings in general. Cooper has identified three separate agendas for POE activities:

- POE as a design aid – as a means of improving building procurement.
- POE as a building management aid – to aid organisational efficiency.
- POE as a benchmarking aid – to help understand, measure and compare performance.

Feedback to questions such as - did we do this effectively? Did it go well? Was it the right thing to do in the first place? - can help designers in future decision making. For the building user, questions related to how the building contributes to business aims, such as efficiency of operation, satisfaction of staff and productivity, are relevant. Many years of research have focused on human and organizational factors that affect the success of organizations and their efforts to develop and change. However, corporate organizations have been slow to recognize the importance of physical space on an organization's performance. Senior management generally want to concentrate on core business and consider buildings as nuisances which they would prefer to ignore. In 2001, MIT and the Gartner Group estimated that fewer than 5% of the corporations in the US were actually linking the workplace to their corporate strategy, and using the workplace as a tool for improving performance (Bell). The past decade has seen the publication of several books on the workplace (Duffy) and recognition is growing within business that the physical workplace can provide a platform for organizational change and business innovation. Some organizations are now becoming concerned about this because research shows that there are significant linkages between the workplace environment, job satisfaction and worker productivity and thus the corporate bottom-line.

Thus, a primary driver for post occupancy evaluation of workspace in recent years has been to identify whether organizational and workplace goals have been achieved and to direct refurbishment and change in buildings. Some large organizations have implemented feedback systems to improve building functioning, and to provide information when a building is to be renovated.

4.5 Design for dismantling

The increased interest in recycling and reuse has led to studies about how to design to facilitate dismantling at the end of a building's life. However, the ease with which components can be recovered from a building is also relevant to adaptability. Systems that allow building components to be easily removed facilitate their replacement and so allow change. Demolition and alteration is often the reverse of construction, and dismantling is greatly affected by how the building was put together in the first place. Thought is needed at the design stage about component and building obsolescence. Thus, the design team should consider the assembly process and prepare a strategy for the alteration and dismantling of the building similar to that developed for many temporary, relocatable buildings. Components should be incorporated into buildings in a way that allows changes to be readily made and facilitates separation, reuse and recycling.

European Union legislation on producer responsibility is putting the responsibility for disposal of products at the end of their life on the producer. This concept may be extended to construction components and require that producers of goods take them back at the end of their life for reuse, recycling or disposal. This will necessitate that buildings are designed to facilitate dismantling, not just at the end of the building's life but as components become obsolete and are removed.

Car manufacturers, encouraged by legislation and competition, have begun to consider the end of life disposal of their products. Cars are now being designed to enable disassembly and for easier replacement and reuse of worn parts. This process has led to a realisation that simpler designs and assembly processed, using less materials, and in some cases leading to cost savings, are more suitable for disassembly. Similar approaches can be adopted in the construction sector.

4.6 Design Quality indicators (CIC)

Design Quality Indicators (DQIs) have been developed in the UK as method of assessing the quality of buildings. They are designed to be used by anybody involved in the production of the built environment. The UK DQIs are divided into three main parts based on an intellectual framework that aims to modernize the Vitruvian concepts of Firmness, Commodity and Delight, by proposing that the quality of a building can be ascertained by measuring functionality, build quality and impact.

Functionality concerns the disposition, quality and inter-relationship of space and the manner in which a building is designed to be useful over its full life. This allows issues of adaptability to be integrated into the assessment framework. Build quality relates to technical performance, including the quality of integration, co-ordination and performance of the structure, fabric, finishes and fittings to meet overall goals, including adaptability. Impact refers to a building's ability to engage both the mind (memory and intelligence) and the senses, to create a sense of place and to impact positively on the local community and environment.

The DQIs are designed to be used through inception, design, construction and again when the building is in use, and allow clients to clearly establish their requirements in the brief (program) and evaluate the extent to which their intentions have been met. The main purpose of the tool is to allow comparison between different respondents' results and between different projects.

5. Conclusion

As the sustainability agenda extends throughout the construction industry a gradual realisation is spreading about the importance of considering the whole building life at the outset of the procurement process. From a commercial point of view, the much quoted 1:5:200 ratio of initial building cost, to lifetime running cost of building, to lifetime value of the activity within the building, justifies a focus on long term performance.

Questions such as - How building components will be replaced in the building during its useful life? How can the building accommodate change? How will it be dismantled at the end of its life to maximise the usefulness of the components and materials? And how is building management affected by these issues? - are beginning to be considered by designers.

In today's world there is a pressure on architects from clients and media to produce iconic or "wow" buildings leading "*to a tension between the need to design rationally and the ambition to produce large scale sculpture"* (Derbyshire). But architectural design with its wide ranging social, environmental and technical implications is not simple. It must combine rational thought with intuitive/emotional creative ideas. The need for greater consideration of the effects of time in the design of buildings seems self evident, yet considerable barriers exist. These include the following categories:

- Clients focus on current needs and often are unwilling to invest in what they consider as the unknown.
- The mindset of *faster and cheaper* rather than *slower and better* thinking.
- The division of the functions of the delivery/construction team and the management/maintenance team which discourage long term thinking.
- Standard practice in the building procurement process does not recognise the concept of continual improvement.

- Lack of R&D focus of the industry.
- Split incentives - fragmentation of the industry with each actor having different incentives and goals.
- Uncertainty about what future needs will be, which leads to scepticism and a resistance to invest in techniques that may not provide a return.
- Knowledge management systems tended to be poor for most of the construction industry so information stays on the shelf and never gets used.

The premise of this paper is that breaking the barrier between building construction and building operation, and extending designer involvement into the building operation phase and user involvement into the design phase, is important to a greater consideration of change in buildings over time. The initiatives described in this paper are part of an overall culture of continual learning that is needed in design consultancies, contractors, building owners and in the construction industry as a whole. They are all related and could together be a catalyst for a culture which considers buildings over longer time periods and fosters continuous improvement. In this age when we need to address issues of sustainability and make our buildings durable and extend their life, we need to remember the importance of user perception in the process of achieving a successful building. As Japanese architect Shigeru Ban suggests, "*permanence is not a matter of the materials you use, permanence is whether people love your building" (McQuaid)*.

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