Technological Adaptability, an Approach Toward A Flexible and Sustainable Architecture

Faiza Nakib,
PhD student, ‘City, Urban Design and Sustainable Development’ research laboratory VUDD, Algiers
Faiza.nakib@yahoo.com

Abstract

Technological progress is an endless accelerating phenomenon. It becomes a major aspect of our wellbeing and influences our everyday life as well as our use of architectural spaces. Buildings must always embrace technological innovations and follow the pace of their evolution, while absorbing the impact of change. This objective can be achieved by maintaining the building quality, entailing a minimum disruption of the ongoing activities, and lowering expenses as well as energy and materials consumption.

The need for technological evolution emanates from users’ needs but also from the surrounding socio-cultural and demographic change, market demands, climate variability, regulations, and aesthetic tendencies. In this context, technological adaptability is crucial to support the building sustainability by ensuring users’ well being and safety (comfort, life quality, positive interaction….), long term value of the building (longevity, cost effectiveness, strong image, etc.) and functional efficiency (multi-functionality, Efficient physical and virtual connections, etc.).

The present paper aims to define strategies as well as a set of guidelines that might help to integrate progressive technological features in the building systems. In this perspective, some approaches dealing with architectural adaptability are studied, and a set of guidelines for technological adaptability are drawn from their combination. The adopted methodology takes into account complexity and uncertainty of the building and considers the interrelation of economical, social, spatial, functional and technical aspects. These guidelines constitute a systemic approach and should be considered as a whole to achieve the intended goal.

1. Introduction: Relevance of technological adaptability

Nowadays, advancements in technology provide us with new opportunities and solutions, which were inconceivable not long ago. It is hard to predict what will be the ultimate effect of future technology on our lives and surroundings. This never-ending progress does and will influence continuously our lifestyles and consequently, our use of architectural space.

In order to make the best use of existing technology and support future innovations while sustaining to the subsequent change , extending the building life-time and maintaining environmental quality; buildings must be able to adapt and adjust with minimum disruption of the ongoing activities, low cost, and low energy and materials consumption.

Advanced technologies come to the forefront in a variety of architecture and building fields such as air quality control (ventilation, moisture and humidity, filtration, etc.), thermal comfort (cooling, heating), acoustic absorption, natural lighting and artificial (Conventional, optical fiber, Light-Emitting Diodes 'LED'), security devices (fire and smoke detection, alarm, access and surveillance), connectivity and IT (data, voice, audio-video, home automation and wireless control, Liquid crystal display 'LCD', Organic Light-Emitting Diodes 'OLED'), renewable energy (solar and photovoltaic, wind), building envelop (materials, insulation, fenestration, shading, etc.), furnishing, appliances, etc.

Obviously, technology deals with the building through two different but complementary sides: it influences our lifestyle and the way we use architectural space and implies modifications and adaptations in one hand; while helping to withstand subsequent changes on the other hand.

The present paper aims to define approaches as well as a set of guidelines that might help to integrate progressive technological features in building systems in general.

2. Needs for technological adaptability

The pressure for change comes principally from the building users but also from the environment like as society, new regulations, fashion, etc. (Stewart 1998). Therefore, the building has to adapt continuously its technological systems according to different changing conditions. It is not only a need for modular standards and normalization, like as for the modular systems during the last century, but a new systemic approach of the complexity of building needs, as explained by the following scheme, (Fig.1):

▪Evolving needs and lifestyle change due to technological and socio-cultural progress or change of owners/users leading to:

- Change of space function
- Space reconfiguration and rearrangement
- Introduction of new elements and products.
- Increase in the number of users (larger family structure, more employee, etc.)
- Evolution of the building and increase or decrease of its size (extension, shrinkage, splitting)
- Reassignment of building use (Change of real estate market demand).
- Limited lifespan of components (aging, operational difficulty or failure). Thus, a need of maintenance, replacement or renovation to increase the total building life-cycle.
- Climate variability and change.
- Search of a better environmental quality and energy management.
- Pursuit of fashion and new aesthetic trends.
- Laws and regulation changes (introduction of new standards for existing facilities).
- Others.

Figure (1): Needs of Technological Adaptability,
(F. Nakib©)

3. Aims of technological adaptability

The building field is becoming one of the most important and advanced industries in the world. Smart solutions are increasingly integrated in architecture, involving a leading-edge-technology with an aim to preserve, yet enhance the environmental quality.

In this context, technological adaptability plays a major role to improve the building sustainable attributes (Greden, 2005). The latter can be classified into three main interrelated systems as follows, Fig. (2):

3.1. Users' well being and safety

- Comfort.
- Health.
- Safety.
- Indoor environmental quality.
- Life quality.
- Interactivity with the building and other users.

3.2. Building long term value

- Longevity and viability
- Upgraded image.
- Up to date components with low cost.
- Fit for different uses and users (residential, commercial, offices, cultural, etc.) to suit market demands.
- Cost effectiveness.
- Fit into and add to the environment by:
- Preserved connection with buildings' surroundings (other buildings, neighborhood)
- Harmless, yet Positive impact of the building on the environment.
- Energy efficiency

3.3. Functional efficiency

- Flexibility, Multi-functional and trans-functional spaces.
- Efficient physical and virtual connections

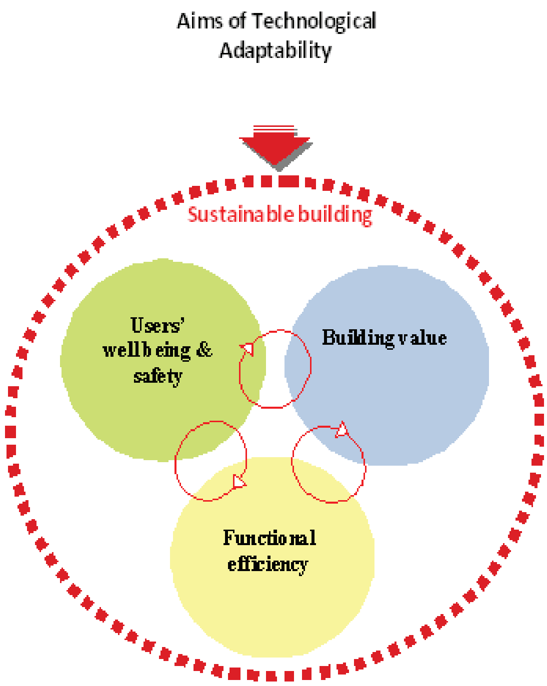

Figure (2): Aims of Technological Adaptability, (F. Nakib©)

4. Approaches to improve technological adaptability

In fact, two major trends emerge actually in the architectural field, according to recent researches.

> «*If one method of achieving adaptability in buildings is through a consideration of use through design in plan, another is through the deployment of technology…(In some schemes), it is the chosen technology rather than the specifics of the plan that is the seen as the primary means of achieving adaptability*» (Till and Schneider, 2005)

In this quote, the authors enumerate two different methods to approach adaptability in the building: functional (by consideration of use through design in plan) and technical, referred in the quote by technological and which encompasses technical aspects such as issues of construction, structure and servicing (Till and Schneider, 2005). The former authors criticize the Cartesian approach that considers only the technical aspect to achieve adaptability in the building and stress the complementarity of functional and technical approaches (Till and Schneider, 2005).

Since the Building is a highly complex structure (Beisi, 2005), it is important to highlight that technological adaptability has to be considered as a combination of spatial, functional, social, technical and financial aspects.

A lack of consideration of one of these aspects may hamper the technological adaptability of the building. The combination of the former aspects can be exemplified by internet connectivity for instance; introduction of this new technology at homes at that time, implied social impact (lifestyle change, virtual communication), functional modifications and financial aspect (a portion of space that had earlier been used for domestic purposes has been converted to business activities: home office, (Friedman, 2002)) and technical adjustments (wiring, networking, accessibility, lighting)

Some researchers helped to formulate methodologies and guidelines to integrate all these aspects in the design and construction of buildings. These methodologies are rooted in the hierarchical principle, and based principally on Habraken (1998) and Brand (1994) works. Although, the most of these methodologies are experimented principally in housing and commercial office buildings, many of the formulated guidelines can be projected on other types of building. The most representative among these approaches, are:

4.1. Open building

This approach is rallied under the Working Commission W-104 of the International Council for Research and Innovation in Building and Construction (CIB). The fundamental principles of Open Building approach are based on the fact that the building is a complex system of which the different subsystems change part by part according to different rhythms and lifecycles (layering and lifespan concepts) and not as a whole entity (Cuperus, 2001). 'Open building' subdivides the building into two main layers:

- The shell/base building: including the building's primary structure; the building envelope; public circulation (lobbies, corridors, elevators and public stairs); and primary mechanical and supply systems (electricity, heating and air conditioning, telephone, water supply, drainage, gas)

- The infill/fit-out which refers to the total configuration of physical parts within the base building.

Furthermore, design decisions and responsibilities are distributed among different parties; no one person or firm or client is in control of the entire built field, or even a single building. Usually, when one part changes (controlled by a given party), it implicates other parts, controlled by other people, but in the frame of this approach, conflicts in coordination between these parties are minimized as well as possible. Open Building is experimented presently in some countries around the world especially in Netherlands, Japan, Finland, but also in France, Belgium, Germany, China, Canada, etc. (Kendall and Teicher, 1999)

4.2. FlexHousing

Based on the principles of adaptability, accessibility, affordability and healthy housing, this approach developed by CMHC (Canada Mortgage and Housing Corporation) aims to allow residents adapting space to their changing needs with minimum costs. Thus, homeowners are able to occupy a dwelling for longer periods of time. This approach formulates some in-built functional solutions that facilitate future adaptations (possibility of dividing a large bedroom into two smaller ones, converting an existing bedroom into a home office, converting an attic into a large family room or master bedroom, and adapt a basement to become a rental suite, etc) as well as technological ones (flexible servicing system and energy efficiency). For more details about 'FlexHousing', see the official website <http://www.cmhc-schl.gc.ca/en/co/buho/flho/index.cfm>.

The adaptable house developed by Avi Friedman in 2002, is based on the FlexHousing concept. Similar concepts are referred to, as Universal Housing in the United States, Lifetime Homes in the United Kingdom, Lifespan Homes in Norway, Aged housing in Japan and Adaptable Homes in Austria, (Starr, 2005).

4.3. Ruimtelab

The Ruimtelab is a research laboratory in Netherlands supervised by René Heijne and Jacques Vink. This laboratory carries out researches commissioned by the government about architectural flexibility. As the other approaches enumerated herein, the Ruimtelab considers the building as a non completed architectural product; a continually changing object, able to accept different infills and allows its users to easily adapt their surroundings. It requires designers who are willing to let go of their design, (Hinte and Neelen, 2003)

4.4. Adaptable futures

This research project, funded by the 'Engineering and Physical Sciences Research Council (EPSRC) through Loughborough's Innovative Manufacturing & Construction Research Centre (IMCRC) in the UK, is based on the idea that a building should be configured initially for a wide range of scenarios and should be able to change, over its lifecycle, facilitating users' evolving needs. This undergoing research focuses on adaptability, in both initial design choices and subsequent changes in use, of complex, non-domestic buildings with a future application on a wide range of buildings, including: offices, manufacturing facilities, schools, health and mixed use (IMCRC, 2006).

5. Guidelines for technological adaptability

The following guidelines are not extracted exclusively from one specific approach, but rather from the different approaches enumerated before. These guidelines attempt to handle uncertainty and complexity, so they are based on economical, social, spatial, functional and technical dimensions.

One has to keep in mind that every building is unique by its physical structure, function, users and environment. We don't pretend by the following guidelines to provide a recipe that fits for every situation, but a way of thinking and some tools which can be used to make the best use of technology by its integration and adaptation in the building.

5.1. Independence of physical layers

Different parts of a building achieve different functions and have different life-spans (Brand, 1994). Most of the waste arising from construction results not from total demolition of the building, but from incremental processes such as refurbishment, upgrading, fit-out changes, etc. (Morgan and Stevensen, 2005)

Technological adaptability requires a separation of flexible components from inflexible ones, so as to enable change where it is valuable while preserving static elements that constitute the base of the building (Greden, 2005). The building should be divided up to distinct system-based layers according to their expected life-spans and rate of change, Fig. (3). this distinction allows modifying, adding, replacing or removing related technological features of each layer without affecting the structure of the others or the whole. On the contrary, integrating the façade with the main structure of the building implies destruction and waste to introduce new technological features or renovate the façade. Embedded services in the building also inhibit technological adaptability.

According to Hinte and Neleen (2003) who base their research on Brand (1994), the distinct layers should be considered in both design and building hierarchically as the following

▪**Location/ Site:** Geographic/ urban location has generally a very long lifespan.

▪**Structure:** its quality determines the architectural endurance of a building. The structure usually lasts between 30 and 300 years.

▪**Access/ Circulation system:** Stairs, escape routes, escalators and lifts have a long life. Emergency and secondary stairs on the other hand may be replaced more quickly because of changing regulations.

▪**Façade:** If the façade has not been designed to last, it usually has to be replaced or renovated after some 20 years for technological or aesthetic considerations.

▪**Services:** Systems for climate control, wiring, sprinklers, water and sewers are outdated after seven to fifteen years.

▪**Space plan:** In a commercial context it is common practice to renew doors, partitions, elevated floors and lowered ceilings as often as every three years.

▪**Stuff:** Furniture and appliances are replaced quite quickly.

Note: the lifetime conscious thinking concerns also materials and all the buildings' components.

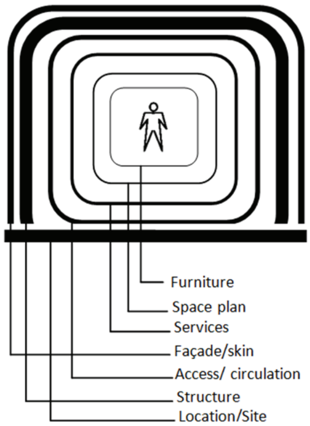

Figure (3): Shearing Layers, (Hinte and Neleen, 2003)

5.2. Independence of decision making levels

Achieving technological adaptability calls for participation of different decision makers (users and professionals), their intervention must be organized hierarchically from the collective to the individual (ex: building inhabitants – floor inhabitants - flat inhabitants- room inhabitants), and from the formal (authority, organism, town planner, architect) to the informal (the users). The clear differentiation between the different decision making levels of the building allows each control agent to better identify his role and his rights of control, therefore to respect its limits. That allows the user to appropriate his space, and adapt it to meet his personal needs, Fig. (4), and as a result to develop awareness, care, responsibility, maintenance and improvement of his place (Cuperus, 2001).

The distinct physical layers of the building also involve different professional specialists (architect, engineer, carpenter, plumber, etc.). The responsibilities should be clearly distributed and differentiated between the professionals in order to reduce dependency and conflict. However, the coordination between them remains necessary. That allows maintaining, modifying or integrating new technologies in one level without affecting the other decision making levels.

The balance between the freedom of users' decision making and formal control assured by the upper levels is crucial for the environmental and socio-cultural coherence and equilibrium of the building becoming thus adaptable and sustainable.

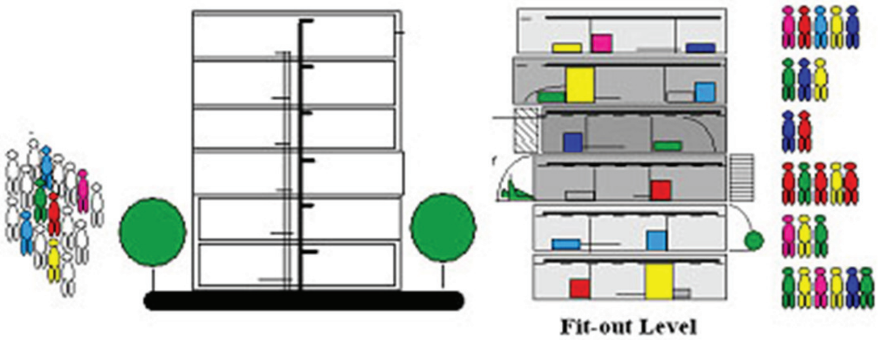

Figure (4): Decision Making Levels in the Building, (Kendall, 1999)

5.3. Spatial/ Functional adaptability

There is an intrinsic relationship between spatial/functional adaptability and technological adaptability; each one involves the other. As mentioned before, one of the needs for technological adaptability is the functional/spatial adaptability (change of function, reconfiguration of the space to adapt it to different uses, etc); multifunctional space for instance requires adaptable lighting system, adjustable HVAC, etc. It is also true that technological adaptability calls for functional or spatial modifications; easy integration of future technologies requires functional and spatial adaptability.

The design of space should be thought on volume rather than plan. Spaces should be oversized rather than closely fit the program. Spatial/ functional adaptability can be achieved with the following, Fig. (5):

5.3.1.Multi-functionality

Multi-functionality refers to physical components of a space, which allow it to be used in different ways and for a set of known functions (Alves, 2005). This depends on dimensions and configuration of the space but also on appropriate technical solutions.

5.3.2.Trans-functionality

Trans-functionality is made of physical components that support the creation of new undetermined and unpredictable functions according to the free users' experience and consumption of the space (Baltazar dos santos, 2007). The design of such a space is 'open in hand' and emphasizes the dynamic of interaction rather than the static feature of space.

5.3.3.Mobility

Mobility refers to the built-in possibilities to move, rearrange, take away, or add elements within an existing main structure. For that, partitions should be demountable, movable, reusable and recyclable (Galfetti, 1997).

5.3.4. Divisibility

Divisibility refers to the possibility of dividing the building into different functional units. This depends on the functional layout of the building, the relationship between units, accessibility to separate units, etc. (Blakstad, 2001).

5.3.5. Elasticity

Refers to the possibility of a building to be extended (or retracted), horizontally or vertically. This depends on available space, the capacity of existing structures and infrastructure and the architectural layout of the building (Blakstad, 2001).

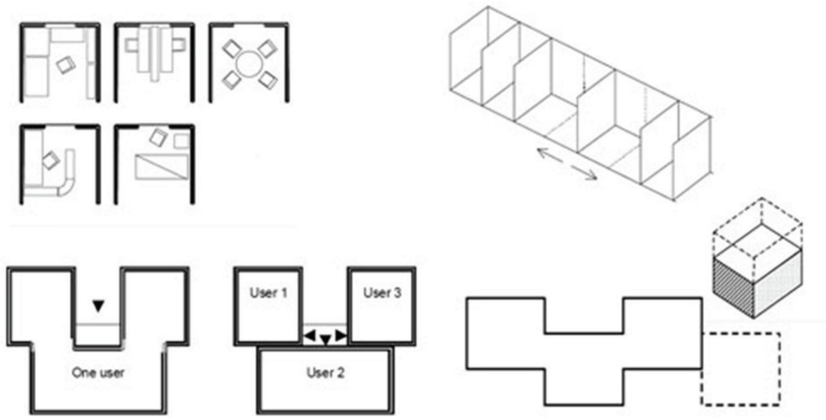

Figure (5): Spatial and Functional Adaptability to Suit Technological Adaptability, (Blakstad, 2001)

5.4. Structural adaptability

The building structure can also contribute in a number of significant ways to achieve the technological adaptability. Thus, the following guidelines should be taken into consideration:

- Design foundations as to allow for potential expansion of the building and extra loads in the future.
- Minimize the number of internal columns and bearing walls which could compromise building adaptability.
- Design support structures to fulfill various long term changes and uses.
- Use dry connections with no male-female connections.
- Make the support structure divisible, enabling future independence of

compartments. Consider in the design, the separation of entrances, stairs and lifts.

- Design generous floor-to-floor height.
- Use a structural floor system that accommodates a variety of technical services distribution schemes based on eventual future changes.
- Use well adapted structural systems to local context, able to resist to major risks.

5.5. Technical adaptability

Technological adaptability cannot be achieved without a suitable adaptation of technical buildings components. Servicing and technical installations are considered as a key factor to adapt buildings (Kronenburg, 2007) and should be designed for longevity, expandability, disassembly, recyclability, maintainability, and energy and material efficiency. Therefore, the following guidelines which are based mainly on the work of Geraedts (2001, 2008), should be respected:

- Avoid embedded ducts and pipes in other buildings' systems (structure, walls, floors or ceiling).
- Ensure an easy access to technical components (pipes, ducts, wires and equipments) by using dropped ceilings, raised floors, central cores, etc.
- Use generous and adaptable plenum systems (either overhead or under-floor) to meet space needs for future HVAC, power, lighting, and fire protection systems change.
- Make a distinction between collective and individual installations.
- Consider the distinction between long and short life cycles.
- Use pluggable connections (plug and play) such that installation components can be easily and safely disconnected, removed or repositioned while limiting the knock-on effect of changes.
- Locate strategically cables and ducts (backbone pathways) and ensure that the location of fixed services' rooms is chosen such that it doesn't compromise different configurations or uses in the future.
- Encourage use of wireless systems (low current, infra-red, etc) as they become commercially viable, to reduce problems related to distribution of cables and ducts.
- Adopt prefabricated and standardized components, and encourage modular coordination (design and construction according to a fixed module) for

easy replacement and recyclability.

- Over-measure energy to accommodate the growing and evolving demands and provide emergency power supply.
- Design installation systems as a dividable system into several independent subsystems, and the interface between them must be reduced as often as possible, making easier to replace one of the subsystems by another one without affecting the system of the upper level nor the wholeness.
- Work out a precise description of different technical elements specifications (location, functioning, etc,) allowing feedback in case of future change.

5.6. Facade adaptability

In order to allow easy interior changes as well as new technologies integration, we should consider the following in the facades design:

- Provide means for access to the envelop system from inside the building and from outside to facilitate maintenance and repair.
- Design sober facades and avoid overabundance of ornaments and extravagance while consider details. That allows easier adaptation to new uses.
- Base the façade design on modular design to allow replacement, updating, integration of new technological features and suit of fashion.
- Choose materials that allow a building to weather beautifully and grow old gracefully.

6. Conclusion:

There is a great reliance on technology to satisfy the evolving needs of users and their environment. However, to serve sustainable development, technology has to preserve, yet enhance the building quality rather than limit it. This balance is possible through the powers of adaptability. The latter is a tool that allows adapting to the unforeseen future changes while optimizing the use of existing technology and supporting future innovations.

This paper has shown that the independence of physical layers allows modifications of specific parts of the building without affecting others, thus facilitates the differentiation of decision makers' roles and their scope of control. Other considerations such as the built-in spatial and functional characteristics, the structure configuration, adaptation of technical components and installations, as well as the façade design are also interrelated key factors for achieving the technological adaptability of the building.

The guidelines defined earlier, aim to empower architects and designers with an efficient use of technology, to meet the requirements of sustainable development.

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قابلية التكيف التكنولوجي، مدخل إلى عمارة مرنة مستدامة

فايزة نقيب
طالبة دكتوراه مختبر بحوث المدينة،
التصميم الحضري والتنمية المستدامة (VUDD)، الجزائر
البريد الالكتروني: Faiza.nakib@yahoo.com

الملخص:

يعد التقدم التكنولوجي ظاهرة متسارعة و متواصلة، تؤثر في حياتنا اليومية، مشكلة أحد الجوانب الأساسية من رفاهيتنا. إنَّ الأماكـن التي نعيش، نتعلم و نعمل فيها، ينبغي لها دائما أن تعتنق التجديدات التكنولوجية المتواصلة، وأن تتبع معدل تقدُّمها. و لكن، أيَّ تكيف يجب أن يتم مع أدنى حد من استهلاك الطاقة و المواد و دون الإضرار بالبيئة الطبيعية.

إنَّ معظـم المباني تكون عرضة للإهمال، للهجر أو للهـدم بسبب تأخرها التقني و عدم قابليتها لمواكبة التكنولوجيا الحديثة. المرونـة و القـدرة علـى التكيف قد يشكلان عامـلا أساسيا لاستقبال التقـدم التكنولوجي و امتصاص العوامل الناتجة عنه بسهولة مع المحافظة على النوعية المعمارية للمبنى و التماشي مع إطار التنمية المستدامة.

عن طريق إدماج قابلية التكيف الوظيفي و الفضائي، الفصل بين الطبقات المادية المختلفة طبقا لاستمرارية كل منها، بالإضافة إلى استقلالية مستويات أصحاب القرارات، الزيادة في تقدير السعة البنيوية و التقنية للمبنى و اللجوء إلى البساطة و المعيارية في تصميم الواجهات، الخ. يمكن استباق التقدم التكنولوجي المستقبلي، و متابعة تطورات البعد الجمالي للمبنى، بالإضافة إلى تسهيل عمليات الصيانة الدورية بأقل تكلفة. و بهذا يمكن للمبنى أن ينجز مهمته الوظيفية بفاعلية، أن يحافظ على بقائه في الخدمة لمدة أطول و أن يلبي الاحتياجات و الترقبات المتغيرة لشاغلي البناية، من أجل مواجهة الظروف الاجتماعية، الاقتصادية و البيئية.

يتم اختبار بعض النظريات المختصة في دراسة و تطبيق قابلية التكيف في مجال التصميم و البناء في بعض الدول المتقدمة حول العـالم. يمكن استخـراج منها بعض الإرشادات التوجيهية التي قد تساعد على تحقيـق قابلية التكيف التكنولوجي في البناية.

الأهداف: تحديد مجالات قابلية التكيف كحل لإدماج التجديدات التكنولوجية في تصميم البناية.

المنهجية: تحديد أهمية و أهداف قابلية التكيف التكنولوجي و تفصيل (وصف) المناهج المتداولة.

النتائج: تحديد مجموعة من الإرشادات التوجيهية للتصميم و البناء في إطار قابلية التكيف التكنولوجي.

الكلمات الرئيسية: قابلية التكيف التكنولوجي، الاستدامة، الاستمرارية، التصميم الطبقي.