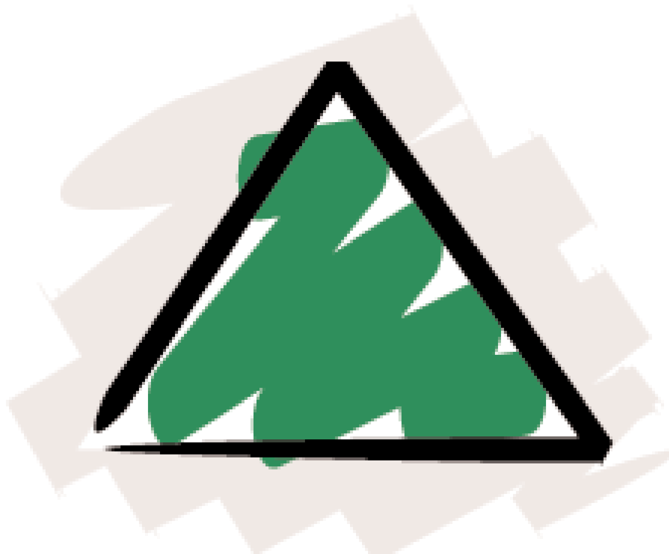
ASSESSING BUILDINGS FOR ADAPTABILITY



Annex 31

Energy-Related Environmental Impact of Buildings

International Energy Agency

Energy Conservation in Buildings and Community Systems Programme

ANNEX 31

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CONTENTS

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EVALUATING THE ADAPTABILITY OF BUILDINGS

What is Adaptability?

Adaptability refers to the capacity of buildings to accommodate substantial change. Over the course of a building's lifetime, change is inevitable, both in the social, economic and physical surroundings, and in the needs and expectations of occupants. All other things being equal, a building that is more adaptable will be utilized more efficiently, and stay in service longer, because it can respond to changes at a lower cost. A longer and more efficient service life for the building may, in turn, translate into improved environmental performance over the lifecycle.

The concept of adaptability can be broken down into a number of simple strategies that are familiar to most designers:

- **Flexibility,** or enabling minor shifts in space planning;
- **Convertibility,** or allowing for changes in use within the building; and
- **Expandability,** (alternatively shrinkability) or facilitating additions to the quantity of space in a building.

In practice these strategies can be achieved through changes in design, and through the use of alternative materials and technologies.

Adaptability is closely related to – but different from – two other design strategies that attempt to enhance long-term environmental performance:

- Durability: selecting materials, assemblies and systems that require less maintenance, repair and replacement. Since durability extends the useful lifetime of materials and technology in a building, it is complimentary to adaptability.
- Design for Disassembly: making it easier to take products and assemblies apart so that their constituent elements can more easily be reused or recycled. Designing for disassembly can reduce the costs and environmental impact associated with adapting buildings to new uses. It is also possible to reduce overall environmental costs by purposely designing a building for a shorter life, and for easier disassembly and reuse of components and materials – as is the case with many temporary exhibition halls.

Why is Adaptability Relevant?

As the world faces resource scarcities and ecological crises, a concern for the adaptability of buildings is especially relevant. The existing building stock represents the largest financial, physical and cultural asset in the industrialized world. A sustainable society is not possible until this key resource can be managed sustainably.

Urban areas everywhere are experiencing problems related to poor use of buildings, and high flows of energy and materials through the building stock. Demolition rates are rising, and due to the artificially low costs of landfill disposal and incineration, much of the solid waste is not being recycled. The average age of a building in Tokyo is now 17 years. In Germany, of the 60% of buildings that survived WW2, only 15% remain standing today.

Kohler[1] summarizes a number of trends found in the German building stock, which also speak to the increased relevance of adaptable stocks:

- New construction levels steadily decreasing;
- Refurbishment activities surpassing new construction;
- Large numbers of old buildings (warehouses, industry) sitting empty;
- Growing numbers of new, highly-equipped office buildings, for lease (resulting from over production and corporate downsizing and outsourcing);
- Flows of basic materials into the stock –for new construction and renovation – exceeding the solid waste flows by 4 to 10 times, (which indicates that the building sector is still a major consumer of natural resources).

While these specific trends may not yet apply to all other countries, the conclusion is clear and universal: increasingly buildings need to be designed for long-term adaptability.

Is Adaptability a Characteristic That Can be Evaluated?

If adaptability is to be a useful design concept, it must be possible to properly distinguish those features of new buildings that will significantly increase their capacity for change. This is difficult. Part of the problem is that few buildings exist today that have been intentionally designed for adaptability, and put to the test of time. Traditionally many designers and owners have preferred to work from the assumption that their buildings will never experience significant change. But even when the inevitability of change is fully appreciated, the marketplace offers little incentive for developers and owners to invest in long-term adaptability. The initial developer who invests in a more adaptable building structure is unlikely to ever realize the economic benefits. For these reasons there are few older buildings purposefully designed for adaptability, and thus little evidence that adaptability is an effective design principle for improving environmental performance.

A more fundamental obstacle is the difficulty in accurately predicting future requirements for buildings. While it is definitely possible to identify features of existing buildings that have enhanced their capacity to adapt, it is in no way certain that such features will function similarly in the future. The type of changes that will occur in the 21st century may be wholly unlike what has occurred in the past. The computer revolution has only just begun, the nature of work is changing, and even the climate is changing. We are almost certain to experience major environmental disasters and large movements of peoples. Even the pace of change may be significantly greater in the next few decades. In truth, the future is largely unknowable when forecasting over the 50+ year life of buildings.

Consider for example a designer from 35 years ago, who may have tried to make a new, 1960s building intrinsically more adaptable. Would the designer have had the foresight to facilitate such changes as removal of asbestos insulation from all the pipes and ducts? Extra ventilation for computer rooms? Larger window areas? Increased plug loads? Installation of natural gas, district heating pipes, or PV panels? Relocating the fresh air intakes to avoid toxic street pollution? Much higher occupancies? Greater expectations for comfort and environmental control?

Probably none of these changes were predictable. In fact long-term forecasts are notoriously inaccurate. This high degree of uncertainty undermines the present value of any potential benefits from adaptable building designs.

In some cases it is likely that changes in function will be so great as to redefine the concept of building. For example the office of the future: does it exist and in what form? The hospital of the future: is it only a throughput place for patients? Bold new concepts in servicing will demand new kinds of buildings.

How might adaptability benefit environmental performance?

Unless a building is capable of responding to changing circumstances it is vulnerable to becoming poorly utilized, prematurely obsolete and unable to accommodate new, more efficient technologies. The combined impact of such failures may be to increase resource use within the building sector by 20 to 30%. Depending upon the additional investment required to achieve adaptable designs and materials, it should be possible to significantly improve the environmental performance of the world's buildings in at least three ways, as outlined below.

1. More efficient use of space - Adaptable buildings are likely to use the same amount of space and materials more efficiently, on average, over their entire life. For example, increased flexibility of spaces might mean that it is easy for occupants to use floor area more effectively as their needs change, or as their business (or family) expands. Convertibility may allow basements, attics, hallways, storage areas, roofs and entrances to be used for other purposes, as new needs arise. Expandability may allow the building to accommodate much higher densities with the same footprint and infrastructure. If such adaptations create even small improvements in space utilization over the lifecycle of buildings, the impact on resource use can still be significant. For example, if the average lifetime space utilization is 10% improved, and all buildings are similarly designed for adaptability, then the world needs 10% fewer buildings.

2. Increased Longevity - Adaptability is also a strategy for extending the total lifetime of buildings. Most buildings are destroyed due to technological obsolesce, not structural deterioration. Adaptability can therefore extend lifetimes without imposing any of the significant environmental impacts associated with all the one-time investments in the building structure and infrastructure. Consider, for example, the embodied energy in reinforced concrete – probably the single greatest pollutant source in a typical commercial building. Or consider the other long lasting elements of a building like wood, metal, glass and landscaping materials. Or consider the energy used in construction, demolition, and haulage and disposal of earth, materials and waste. If adaptable designs can extend the average lifetime of buildings by 10%, (and possibly much more), then we can similarly reduce the total world investment in replacing these long-lasting elements of the building stock. The most environmentally benign building is the one that does not have to be built.

3. Improved Operating Performance - Adaptability can also mean easier change-overs as new technology becomes available. Thus adaptable buildings benefit from technological innovation sooner and at lower cost. The average efficiency of many technologies used in buildings – like lighting and ventilation systems - has more than doubled over the past 10 years. Many other technologies, like combustion heating systems and electrical motors, have improved at least 20%. If a building has features that allow easier adoption of new, efficient technology, it is reasonable to assume an increase in average lifetime operating efficiency of 10% or more. This in turn would reduce the total environmental impact of operating the world's buildings by 10% – a very significant improvement.

Estimating Impact on Environmental Loadings

There appears to have been no effort yet made to directly link adaptability with environmental loading. Generally it is assumed that the improved use of space, and longevity, translate into a proportional improvement in all the environmental loadings associated with building operation and material use and disposal.

A paper by Larsson[1] examines adaptable office buildings, and assumes that the environmental benefits are largely related to two factors: the annualized reduction in embodied and replacement energy, and the annualized reduction in solid waste generation from renovation and demolition. Using data from research studies that document the quantities of embodied energy and demolition energy used by office buildings[2 3], Larsson estimates an equivalent reduction in two categories of environmental loadings:

- ~15% reduction in air emissions, and
- ~15% reduction in demolition solid waste.

No estimate was made of the potential impacts of using office space more efficiently.

Can Building Stocks Also be Evaluated for Adaptability?

If a building stock is made up of buildings that are individually more adaptable, it is reasonable to conclude that the entire stock is also more adaptable to change. For example, if a community experiences a sudden growth in population, the expandability and convertibility of existing buildings may contribute to relieving housing shortages at lower cost, more rapidly, and with less damage to the community character and urban fabric. Given the strong current trend towards mixed building uses and higher densities in urban planning, it is likely that the convertibility and expandability of individual buildings will help older neighbourhoods modernize and adjust to new urban growth patterns, with less social and economic disruption.

It may also be possible to purposefully design infrastructure, and select building types, in ways that make the entire stock more adaptable. Some examples include:

1. **Connecting all buildings to a district heating and cooling system.** A district-wide system makes it easier for the entire stock to quickly switch fuels, install pollution control equipment, and upgrade to more efficient technology. Changes to a single piece of equipment can instantly adapt the network of buildings to changing circumstances.

[1] Larsson, Nils K., Sustainable Dvelopment and Open Building, Presentation to CIB TG26, Brighton UK, 1999,
[2] Environmental Research Group, School of Architecture, UBC, Life-Cycle Energy Use in Office Buildings, 1994
[3] M. Gordon Engineering, Demolition Energy Analysis of Office Building Structural Systems, 1997

2. **Creating an appropriate level of diversity among buildings, in terms of materials, components and designs.** It is easier for a stock of buildings to adopt new designs and technologies if a modicum of local expertise and acceptance already exists. From this perspective, it may be desirable to include in the stock at least a small percentage of buildings with alternate energy systems, or innovative envelope designs, even if these are currently not the most cost effective and environmentally appropriate.
3. **Design buildings with more on-site, distributed infrastructure components.** Smaller scale, distributed infrastructure may be less vulnerable to environmental changes or social transformations. It may also be more amenable to incremental growth and thus to introduction of innovative technologies and policies. For example, locating primary sewage treatment, and storm water management systems, on the building site or block, can eliminate the need for large scale and expensive pipes, pumps and centralized facilities that are much more resistant to change. This may be at odds with item 1 above.

The difficulty with enhancing stock adaptability in these ways is the need to coordinate many players, including many building design teams, land use planners and civil engineers. It is also difficult to convince private developers to voluntarily incur additional cost for improving performance of the stock, if everyone shares the benefits equally. For these reasons the most effective approach to achieving more adaptable stocks may be to create guidelines for use by building design teams. The guidelines can be created to optimize performance at a neighborhood scale, or at the scale of an urban development project. Evaluation procedures for rating adaptability of buildings could then include any criteria established by such "stock" guidelines.

Ideally the concept of adaptable design needs to be closely connected to the developer's profitability. It should translate into faster sales, higher occupancy rates, and reduced refurbishment costs. If developers can be thoroughly convinced of such benefits, they will participate enthusiastically and add their creativity to the design concept.

Other types of regional policies may be necessary to maximize the adaptability and usefulness of the existing building stock. Often buildings stand empty, or deteriorate, due to mismatches in zoning and land rent, or costly regulations for upgrading buildings and parking, prior to adaptive re-use. It is possible that the greatest single improvement towards adaptable buildings is removal of the institutional obstacles that prevent affordable transformations of the stock, and that prevent partial, low-intensity, temporary uses for unoccupied buildings.

How Can the Costs be Justified?

The high degree of uncertainty about the next 50 years makes any investment in adaptability less valuable, regardless of intentions. For this reason the concept of adaptable design may be largely restricted to:

- accommodating changes that are expected to occur in the very near future,
- applying simple 'common-sense' principles that are known to facilitate a wide range of possible changes.

- incorporating 'adaptability' features that can be justified for other reasons; or
- adopting features that enhance adaptability with little or no additional capital and resource investment.

In cases where a significant investment is required primarily for the purpose of enhancing adaptability, the potential advantages must be carefully weighed against the added materials, construction and maintenance costs.

Consider for example a design strategy that enhances adaptability by providing higher floor-to-ceiling heights. Such a feature provides many more possibilities for alternative space use, and for convenient routing of new services through dropped ceilings and floors. However if the building is 10 storeys in height, and each storey has been extended by one meter, the overall height will increase by 10 meters, with a resulting 40% increase in costs for structure, services and finishes. Thus a major cost is incurred for purposes of enhancing adaptability, without much certainty of returns.

The risk of investing in such design modifications can cut both directions. Should changes occur in the marketplace demand for buildings, higher ceilings might make the difference. It may allow conversion, and avoid the major expense of demolition and new construction. For example, studies in hospital buildings have shown that the capitalized costs of alterations over a typical ten year period equaled the original capital cost for the entire building; - a very convincing case for adaptable buildings that can change at much lower cost.

Ideally the costs of incorporating adaptability should be significantly less than the avoided costs of traditional alterations in a less adaptable building. If so, the cost savings can be balanced against the uncertainty of when and what alterations will be required. Unfortunately, such benefit/cost planning is uncommon and difficult.

In today's marketplace, the adaptability of a building will typically be subordinated to the short-term needs for maximizing return from capital expenditures, and for satisfying the functional and comfort needs of occupants. Two kinds of changes may occur that may influence adaptability. Incentives can be incorporated into new public policy directed at sustainable urban development. Or businesses can commit to the basic principles of sustainability[4], and adjust their behavior accordingly.

If adaptability is embraced in public or private policy, it may be necessary to relate adaptability to basic principles of sustainable development, such as stewardship and intergenerational equity. From this perspective, the responsibility of the designer or developer is to meet the client's needs and expectations without compromising those of future building owners and users.
A design team that is committed to sustainable, environmentally-sound building needs to take the extra effort to identify opportunities for enhancing adaptability, and to estimate the related cost and environmental advantages.

[4] Principles of Sustainability are outlined in Our Common Future by the Brundtland Commission. Two references especially relevant to the building industry are The Natural Step, and the Hannover Principles.

Key Principles of Adaptability

The first step in evaluating the adaptability of a building is simply to determine whether or not a conscious effort has been made to address Key Principles of adaptability. Key Principles are design strategies that apply to all elements of a building. These principles have been described in a survey[5] of the literature prepared by CMHC and Natural Resources Canada.

Table 1 provides a quick summary of each Key Principle.

Independence	• Integrate systems (or layers) within a building in ways that allow parts to be removed or upgraded without affecting the performance of connected systems.
Upgradability	• Choose systems and components that anticipate and can accommodate potential increased performance requirements.
Lifetime compatibility	• Do not encapsulate, or strongly interconnect short lifetime components with those having longer life times. It also may be advantageous to maximize durability of materials in locations where long lifetimes are required, like structural elements and the cladding. Durable claddings and foundations can greatly facilitate adaptability, often tipping the scale in favour of conversion over demolition.
Record Keeping	• Ensure that information on the building components and systems is available and explicit for future use. It will assist effective decision-making with regard to conversion options and prevent costly probing exercises.

Table 1 *Key Principles of Adaptability*

Independence and the Open Building Concept

By far the most important Key Principle for enhancing adaptability appears to be the independence of building elements. The more each feature is uncoupled from the others, the more adaptable a building becomes. It is especially important to uncouple those layers of a building that have significantly different lifetimes. According to Francis Duffy, co-founder of a British firm that specialised in advance office designs, a building over its lifetime changes not as a single entity, but rather as four separate layers: Shell, Services, Scenery and Set. Each layer has a unique time period for repair and replacement. Table 2 describes the differences.

Layers	Elements	Average Life time
1. Shell	• Structure of building, including skin if load-bearing	>50 years
2. Services	• Pipes, ducts, cables, machinery, elevators, escalators	~15 years
3. Scenery	• Partitioning, ceiling, finishes	~ 6 years
4. Set	• Furnishings, furniture, computers	monthly

Table 2 *Layers to be keep Independent within a Building*

[5] CMHC and CANMET, Building Adaptability: A Survey of Systems and Components, May 1997.

Of course uncoupling layers of building for enhanced adaptability must not interfere with the integration of systems and materials at a functional level, in terms of controlling heat, air, moisture, light, and sound. If a design team subscribes to *building-as-a-system* principles, each part and system of a building will be carefully designed to contribute in a unified manner to the overall performance of a building. The challenge is to achieve functional interdependence, without loosing the independent features that enhance adaptability such as redundancy, robustness, and ease of access, repair and replacement.

The "Open Building" Concept

Among the first to formally recognize the importance of independence in design was N.J.Habraken[6] of the Netherlands who espoused the advantages of the "Open Building" concept. Implied in this term is the notion of uncomplicated structures that lend themselves to flexibility and change of use in the course of time. Most Open Building design has concentrated on flexibility within a single use category, although it can also apply to convertibility. A key feature of Open Buildings is the separation of 'fit-out' from structure, skin and services. Fit-out refers to all the componentry and elements that contribute to a particular use of a building, but are not needed for the basic functioning of a building. The better the separation of fit-out, the more adaptable the building.

Open Building is the subject of an international research association (CIB Task Group on Open Buildings W- 26 Chaired by Stephen Kendall[7]). The Chairperson of the committee describes Open Buildings as ones that *distinguish between building part, which can have a long life, and those parts that can change more quickly, and organizes the building process accordingly.* He further suggests that *this is perhaps the most fertile, wide-reaching basis for advancement in sustainable architecture*.

What Features of Buildings Contribute to Convertibility?

Commercial to Residential Conversions

Canada Mortgage and Housing Corporation (CMHC) initiated a study[8] of 10 commercial buildings that had been converted to residential property as part of private market activity. A number of features were shared by all the buildings, as shown in Table 3, and thus appear to facilitate convertibility. Not surprisingly a number of these features reinforce the Key Principles described earlier.

[6] N.J.Habraken , Open Building Approach: Examples and Principes, A Paper for the Housing Seminar Taipei, ROC 1994
[7] CIB Program Committee, Proposal for the Formation of a Working Commission on Open Building, Correspondence Dec, 1996
[8] CMHC housing conversion Study

1.	**Durability**	• Repair, maintenance and replacement periods, especially for the structure and shell
2.	**Versatility**	• The shape of the space lends itself to alternative use.
3.	**Access to services**	• Dropped ceilings, raised floors, central cores that provide easy access to pipes, ducts, wires and equipment
4.	**Redundancy**	• Structural elements can bear larger loads than were originally imposed.
5.	**Simplicity**	• The absence of complex systems vital for the continued operation of the building.
6.	**Upgradability**	• Systems and components that accommodate increased performance.
7.	**Independence**	• Features that permit removal or upgrade without affecting the performance of connected systems.
8.	**Building Information**	• Records of drawings, specifications and design limits that assist in future economic analysis of renovation and expansion.

Table 3 *Features of buildings that have undergone conversion in usage*

Residential to Office Conversions

Conversion of Residential buildings to commercial uses is uncommon due to the rigidity of apartment layouts and structures – especially apartment buildings constructed over the past 40 years. Conversion to apartment-hotels is probably the most common type. Conversion to office use, or retail, is much more difficult. Larsson[2] has described a general-purpose building type that could more easily convert from residential to commercial use.

In the North American context, the changes in design to apartment buildings that would be required would include:

- Floor plate increased from typical 21 m to about 25m;
- Structural bay spacing set at about 9 or 10m;
- Floor to floor height increased from about 2.9m to about 3.35m; and
- Strategic placement of core and vertical services.

Are There Trade-offs Between Adaptability and Quality?

It may be necessary to explicitly recognize the possibility of trading-off adaptable building designs for improvements in overall quality of design and construction. Aesthetically pleasing, long-lasting buildings can be so enjoyable that people will adapt their needs to the existing form of the building, rather than renovate or demolish the structure. This extends building life and improves the use of space in a similar manner to adaptable designs. It means that adaptability in design may be of greatest importance for those buildings that lack high quality design and construction features.

The impact of quality on longevity of buildings has been explored by Stewart Brand in his book *How Buildings Learn*[9]. Brand divides buildings that learn (namely those that survive changing circumstances abnormally well), into what he describes as low road and high road buildings. About the former he says, "nobody cares what you do in there" or in other words the building is so devoid of aesthetic value that building owners and users have no regrets about altering the building to fit any new purpose. Such buildings are akin to the cat with nine lives, and may live on forever if they possess adaptable structures with such features as high ceilings and large structural spans. On the other hand 'high road' buildings are those that because of their fine features deserve and receive unusual care and attention. Often these features include durable and beautiful cladding, unique and handcrafted detailing, high quality interior finishes operable windows, numerous private well-lit rooms, and so on. Such buildings may go through major changes in use, despite their relatively low capacity to physically adapt to change.

Trade-offs between adaptability and quality may be especially problematic with design of interior finishes and furnishings. Over the lifetime of a building, the cost of interior finishes may exceed by several times the entire cost of all other elements of a building. While the potential for reductions in costs, embodied energy and emissions is great, it is not clear that more adaptable spaces will actually reduce investments in office fit-out. In fact flexible spaces may encourage re-fitting of offices for reasons of fashion, and thereby contribute to increased lifetime costs and environmental loadings.

Even if flexible spaces do not encourage changes, it is difficult to know if they will continue to serve adaptations over many decades. In the long-term, the changes to finishes and furnishings - partitions, equipment, and workstations – can be highly unpredictable. A better investment might be to enhance the social and cultural environment within the building, since beautiful design features do tend to have long lifetimes.

Methods and Tools for Achieving Flexibility and Adaptability

Flexis

Two Dutch research institutes[10] jointly commissioned a study to investigate ways of curing the premature obsolescence of aging office buildings. The research concluded that the increasing changes in user demands require buildings and installations to be flexible enough to cope in both new construction and adaptive re-use projects.

From the Dutch research comes a tool called Flexis. It is a method of communication that allows the project team to formulate the flexibility demand, and to address the flexibility supply. Flexis uses a kind of scorecard called an assessment form to judge the flexibility of an installation. Flexibility is broken down into four subcategories: partitionability, adaptability, extendibility and multi-functionality. Each of these has its own group of issues that are numerically

[9] Brand Stewart, How Buildings Learn: What Happens After They're Built(1994), Viking ISBN 0-670-83515-3

[10] The Dutch Building Research Foundation (SBR), and the Dutch Institute for the Study and Stimulation of Research in the Field of Installations (ISSO)

rated, weighted and totalled. The end result is a designation of the installation from Class 1: *not flexible*, to Class 5: *highly flexible*. The four attributes of flexibility can be graphically displayed using a diamond-shaped graph.

Flexis breaks down a building into four levels of installations, and divides the spatial levels within a building into local and central. In this way it is possible to examine and rate the performance of a building at various scales.

Evaluating Elements of Buildings for Inherent Adaptability

It is possible to rate each element of a building in terms of its inherent adaptability, or number of specific features included in the design of the element. Such features may be identified through surveys of buildings that have adapted well to changes. Or common sense can be used to identify features that are likely to work well in typical change scenarios.

Adaptability of buildings should increase in proportion to the number of such features that are incorporated into the design. A number of design strategies and features have been identified for each element of a building, and are outlined in Table 4.

When evaluating elements of buildings it is important to recognize that major tradeoffs can exist when designing elements of a building, and that neither strategy may be inherently more adaptable. Consider for example, the scale and location of HVAC systems. A centralized system can facilitate some types of changes like upgrades and conversions. A distributed system, on the other hand, may facilitate changes in primary use within a building, or the expandability of the building. Ideally a designer should strive for a hybrid system that captures the benefits of both centralized and distributed systems.

Another area with major tradeoffs is the evaluation of complex, integrated systems in buildings. Complexity and integration are commonly employed by natural ecosystems as means for increasing the efficiency and sustainability of plant and animal communities. At the same time functional interdependence of elements can create obstacles to adaptation over specific time periods, since everything depends on everything else.

Ideally indicators should be used to provide a specific, standardized method for rating inherent adaptability, in terms that can be measured and monitored. For example, a possible indicator for adaptable foundations might be:

- *Potential for vertical expansion with or without alterations to foundation (in storeys).*

The lack of specific indicators of this type makes it difficult to create benchmarks for comparison purposes, to establish trends within the stock, and to set appropriate targets for each type of building.

Foundation

- Design to allow for potential vertical expansion of the building. A rational analysis should be done to arrive at a reasonable estimate for possible future expansion.
- Install isolation joints or other features that avoid the potential for differential settlements and for progressive collapse due to accidental loading.

Superstructure

- Give preference to use of reinforced concrete, since it enables the shifting of internal and external elements without affecting the building's structural integrity
- Rely on a central core for lateral load resistance. This allows local modifications to the structure while maintaining complete structural integrity.
- Use a wide structural grid upward of 6m. The slight redundancy in structural strength that a wide grid introduces will increase adaptability considerably.
- Design the lower three floors for 4.8-kPa live load. This increased capacity will enable the building to easily accommodate all of the likely conversions with no structural modification.
- Add sufficient height to the lower floor to enable a range of other uses
- Choose a structural floor system that accommodates a number of mechanical and electrical service distribution schemes based on different occupancies.

Envelope

- Make the building envelope independent of the structure. They should be functionally discrete systems, with the interfaces designed for separation.
- Provide means for access to the exterior wall system from inside the building and from outside.
- Design a versatile envelope capable of accommodating changes to the interior space plan; (e.g. a modular or panellised system where transparent and opaque units can be interchanged for example).

Services

- Give preference where possible to using hybrid HVAC systems, with a balance between centralised components and distributed components. The hybrid should be designed to provide the flexibility of changing the central system fuel and capacity, while allowing for easy upgrading of localised conditioning units and distribution network.

Interior Spaces

- Design spaces for a loose fit rather than tight fit.
- Include multifunctional spaces.
- Install interior partitions that are demountable, reusable and recyclable.
- Provide more than the minimum spatial areas and floor heights.
- Use adaptable floor plans, including large grids that can be subdivided.

Table 4 *Strategies for Inherent Adaptability*