

A Review of Flexibility and Adaptability in Housing Design

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Abstract

A house is not a solid building; it is a system of activity. Any changes in the house users, their needs and the physical and cultural environment require a flexible system to adapt itself according to the changes. In general, flexibility is ability and potential of a building to change, adapt and reorganize itself in response to the changes.

This paper presents a comprehensive review of all significant research about flexibility and adaptability in architecture with particular focus on housing design. A summary of different definitions from different points of view is given. A matrix compares these definitions from social, economical and environmental aspects. In the analysis part, strengths, weaknesses and limitations of each study are compared with other researches.

1. Introduction

House as a place for living from birth to death must cover all of human development phases. A house is a place for human activities during days and nights in all years. The wide variety of human activities as well as a wide range of times spent in the house emphasis on the necessity of flexibility in housing design. Any changes in the house users affect the space requirements, but the problem is we cannot predict and control the changes, for example, the family size and family structure change during the time without any fixed patterns. Only a flexible system (house) is able to response the predictable and unpredictable changes [1].

In this paper the terms flexible and adaptable housing are used to cover the flexibility and adaptability of the eco-system not only the building. In general, the potential of change is described in terms of flexibility and adaptability. These two words are sometimes confused or used synonymously in literature [2]. So what is the difference between them?

Usually, researchers and architects use "flexible" for physical changes and "adaptable" for non-physical changes. Steven Groák (1944–1998) proposed a distinction between these two terms; he defined "adaptability as *capable of different social uses* and flexibility as *capable of different physical arrangements*"[3] cited by [2, p. 5].

Using a space in a variety of ways without making physical changes refers to the adaptability, and according to the Groák's definition the flexibility is achieved by modifying the physical form of the building; by joining, splitting, extending, and merging spaces [2]. This study tries to use the Groák's definition, but since the functional and physical changes in the houses usually happen at the same time, there is no rigid or clear border between these terms. Tatiana Schneider and Jeremy Till [2] in their book used the term "flexible housing" to cover issues of both flexibility and adaptability.

Keywords:	Review; Flexibility; Adaptability; Housing design
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Article history:	Received: 14 January 2016
	Revised: 07 March 2017
	Accepted: 18 May 2017

Before addressing the flexibility and adaptability, it is better to distinguish between the development of a house type and the evolution of an individual house. House types develop over time and are adapted to relatively stable natural givens (climate, topography, availability of building material, etc.) and more rapidly changing social and cultural conditions and new economic situations. The introduction of technical innovations also changes house types as well as lifestyles. These long-term transformations take place gradually over generations of builders and users.

The adaptability in the individual houses usually involves short-term adaptation. A specific house changes over time to be adapted to the new requirements of residents. The house is evaluated to cope with the new lifestyle, new size of family, new economic situation and so on.

2. Research method

A primary search for relevant research was conducted using Google Scholar with search terms including 'sustainable', 'adaptable', 'flexible', 'housing' and their cognate and synonymies words. This initial search helps to find the leading researchers and research groups in this field. In the next step, detailed searches were performed in the archives of the architectural journals and conference proceedings. Finally, books and papers cited by works found were checked for relevance.

This comprehensive review presents a summary of different definitions from different points of view and tries to categorize and classify the findings of researches.

3. Sustainability, flexibility and adaptability

The words 'sustainability' and 'flexibility' have become increasingly prominent in recent years. Figure 1 displays a graph showing how those phrases have appeared in English books over the previous years. It indicates that use of the phrase "Flexible Architecture" became more widespread in the late 1960s, and also the phrase "Sustainable Architecture" was more common from 1987 after the first consensus was reached between countries on sustainable development under the auspices of the World Commission on Environment and Development (WCED), known as Brundtland report [4]. According to the (WCED) "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [4]

However, the biggest problem in the architectural case is the users of buildings, their needs, and their wishes change rapidly during the time. Buildings require a

flexible physical, spatial, and cultural structure to respond to the changes. It is interesting to note that even though flexibility is only one aspect of sustainability, in recent years both terms are used almost to the same extent in literature.

Building construction and operation consume large amounts of energy and material. Sustainable architecture is designed to reduce this consumption of material and energy. If a building does not only serve the present purposes but is also able to meet future requirements to a certain extent, a lot of energy and material can be saved. Therefore the biggest challenge in architecture is rapidly changing needs and requirements. Buildings need a flexible structure and flexible spatial configuration to be able to meet rapidly changing demands.

"A sustainable building is not one that must last forever, but one that can easily adapt to change." [6, P. 7]

"If a building doesn't support change and reuse, you have only an illusion of sustainability...." [7, P. 147]

In general, one of the most important ways to achieve sustainability is to develop the flexibility and adaptability of systems. Sebastian Moffatt and Peter Russell [8] argue that adaptable designs and materials can improve the environmental performance of buildings in at least three ways:

- a- "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."
- b- "Increased longevity - adaptability extends the total lifetime of buildings."
- c- "Improved operating performance" [8, pp. 4-5]

4. The history of flexibility and adaptability in housing design

If we accept that, the ability of users to change and control the design process is flexibility we can extend the history of flexibility to the history of housing. *Nomadism* as an earlier lifestyle let people move between summer and winter pastures for hunting, ranching and farming. The regular movement helped nomadic tribes to find the seasonal water resources and fertile pastures and at the same time avoid the harsh weathers and environments. The Tribes and traditional nations designed, made, repaired and extend their houses collaborative. Schneider and Till believed that flexible housing have developed in two ways: non-architect vernacular houses and the second is a result of external pressure that have promoted housing designer. [2] (Table 1)

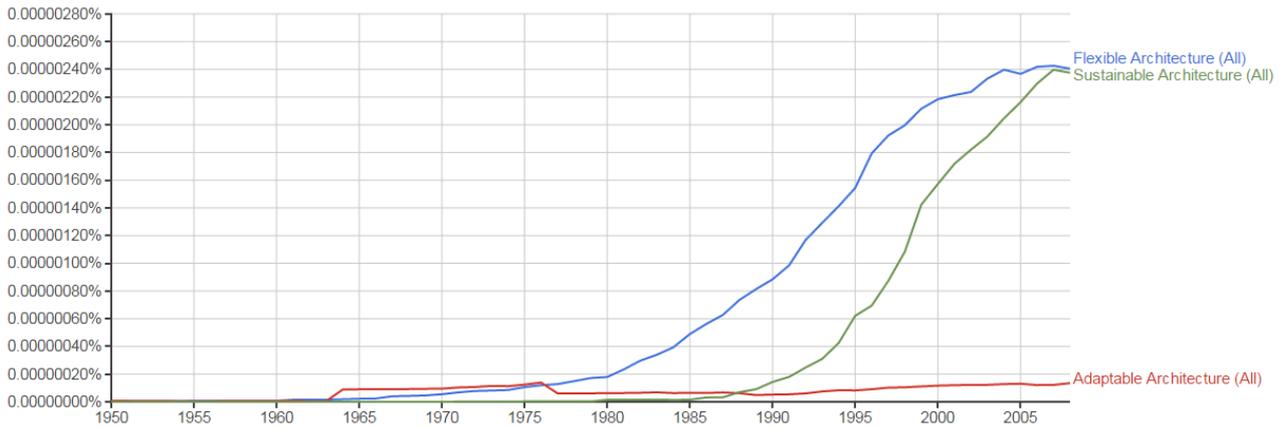


Figure 1. Comparing the use of the terms sustainable, flexible and adaptable architecture over time, Google Books Ngram Viewer [5]

Table 1: Flexible housing development (adopted from [2])

	way	Designer	Deriving design solution
Housing Development	Evolving conditions of vernacular	Non-architect	long-term adjustments to patterns of use and cultural formations
	external pressure that have promoted housing designer	professional architect	Authority of expertise

Table 2: Mies van der Rohe’s open plans adapted from Ransoo Kim [13]

Flowing space	“continuously connecting space, in which neighboring rooms are open to each other”
Dynamic space	“open plan that characterized by a complementary contrast between interior material freestanding walls and exterior full glazed walls”
Clear space	“single uncluttered volume enclosed by glazed skin, and thus, the building is literally clear from both the inside and the outside.”

Vernacular houses emerged gradually, based on the exigencies of a given time. Vernacular architecture can accommodate a certain range of uses and respond to economic and social developments to a limited extent. For this reason, in certain critical situations (e.g., destruction after natural disasters and war, the sudden increase in population, rapid economic growth and changing lifestyle) vernacular architecture is not able to cope with the rapid changes. These rapid changes happened almost simultaneous with the First World War and the beginning of modernism in Europe. This review starts with some leading flexible ideas in the beginning of modernism then focuses on the recent projects and research on flexible and adaptable housing field.

4.1. Modernism and flexibility

After the First World War and necessity of industrialised systems for housing on a mass scale Le Corbusier proposed Domino system in 1914. Domino system was a concrete frame structure that consists of columns and slabs (Figure 2). This design system enables the architects to separate the interior from structure. Le Corbusier used the term ‘plan Libre’ for this spatial flexibility [9]. He proposed his ideas about the modern architecture- Five Points of Architecture- in his book ‘Towards a New Architecture’ (1923). Two of the five points are free floor plan and free façade design. Using the columns instead of the load bearing walls increases the internal usage of building. This idea enables the building to separate the exterior of the building from its structural function [10].

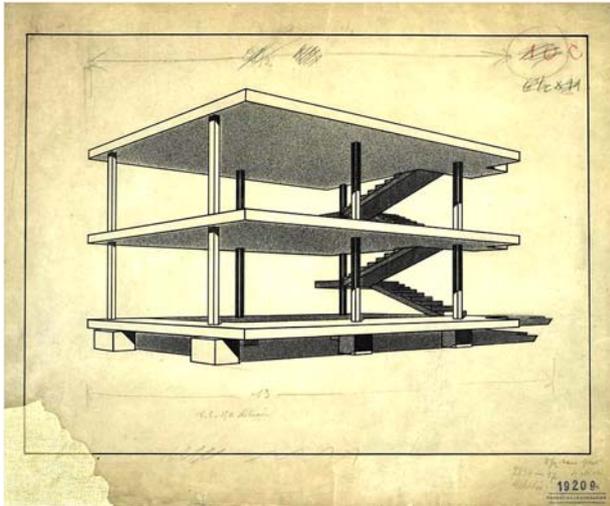


Figure 2. Le Corbusier’s Domino House 1914 [11]
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In 1924, Theo van Doesburg published his manifesto, *Towards a plastic architecture*, about *De Stijl* movement. He proposed his manifesto in sixteen clauses. He believed that architecture is elemental, formless and open. The elements - such as function, mass, surface, time, space, light, colour, material, etc. - are plastic. In addition, “produce the functional surfaces arising out of practical, living demands ... The dividing surfaces, which separate the spaces, may be movable” [12].

In 1926, Ludwig Mies van der Rohe attempted to create various kinds of open plans, he classified the open plans into three attitudes towards space design, Ransoo Kim [13] called them flowing space, dynamic space, and clear space (Table 2).

The other idea proposed by Mies (1923) was ‘skin and bone structures’ , “Supporting girder construction with a nonsupporting wall” [14].

He described his idea in the following statement:

“The variability you want is best by an undivided expanse of the individual floor levels; for that reason I have placed the supports in the exterior walls. . . . You need layered floor levels with clear, uncluttered spaces” [15].

4.2. Layer system

After reading a large number of papers and ideas about the flexibility, it was found that the most of them are based on ‘*Building Layer*’ idea. Therefore, this paper tries to review this idea in detail.

In 1961, N. Jahn Habraken published ‘*De Draggers en de Mensen: het einde van de massawoningbouw*’ in Dutch, that was translated into English as *Supports: An Alternative to Mass Housing* in 1972 [16]. The main idea of Open Building approach is the separation of Support and Infill, proposed by Habraken. Open Building is the term used to indicate a number of different, but related ideas about the making of environment (Table 3).

Habraken found a close relation between physical levels and hierarchical territorial structure of environment. He used the five levels of physical systems to study the different projects relate to the levels. Figure 3-A shows the most common distribution of control in the 1980s housing projects. Professional design and control all levels except the furniture, the user only can buy the furniture and change the layout of them.

Table 3: Open Building ideas about the making of environment (based on Habraken [17])

Environment making Idea	Example
Distinct Levels of intervention in the built environment	'Support' and 'Infill', or urban design and architecture
Users / inhabitants may make design decisions as well	The house buyers/renters infill the house according their needs or rearrange them to respond changes
Designing is a process with multiple participants also including different kinds of professionals.	
Interface between technical systems allows the replacement of one system with another performing the same function.	different fit-out systems applied in a given base building
Built environment is in constant transformation and change must be recognized and understood.	
Built environment is the product of an ongoing, never-ending design process, in which environment transforms part by part.	

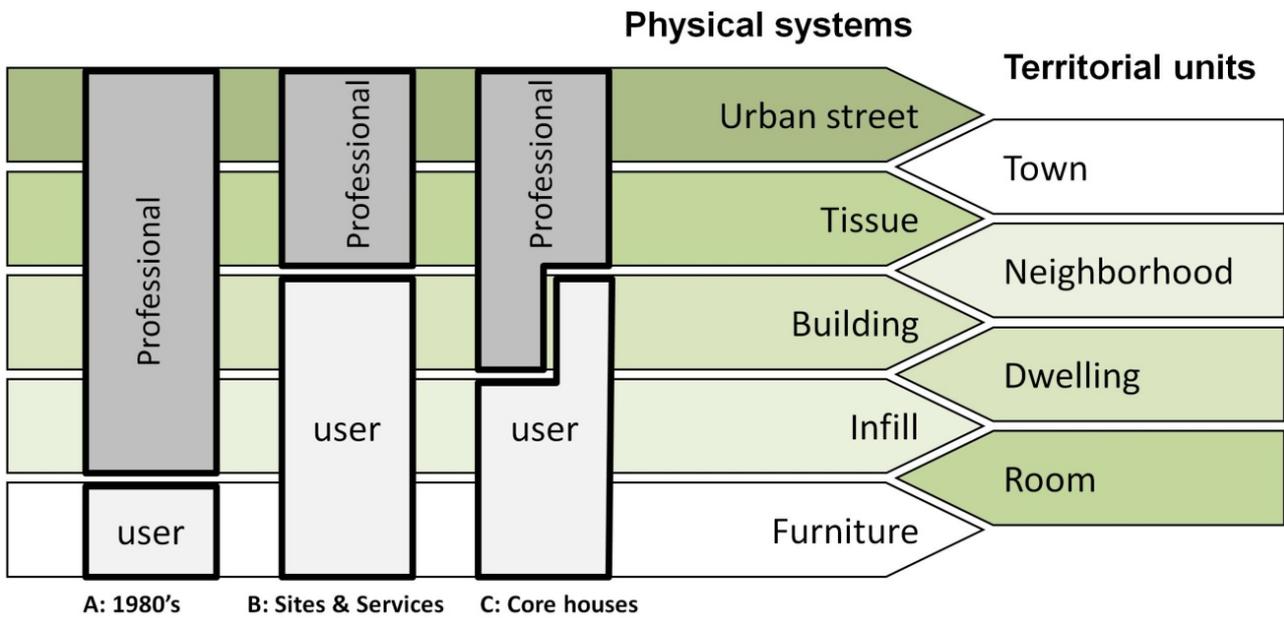


Figure 3. Different control patterns for the uses of environments (based on Habraken [19])

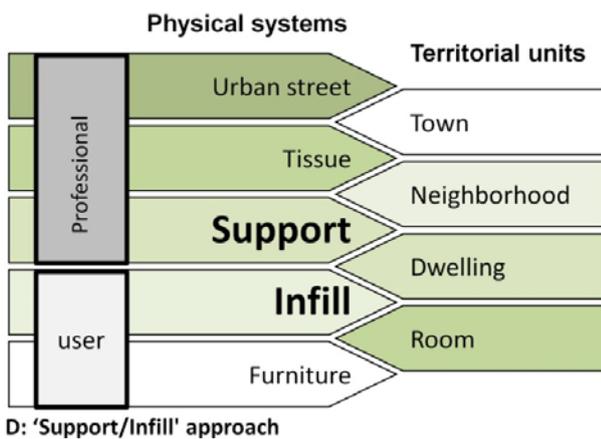


Figure 4: control pattern for Support /infill idea (based on Habraken [19])

Habraken found a close relation between physical levels and hierarchical territorial structure of environment. He used the five levels of physical systems to study the different projects relate to the levels. Figure 3-A shows the most common distribution of control in the 1980s housing projects. Professional design and control all levels except the furniture, the user only can buy the furniture and change the layout of them.

In the early 1970s, the World Bank started funding housing and urban development initiatives in many part of developing world. One of these ways of support was called 'sites and services'. In this approach, people house themselves while adhering to some minimum standards advocated by the bank and local governing agency [18].

The users are made responsible from the level of the dwelling downwards [19] (Figure 3-B).

The other type of housing financed by the World Bank (In the 1970s) was Core houses, these projects provided primitive shelters and let users fill in themselves (Figure 3-C).

The Support /infill idea came from the necessity to build large apartment buildings for high-density situations. Some people challenged that infill is also part of 'building' level. For this reason, Habraken renamed it to 'support' level [19]. This approach lets the house users to control and set their own floor plan (Figure 4).

Habraken's method has a significant influence on the history of adaptable and flexible architectural design. However, there is a limitation; this approach limits the flexibility and adaptability to the infill level.

British architect Frank Duffy [20] also took into account the temporal dimension linked to the building layers. He proposed the first theory of the rate of change in buildings, "Shearing Layers", in 1990. Stewart Brand [21, p. 12] quotes Duffy: "Our basic argument is that there isn't such a thing as a building.... A building properly conceived is several layers of longevity of built components." Duffy classified the physical and temporal layers of buildings in four layers: Shell, Service, Scenery, and Set. Shell is the permanent structure and enclosure of the building. The service parts - heating, cooling, ventilation devices, pipes and cable- with shorter lives are attached to the building shell. Scenery refers to the fitting-out components which accommodate the particular use in the solid shell. And finally, the setting is

a short-term managing or rearranging of the furniture and stuff to be adapted to the daily activities [22].

Brand developed and revised the "Shearing Layers" idea in his book in 1995. He expanded the Duffy's "four S's" into "six S's" (Table 4). The time layer idea helps architects to understand how buildings actually behave and how a building relates to the people [21].

The complete separation of different layers in building construction can help to increase the lifespan of the building. Inner partitions and façade elements which are not load-bearing can easily be changed and rearranged to accommodate new uses while the structural carcass is maintained. The main advantage of this approach is adding the time (longevity) to the building layers. That opens a new window in design, maintenance and restoration presses.

The other idea in Brand's concept is the differences in the decision level which facilitate or hamper changes. Different levels of stability and flexibility can be defined according to the 'shearing layers' idea; the sequence is as follows: city, neighborhood, load-bearing structure,

façades, inner partitions and finishing and furniture. The city structure is the most stable element, followed by the neighborhood. Changes in this "layer" require a high decision level – a political conception of (top down) town planning intervention or a concerted (bottom up) action from the residents' side. A few persons or even an individual can implement the changes in the lower levels – finishing, furniture.

5. Different approaches

Humans can adapt themselves with physical environment by three flexible skins, first is the skin of body, it can control temperature changes by altering blood vessel diameter. The second level is the clothes you can add or remove some clothes to cope with the heat and cold. The final shield in the face of environmental changes is Architecture. All buildings are flexible on some level e.g. you can open the windows in hot days (passive action), turn on the heater (active action) in cold days, or adjust the thermal comfort by using a smart system (Table 5).

Table 4: Building layers and Longevity (image and data: Brand [21])

Shearing Layers (different rate of change)	Layer	Description	Longevity
	Site	Geographic setting, urban location	Eternal
	Structure	Foundations and load bearing elements	30 to 300 years
	Skin	Exterior surfaces (Façades)	20 years
	Services	Wiring, plumbing, HVAC systems and ...	7 to 15 years
	Space Plan	The interior layout	3 years
	Stuff	Furniture, kitchen	Daily to monthly

Table 5: Levels of adaptation in order of complexity based on Lelieveld, et al. [23]

Level	Description
flexible	"This level of adaptability needs the direct control of the user, which means that the building elements do not have the ability to change themselves."
Active	"An active building component will give a set reaction on a specific change "
Dynamic	"Dynamic architecture has the possibility to give different output on a certain input."
Interactive	"The building component is able to have a two-way conversation with the users and/or its environment."
Intelligent	"The building can take its own conclusions for certain situation."
Smart	"Smart architectural components have the ability of self-initiative. The system is self-learning and would be able to design itself."

Table 6: Characteristics of Adaptability based on Robert Schmidt, et al. [24]

characteristic	Definition (samples)	
<i>Capacity for change</i>	change the size or use of spaces [25]	
	change its capacity, function, or performance [26]	
	Less frequent, more dramatic changes [27]	
	subsequent alteration [28]	
	modified, relocated [29]	
<i>ability to remain "fit" for purpose</i>	reduced in mismatches between the building and its users [30-32]	
<i>value</i>	maximizing its productive use[6]	
	to fit both the context of a system's use and its stakeholders' desires [33]	
	minimum cost [34]	
<i>time</i>	<i>speed of change</i>	quick transformations" [35]
		respond readily [36]
	<i>through life changes</i>	future changes [37]
		in the long term [25]
		extension of use [38]

You can change the furniture layout of living room to host a party or make some major changes to divide a flat into two parts for renting. The flexibility and adaptability in architecture follow a fuzzy logic like a tonality between black and white. These different degrees of adaptability bring a wide verity of definitions and approaches in literature. Robert Schmidt III and his colleagues at Adaptable Futures Research Group, Loughborough University [24], identified four overarching characteristics gathered from their literature review (Table 6).

They proposed a definition based on these criteria: 'the capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life' [24].

Table 7 indicates some definitions of flexibility and adaptability in housing design and the concept of each approach.

5.1. Accessibility for all ages

Due to aging population increases in the developed countries, the need for accessible housing rises. One of the most repetitive approaches in adaptable housing is focus on accessibility for elderly people especially in practical projects and national standards.

Avi Friedman and Witold Rybczynski of the Affordable Homes Program in McGill University developed the "Grow Home" in 1990. The project was a housing design that is easily modifiable and can suit people of all ages and family situations especially for low and moderate-

income households. The Grow Home was a narrow, three-storey house with a floor plan of 4.3 m by 11.0 m with fixed and loud baring wall as a structural core, enclosing soft, flexible interior spaces that can be reconfigured, rearranged and expanded upon in the future. Only the first floor was furnished the upper floors were unfurnished and homebuyers could fill in the house according to their needs [48].

In 1995, some people at Canada Mortgage and Housing Corporation developed an approach to design, "FlexHousing", based on "Grow Home" idea. "To buyers, having a FlexHouse means never being forced to move. Building houses to physically grow and adapt, to meet the changing lifestyle needs of singles, families, seniors and different owners is the new direction in residential construction" [49]. The focus of FlexHousing project is to allow people to adapt their houses according to their needs easily and economically. In addition, increases the lifetime of houses. FlexHousing was originally based on four basic principles of flexible design: Adaptability, Accessibility, Affordability and Occupant Health [42].

The Canada FlexHousing project is similar to "Universal Housing" in the U.S. and "Lifetime Homes" in the U.K. [42] (Table 8).

6. Indicators

Table 9 presents different indicators of flexible/adaptable architecture. It is clear each project according to its unique circumstances applies a limited numbers of these strategies.

Table 7: Definitions of flexibility and adaptability in housing design

Author	Date	Title	Definition or essence	Ref	Concept
James A. Bostrom Ronald L. Mace, AIA Maria Long	1987	Adaptable Housing: A Technical Manual for Implementing Adaptable Dwelling Unit Specifications	"Adaptable housing is accessible housing that does not look different from other housing and which has features that in only minutes can be adjusted, added, or removed as needed to suit the occupants whether they are disabled, older, or non-disabled."	[39]	Accessibility
Stewart Brand	1995	How Buildings Learn: What Happens After They're Built	"An adaptive building has to allow slippage between the differently-paced systems of Site, Structure, Skin, Services, Space Plan, and Stuff."	[21]	Layering system
Australian Standard	1995	AS 4299: Adaptable housing	<ul style="list-style-type: none"> - develop the accommodation needs of users of all ages and abilities. - Should be possible at relatively little extra initial cost. - provide safer houses - Continuation of existing community and family networks - Suitability for people with any level of ability 	[40]	Affordability Accessibility
Canada Mortgage And Housing Corporation	1999 2012	FlexHousing Homes That Adapt To Life's Changes Sustainable Housing and Communities - Flexible Housing	An approach to design easily adapt to the changing lifestyle requirements of its occupants, developed in 1995 by the people at Canada Mortgage and Housing Corporation	[41, 42]	Accessibility Affordability Healthy Housing
Sebastian Moffatt, Peter Russell	2001	Assessing the Adaptability of Buildings	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.	[8]	General
Roger Bruno Richard	2006	Individualisation & Industrialisation	"Adaptability itself is the capacity to alter a course of action when new information becomes available or when new conditions arise."	[43]	Industrialisation
James Douglas	2006	Building adaptation	"'Adaptation' is ...any work to a building over and above maintenance to change its capacity, function or performance (i.e. any intervention to adjust, reuse or upgrade a building to suit new conditions or requirements).	[26]	General
Tatjana Schneider, Jeremy Till	2007	Flexible Housing	"... definition of flexible housing is housing that can adjust to changing needs and patterns, both social and technological."	[2]	General

Minister of Housing and Social Development (Canada)	2009	British Columbia Building Code	"Adaptable dwelling unit means a dwelling unit designed and constructed to facilitate future modification to provide access for persons with disabilities."	[44]	Accessibility
Manewa Anupa, et al.	2009	A Paradigm Shift Towards Whole Life Analysis in Adaptable Buildings	"We define adaptable buildings as dynamic systems that carry the capacity to accommodate a set of evolving demands regarding space, function, and componentry."	[45]	Lifetime
Holger Schnädelbach	2010	Adaptive Architecture – A Conceptual Framework	"Adaptive Architecture is concerned with buildings that are designed to adapt to their environments, their inhabitants and objects as well as those buildings that are entirely driven by internal data."	[46]	General
Robert Schmidt III, et al. (Adaptable Futures Research Group, Loughborough University)	2009	Adaptable Futures: A 21st Century Challenge	"the capacity of a building to accommodate effectively the evolving demands of its context, thus maximizing value through life." [24]	[47] [24]	General
	2011	What Is the Meaning of Adaptability in the Building Industry?			

Table 8: practical projects and standards, Accessibility for all ages

Project	Date	Place	Founder/Sponsor	Description	Ref.
Universal housing	1988	U.S.	Ron Mace, The Center for Universal Design/ North Carolina State University	Universal design is the design of products and environments to be usable by all people, to the greatest extent possible, without the need for adaptation or specialized design.	[50] [51]
Grow Home	1990	Canada	Avi Friedman and Witold Rybczynski /McGill University	"Modifiable house that can suit people of all ages and family situations especially for low and moderate-income households"	[48]
Lifetime Homes	1990	U.K.	A group of housing experts, including Habinteg Housing Association and the Joseph Rowntree Foundation. / Foundation for Lifetime Homes and neighbourhoods (from 2010)	"Lifetime Homes are all about flexibility and adaptability; they are not 'special', but are thoughtfully designed to create and encourage better living environments for everyone. From raising small children to coping with illness or dealing with reduced mobility in later life, Lifetime Homes make the ups and downs of daily living easier to manage."	[52]
Flex-Housing	1995	Canada	Canada Mortgage And Housing Corporation	Building houses to physically grow and adapt, to meet the changing lifestyle	[49]

				needs of singles, families, seniors and different owners is the new direction in residential construction	[42] [41]
Universal housing	1997	Australia	Landcom Projects/ Australian Network for Universal Housing Design	"Universal housing refers to homes that are practical and flexible, and which meet the needs of people of different ages and abilities over time."	[53]

Table 9: Some Indicators of Flexible/ Adaptable Architecture

Type of Flexibility/ Adaptability	Definition	Ref.
Convertibility	allowing for changes in use within the building	[8]
Expandability	facilitating additions to the quantity of space in a building	[8]
	"Allowing for increases in volume or capacity (the latter can be achieved by inserting an additional floor in a building, which does not increase its volume)"	[26]
Durability	"Selecting materials, assemblies and systems that require less maintenance, repair and replacement"	[8]
Design for Disassembly	"Making it easier to take products and assemblies apart so that their constituent elements can more easily be reused or recycled."	[8]
Upgradability	"Choose systems and components that anticipate and can accommodate potential increased performance requirements"	[8]
Lifetime Compatibility	Do not encapsulate, or strongly interconnect short lifetime components with those having longer life times.	[8]
Partitionability	"... is the possibility of splitting up, rearranging or combining different spatial units in a simple way."	[54]
Connectability	"... refers back to the traditional system of 'Enfilade', whereby a series of adjacent rooms can be connected through sliding wall panels or doors."	[2]
Extendibility	"... is the possibility of adapting the building and its installation in a simple way to additional user demands..."	[54]
Multi-functionality	"...is the possibility of using or deploying space, construction or installation components for several functions."	[54]
Neutral Functionality	"Room without labels that do not have a specific use... this means that the later can take on other uses (i.e. work spaces, sitting in the bedroom)."	[2]
Divisibility	(Dividing up) The potential to divide a larger unit	[2]
Visitability	"means that a person who uses a wheelchair, scooter or other mobility aid is able to visit friends and relatives."	[55]
	"... people with disabilities will be able to enter the front door without difficulty and at least be able to get to the living areas and be able to use the toilet."	[40]
Disaggregatability	Materials and components from any dismantled building should be as reusable or reprocessible (i.e. recyclable) as possible.	[26]
Demountability	A system capable of major reconfigurations or even of a complete dismantling for rebuilding somewhere else	[56]
Convertibility	Allowing for changes in use (economically, legally, technically)	[26]
Dismantlability	Capable of being demolished safely, efficiently and speedily – in part or in whole.	[26]
Rearrange-Ability	Change the layout of spaces	
Rejection	which extent the use surface of a building can be decreased in the future (horizontal and/or vertical).	[57]
Responsive	Smart, Intelligent, Automated	
Transform-ability	Change of shape and arrangement of spaces	
Scalability	Change of size	

Refittability	Change of performance	[24]
Convertibility	Change of function	[24]
Recyclability	(Reusability) The ability of reuse (space, component and material)	
Combinability	Generating a multitude of combinations from a set of basic components produced in large quantity.	[43]
Polyvalency	"It means that a building can be used in different ways without adjustment to the way it is built."	[58, 59]
Redesign-(ability)	"... concerns the wishes/demands for changing the layout of the user units in a building and/or the functions of the user units in the building."	[57]
Expansion	"This factor concerns to which extent the use surface of a building can be increased in the future (horizontal and/or vertical)."	[57]
Transferability	Portable-ability, Movability, Change of location, "This factor considers whether or not the building can be transferred to another location."	[57]

7. Conclusion

This review determines that most of these approaches focus on the physical flexibility and adaptability. House as an eco-system consists of three main parts: Environment, users and system (building). Any changes in one of them affect on the others, to maintain the balance and stability of the eco-system the other variables must change and reorganize themselves according to the new situations. Too much attention to the physical and technical solutions may disrupt the balance of the house (eco-system). I found some lacks of comprehensive researches in the following areas that I can suggest for further studies:

- Flexible Environment (physical and cultural)
- Flexible Society (users)
- Flexible Spatial Configuration, relationship between spatial layout and users (using Space Syntax theory)
- Assessing the flexibility (quantitative research)
- Case study feedback from the occupants of flexible houses- Post Occupancy Evaluation (POE)

Acknowledgements

The sections one to four of this paper is based on the second chapter of my PhD dissertation. I would like to thank my supervisor Prof. Karin Raith, University of Applied Arts Vienna, Building Technology Department, for her comments.

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