T.C.
BAHÇEŞEHİR ÜNİVERSİTESİ

APPROACH TO FLEXIBILITY IN ARCHITECTURE IN THE 21ST CENTUREY

Master Thesis

NOOR BALBAA

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ABSTRACT

APPROACH TO FLEXIBILITY IN ARCHITECTURE IN THE 21ST CENTURY

Noor Balbaa

Master of Architecture

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In our everyday life people communicate, ideas are exchanged and the society evolves. Therefore we need to recognize that nowadays flexible architecture is rapidly increasing the dynamic interaction between both users and buildings with the help of digital technology. Flexible buildings are intended to respond to changing situations in their use, form or location. This architecture that easily adapts rather than restricts, is motive and dynamic and it is in constant interaction with its users rather than inhibit. It is a design form that is, cross disciplinary and multi-functional; therefore, it is more frequently innovative and expressive of contemporary design issues.
This thesis is aims to explore the theories of flexible and constantly evolving activities in architecture which has inspired designers around the world, with its singular characteristics of lightness, transience and practicality, the possibilities of adaptable, transformable and interactive designs.

The focus would be on flexibility which in this thesis is considered as an inclusive concept that encompasses adaptability, transformability and interactivity, is used to structure the framework of the discussion. The thesis draws on existing literature to investigate previous and on-going research relating present a conceptual framework of flexible architecture. The aim is to give a broad overview of what are flexible architecture and its types. Examining their functional performances will help in knowing how the requirements of the design have been achieved. Adaptive, transformable and interactive; in many cases show that sometimes there are potential overlaps and examples easily fit into multiple categories, this shows that there are various strategies that architects have at their disposal. With the advancement of technology what was thought to be impossible back then, is now possible.

Keywords: Flexible, Adaptability, Transformability, Interactivity, society and architecture.

ÖZET

21. YUZYILDA "MIMARLIKTA ESNEKLIK" YAKLASIMLARI

Noor Balbaa

Mimarlık Yüksek Lisans

Tez Danışmanı Prof. Dr. Sema Soygenis

Mayis 2016, 59 Sayfa

Bu tez, esnek tasarimcilar için ilham kaynağı olan mimari yenilikleri, flexibilite kavramı amaçlamaktadir üzerinden "uyarlanabilir", "dönüşürüleblir" ve "interaktif" incelemeyi amaçlamaktadir.

Çalışma uyarlanabilir, dönüşürüleblir ve interaktif gibi kavramları içeren " esnele mimarlik" üzerine yoğunlaşmakitadir.
Esnelik kavramı, mimarı literature yansıması, kronolojik bir sıralama ile incelenmiş, seçilen örnelerde uyarlanabilir, dönüşürüleblir ve interaktif mimarlik örneklerinim ölçude örtüştüğü önemli rol oynadığ bazı örneklılerde bugün teknoloji un gözlenmiştir.

Bu tez kapsamında batı örneklerine odaklanılmıştır. Bu konudaki çalışmaların diğer kültürlerde ve şehirleşmekte olan ülkelerdeki örnekler üzerinden araştırılmasının "Esnek Mimarlık" konusuna katkısı olacağı düşünülmektedir.

Anahtar Kelimeler: uyarlanabilir, Esneklik, Dönüştürülebilirlik, Etkileşim, Toplum ve Mimarlık,

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1. INTRODUCTION

Movement and change manage our lives in the environment we live in, we are no longer a community of static individuals; with worldwide communities and global infrastructure, we live in a time of constant transition, no longer fixed in one place for an entire life time; man has always been on the move, to different degrees through history, we move continually from one job to another, change houses and travel from country to country. What has changed with time, and what we can witness today is the speed and scale at which the constant restlessness that occurs. In order for modern architecture to serve the contemporary society, it must embrace and respond to the state of that constant transfer, exchange, relocation and adaptation; all the qualities evolved by contemporary societies. Technology has transformed the world into a global phenomenon. The time wasted while travelling has shrunk a great deal during the last century. Journeys that would have taken weeks at the beginning of the century are reduced to just a few hours today. Exchanging information has become instant thanks to the web connections. People use metal capsules to travel across land, air and water. A considerable measure of today's life aspects must adapt and adjust to the continuously changing surroundings and become flexible in our response. So, can architecture therefore adopt this concept of change and flexibility? Will structures perceive and react to the numerous adjustments in life and become more efficient? New architectural types are rising and advancing within today's technologically developing society. In spite of the fact that flexibility is not another idea or thought; it has been existent since the beginning of time, whether it is in the form of shelters and dwellings such as tents that allowed people to move with their herds and food sources, or in recent times such as movable houses, retail vehicles, it exists in demountable markets, fairs or even carnivals. With the technological advancements and developments flexible architecture encompasses a wide range of terms such as adaptive, movable, demountable, transformable, interactive, and responsive and many more which are often used to describe similar designs. In this research the focus would be on only three types which are adaptive, transformable and interactive architectures. Although these terms share a similar meaning, they can be interpreted differently depending on the specific circumstances.

1.1 PROBLEM DEFINITION

There are debates concerning the diversity of flexible architecture and its value for the society environmentally and technologically. Flexible architecture is a diverse type of architecture and has an amazingly high value for social, environmental and technological developments which will be clearer later on in this research. This diversity has encouraged many researchers and architects to further investigate the use of flexibility in architecture and coming to the point that there is no direct evaluation system found that could be applied to this kind of architecture. This thesis is to explore the theories that address dynamic, flexible and constantly evolving activities in architecture by understanding its establishment and constraints. This thesis will focus on flexible because:

(i) Flexible buildings have been comprehensively utilized around the world and are becoming progressively paramount. There is a growing need for empirical research related to this area for many reasons including the application of technology to it.

(ii) Flexibility in architecture has been present since the beginning of time whether in the form of tents, igloos, emergency shelters and many more examples; it is not a new idea. Any building could be recognized as flexible; however, this research would focus on flexibility in terms of adapting, transforming and interacting.

(iii) The application of flexibility in architecture started out in mostly private residential buildings. In recent times with the help of technology, flexibility could be found almost everywhere ranging from private buildings to public buildings to art installations.

The focus would be on both public and private buildings with the goal to see the progress and alteration of flexibility in both types of buildings and to have the capacity to comprehend its potentials for further use in architecture. By considering both types of buildings which is considered a diverse selection, it gives room for evaluating and criticizing flexible architecture.

1.2 RESEARCH OBJECTIVES AND QUESTIONS

The objective of this research is to investigate flexibility in architecture and give a wide outline of what is flexible architecture. There are multiple approaches when designing flexible architecture, such as mobile, portable, transformable, demountable, kinetic, floating, dynamic, adaptive, responsive and interactive architectures. Robert Kronenburg in his book flexible: architecture that responds to change, argues that for a building to be "flexible", it must be prepared for: an adjustment, that is to be adaptive as way to better react to different capacities, uses, and necessities and it should also be prepared to change and transform by altering the building's shape, volume, structure, or appearance. Finally the building should be able to collaborate and interact, which could be applied within the building's interior or exterior (Kronenburg, 2011). Such capacities in buildings will be provided by "intelligent" building systems which are driven by numerous variables from environmental ones such as the control of energy use, to changing the whole appearance of a building through multiple images and patterns.

Therefore in this research those approaches have been restricted under three types which are; adaptive, transformable and interactive architecture in which they somehow grasp the whole subject of flexible architecture. These three approaches may seem completely different at one point, in many cases however, they show that there are potential overlaps at some points, and one example of a building can easily fit into multiple other categories, showing that there are many different strategies that designers and architects have at their disposal to design such buildings.

With the information acquired from this research the main goal is to answer these questions:

a. What are the potentials of flexibility in architecture?
b. Where do these subcategories overlap?
c. In what way flexibility might inspire the making of new architecture and why are we heading towards this kind of architecture?
d. What is the role of technology in the design of flexible buildings?

1.3 METHODOLOGY

Flexible architecture is a complicated field and probably cannot be directly evaluated that is because it ranges from media facades to environmental friendly and low carbon buildings, from stage and stadium designs to responsive building types and from artificial intelligence to ubiquitous computing (Tscherteu, 2009, Roaf et al., 2007) (Bullivant, 2005) (Eng et al., 2003) (Rogers, 2006).

Flexible architecture today joins together various different concerns originating from a wide assortment of different fields such as; arts, computer science and engineering and cybernetics and many more. Whether buildings in this context are portrayed as adaptive, interactive or transformable, they grasp the thought of design being flexible in terms of changing, adjusting or transforming according to the user's needs. This is frequently refined in contemporary times with the assistance of advanced innovation and digital technology. Flexible architecture is considered to have great focal points when numerous different fields of study and disciplines merge to make energizing new outlines, encounters and lived-in structures. Nevertheless having all those fields combined together can make the rising field of flexible architecture appear excessively complex.

The main challenge is to distinguish the key features of each: adaptive, transformable and interactive designs and to form the elements into a progression of assessment indicators. The methodology is to altogether investigate the design, operation and innovation of contemporary flexible buildings. The research aims to come up with conclusions on the reason why designers chose to proceed with these types of flexible designs. "The only way to experience architecture of the past or present and to make it work in one's professional and personal development is to study the full realm of environmental circumstances that have brought about this kind of architecture. Only then, can the past remain a living agent of our time and can tradition really function" (Charles E. Tuttle, 1985). Therefore a qualitative method would be used by discussing an arrangement of buildings, designs, speculations and contextual analysis of flexible architecture. Reviewing the historical background of flexible architecture and investigating the advancements of the designer's techniques and the technological innovations, would help in understanding the common ground

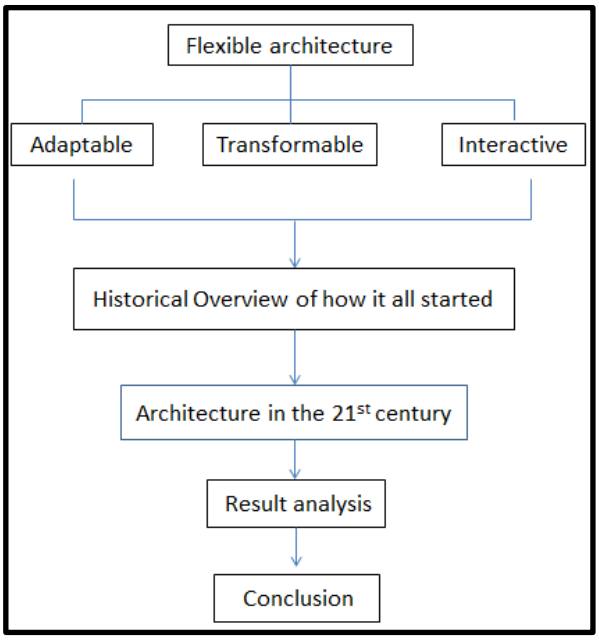
that has been existent throughout all those years. The previous research questions would be answered using the "critical constructivist lens" by comparing and looking over various different projects selected from articles, books and journals.

The research will be founded on three case studies of different building types offering a wide premise in order to answer the questions related to the problem. Location, form, structure, function and the use of technology in these case studies would be analyzed. This comparative analysis would therefore demonstrate the discussions, speculations and controversial arguments done by different critiques and architects.

The hypothesis used for this research based on the: "Level and quality of architectural adaptation can be fundamentally enhanced by replacing traditionally centralized and hierarchical organization of architectural systems by largely distributed open and extensible one, promoting establishment of new procedures for intuitive architecture"(Jaskiewicz 2013, p.5), The general assumption could and ought to be tested; transformable , interactive, adaptable design is well placed not only to solve an extensive variety of architectural issues, but to do it "better than" more conventional responses

1.4 STRUCTURE OF THE THESIS

Table 1.1 Structure of the thesis outline



The first part of this research focuses on defining flexibility and its history. Moving later on to understand the three types of architectures that go under the term flexible architecture, first, adaptive architecture which means that buildings could adapt and adopt space, or adjusting itself to its surroundings. At the same time the study examines its key components such as the types of adaptability and what drove architects into designing such designs. This is to understand the reason behind those buildings and uncover the situations they serve.

Second is, transformable architecture which is a more technological integrated type of flexible architecture that can change shape, color, skin or structure according to the circumstances in which it is designed to uphold. Third, interactive architecture is considered the newest type of designs that designers are working on developing today, it is an architecture that is with the advancement of technology can now respond and interact with its users.

The thesis then moves on to discuss the architectural characteristics and how to identify each type and their key components, understanding where they usually overlap.

The last part of this research is the case studies, in which three different types of buildings one from each component (adaptive, transformable and interactive) respectively, are analyzed based on their form, structure and function. The three case studies have been chosen according to their technological level. The first case study is considered a flexible building with low technological interference, the second case study with a moderate interference and the third is based mainly on technological interference. This is to analyze whether technology has helped the building in achieving flexibility and how it could affect future designs.

2. FLEXIBLE ARCHITECTURE

2.1 AN OVERVIEW OF TERMINOLOGY AND THEORIES OF FLEXIBILITY IN ARCHITECTURE

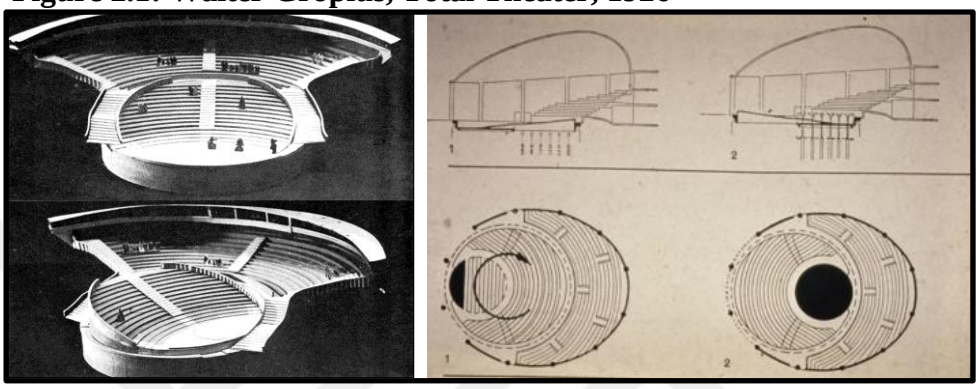
The term flexible architecture has been mainly understood as the sort of architecture that responds and modifies itself to change, offering an extensive variety of assorted qualities due to its dynamic condition and giving its users the freedom to manipulate and control it according to their needs. Kronenburg in his lecture on adaptive buildings defined flexible architecture as a fluid type of architecture that can be altered or adjusted according to its occupants and how they utilize it (Kronenburg, 2011). The term 'Flexible' is usually described as something which has the capacity of being bent, easily adjusted or modified, prepared to adapt to different situations and needs making it free from stiffness (Oxford English dictionary online, 2009).

Human beings are flexible, they manipulate objects and move things from one point to the other, and they operate in a wide range of environments. Based on that, architecture becomes dependent on people's behaviors and on society, meaning a dynamic society will make room for dynamic architecture. For instance, Bedouins and nomads based on their moving nature, need a moving and easy to assemble kind of structures, while a more based type of people would create fixed concrete types of buildings (Lebbeus woods, 2004).

The term ”flexibility” was introduced in the field of architectural terminology around the early 1950s. One of the earliest assumptions of flexibility was that architects needed to imagine building not as a monument, but rather a container for the stream of life. This conception ought to be sufficiently flexible to make a background, fit to retain the dynamic features of our current life (Walter Gropius, 1954). This was shown in Gropius's inbuilt Total Theater of 1926. This theater was designed for the director Erwin Piscator who was famous for having a "full house" theater mainly for making the actors interact with the audience. Erwin Piscator wanted to attract people with lower income and therefore, he needed a 3,000 or 4,000-seat theatre to make the entry prices affordable. Therefore, in particular, he required removal of the stage and adding "convertibility, flexibility and anonymity"

in the architectural design in order to bring the performers and the audience closer together. Therefore Gropius, responding to the director's needs, wanted to create a building which could respond in terms of convertible space and flexible lighting, in order to draw the spectator into the drama and making the building highly flexible for modifications (Gropius, 1934).

Figure 2.1: Walter Gropius, Total Theater, 1926



Source: https://thecharnelhouse.org/2013/07/20/theater-buhne/

Numerous arguments have developed over "flexibility" in the 1960's, regardless of whether an architect ought to leave the design of the building "unfinished", giving it a chance for further improvements in the future. John Weeks, the English architect supported the "unfinished" solution. In his opinion, most of the large scale projects such as airports or hospitals will not have the capacity to foresee the progressions that may happen in the future or what the users may require throughout their usage of the building, therefore, leaving the building unfinished would permit further improvements to be made. Then again other architects would consider that an unfinished building would be pointless as it would not serve what it has been built for properly. In spite the fact there is no direct solution; one cannot say that leaving the building unfinished would offer more flexibility than a finished one. Yet with that being said, knowing how long and to what extent a building will and can be utilized depends very much on a long lasting freedom of use and the buildings flexibility. Of course the more a building allows for future changes and adaptions of use, the more it's allowing for diverse future use and as long as the structure and

underlying ideas are allowing for program changes, the longer the building will last and be utilized.

Whether flexibility has been inserted from the beginning or leaving it for the future, the fundamental explanation behind designing a flexible building as stated by Adrian Forty, is "the incorporation of ‘flexibility’ into the design allowed architects the illusion of projecting their control over the building in the future" (Adrian Forty, 2000). Therefore it depends more on the architects' satisfaction of their desires for control.

Meanwhile, Looking at the vast majority of the theories and arguments concerning flexible architecture, one of the main reason architects design flexible buildings is, the capability of adjusting and changing, recommending an open ended solution according to the 'diverse social uses'. Moreover, in Kronenburg's lecture on adaptive architecture (2011), he stated that there are several potential benefits of building flexible buildings such as; buildings might remain in use longer, fit their purpose better, accommodate user experience and intervention, economically and ecologically more viable to remain relevant to the cultural and societal needs. It can also lead to "affordability", such as the manufactured houses, or it can be lifesaving like "shelters. In order to explore flexibility in a wider range one must know the meaning of each; adaptable, interactive, transformable architectures.

2.2 HISTORICAL OVERVIEW

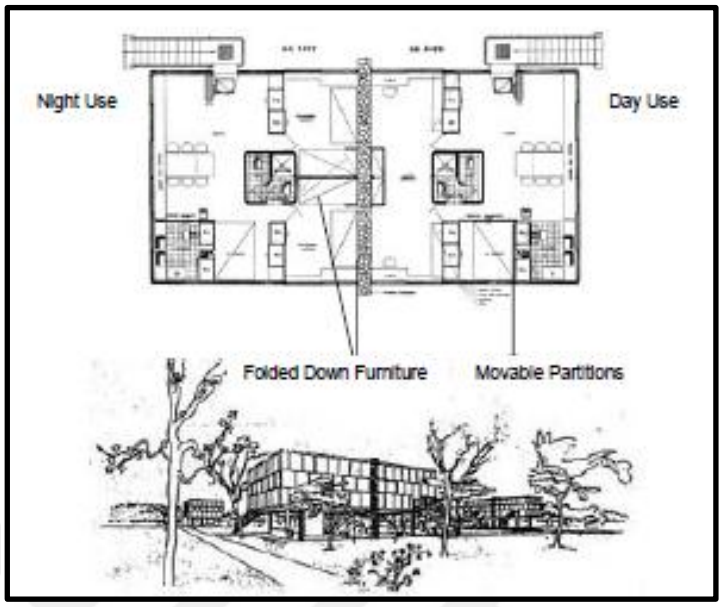
Flexible architecture is not a new concept, having the concept of buildings that adapt, transform and interact has always been around, but the methods and applications were different. It began in the 1920s where open plans and modular designs structures were used in the designs, then came industrialization where the use of mechanical engineering was the main design concept. It wasn’t until the 1980s and 1990s, development began to take place within the field of computer science where fields such as “intelligent environments” were formed to study spaces with embedded computation and communication technologies and creating spaces that bring computation into the physical world. In the late 2000s modern technology has

very much evolved and architects starting focusing more on designing buildings that seemed to be alive and would mostly interact unpredictably with its users.
Reviewing the series of developments in flexible architecture throughout those years would later on explain how flexible architecture evolved and the reason behind the design of such flexible buildings.

2.2.1 Minimal Dwelling

Whether flexible buildings are adaptable, transformable or interactive, they grasp the idea of architecture as dynamic rather than a static artifact. In the 1920s flexible architecture began to take fold, it started with the idea of flexibility in the context of housing. The requirement for minimal dwelling was a result of the housing crisis after the World War I which then prompted designers to develop alternative design solutions. Architects especially in the 1920s, began to question and doubt the existing living patterns and approached the building as something that could change and adapt to its occupants over time (Schneider, 2005). The 'minimal dwelling' is characterized as living on the base that would at any rate fulfill the basic minimal requirements for healthy living (Teige, 2002). The Schroder house designed by Rietveld in 1924 is a good example which best explains the concept of the minimal house and its adaptability and flexibility in its interior design. The Maisons Loucheur is another good example of flexible minimal housing project designed by Le Corbusier in 1928, in response to the French government that passed a financial asset program for housing. The concept of flexibility played an important role in the development of this minimum dwelling by turning a small compact space of 46m2 into what is equivalent to a 71m2 space, by doubling the functions in the building, using movable walls and folding furniture so that the space could be used to perform a certain function in the morning and a completely different one at night. This idea of dealing with small spaces led architects to develop new plan types for housing, many of which had elements of flexibility (Schneider and Till, 2007).

Figure 2.2: Maison Loucheur housings project, Le Corbusier, 1928



Source:http://www.afewthoughts.co.uk/flexiblehousing

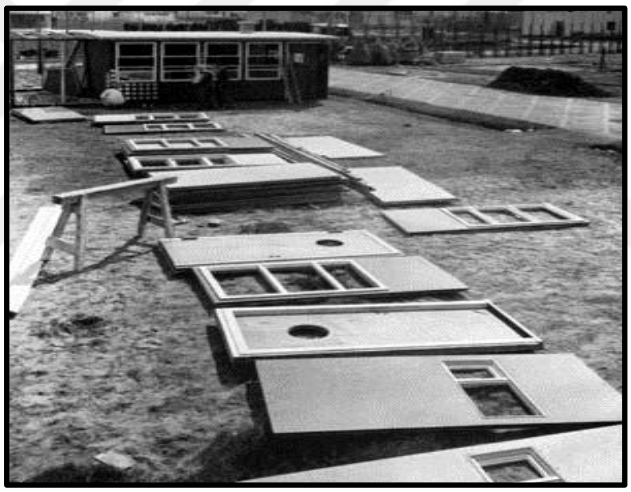
Although, spaces that include moving partitions and folding furniture as La Maison Loucheur are considered highly flexible, this type of flexibility is predetermined or is considered as "hard" flexibility as Schneider and Jeremy Till put, it because it involves technical elements that specifically determine the way people will use their space according to the architect's decision.(Edward R. Ford 2003).

2.2.2 The Support and Infill System

The support and Infill system, is a design that gave the users the choice to use their space according to their functional needs. This is a more developed idea than the predetermined design. This drove architects to come up with the 'modular design' idea, which implies separating the fixed structural system from the architectural layout making the units separable and reconfigurable so that the users could configure it according to what they wanted and needed. The Growing House designed by Otto Bartning in 1932 is an example of the modular design, support infill system which is another form of flexible design. The house is a 25m2 box with a little hall, a washroom, a kitchen and a merged living and sleeping space of around

18m2. The house could be developed utilizing the same arrangement of components turning it into a 60m2 house, due to the flexibility of rearranging all the partitions and door panels inside the house. One of the premises for the layout of the house was a straight forward assembling and dismantling of its parts. The structure of the house is fixed yet it could be disassembled effectively and the interior of the house consists of dividers which could be put or removed as indicated by its occupant's wishes. This construction took into account not only the reconfiguration of its interior but also it could be put together or dismantled any other location as well(Ludwig, 1998) making it a flexible building from inside and out.

Figure 2.3: Growing House (Das Wachsende Haus), Otto Bartning, Berlin, 1932



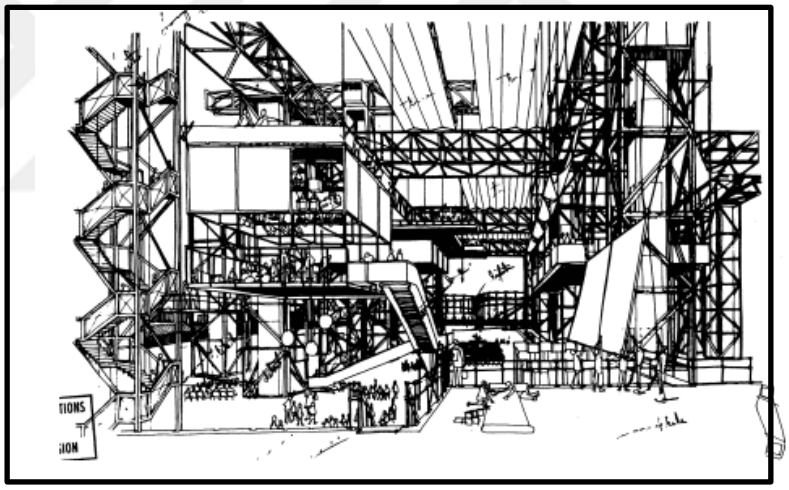
Source:http://www.afewthoughts.co.uk/flexiblehouse

2.2.3 Buildings Can Interact

The idea of having a modular structure and having it move from one place to another or transform caught the attention of most architects. Architects started to think about ideas of architecture that could transform and interact with users. It began with the work in Cybernetics by Gordon Park and other cyberneticists (such as Norbert Wiener). Gordon Pask's "Conversation Theory" came from the study of cybernetics which is a theoretical study of correspondence/control forms in electronic, mechanical, and biological systems. The theory attempted to explain learning in both living organisms and machines. Le Corbusier was one of the persuasive and early architects to embrace the early hypothetical work in cybernetics and developed it to an architectural concept of 'anticipatory

architecture' that allowed its users to freely modify the organization of space. Thus, user activities would be observed and future organization of space would independently attempt to change and adjust according to its users, leading to the creation of a space that interacts rather than being controlled by its user (Sengala,2006). In 1961 The Fun Palace one of Le Corbusier's inbuilt projects, was based on the idea of making the building indeterminate, flexible, and responsive to the changing needs of users. Corbusier wanted to create a space that would self-manage, anticipate and react to the users and the environment without a specific program or objective embedded in it. The technical challenge and creative social implications of the "Fun Palace" introduced new kinds of flexibility into the field of architecture, where a place could interact or try to anticipate its users' needs and actions (Price, 1984, p54).

Figure 2.4: The Fun Palace, Cedric Price, 1961, conceptual project



Source: http://www.bcchang.com/transfer/articles/2/18346584.pdf

Another group of architects viewed special interest in making a building transform and interact with its users. Archigram's early projects attempted to combine both interactivity and transformability in their designs, this time on a city scale like the Plug-in City borrowing Le Corbusier's words "a machine for living". The project suggested a hypothetical fantasy city, embracing the 'modular design' system making the private units “plug in” to a central infrastructure. The Plug-in City was designed as a constant developing structure that consolidates residences, transportation and other fundamental assets, all which are movable by giant cranes. Other projects such as the "Walking City"

were like a giant reptilian structure that moves. "Living Pod", a small case home and "Instant City" which is like an airship containing all the social and education assets of a city that could land in remote areas giving inhabitants a taste of city life, opened up doors for innovations and new ideas questioning how far can flexibility go in a design (Gilles Deleuze, 1987).

In the 1980s, architects started working on the idea that buildings could learn, decide and respond. The use of embedded computation started out mainly in the design of surfaces, such as facades of a building. One example is The "Tower of Winds" designed by Toyo Ito in 1986. The project not only embraces technology includes in it in a dialogue with the city, but also establishes a direct relationship between nature and the installation. During the day the "Tower of Winds" protects the interior of the building at night using the lights reflective surfaces which dances to the music of the city. By using computer-control system which reacts to both man-made and natural forces, the building reflects the complexity and nature of its city and its inhabitants (figure 2.5) (Schnädelbach, 2009). The building is then considered an interactive flexible building that responds to its surrounding environment and changes itself accordingly.

Figure 2.5: Tower of Winds, Toyo Ito, 1986, Japan

Source: http://www.archdaily.com/344664/ad-classics-tower-of-winds-toyo-ito

2.2.4 Modern Technology

The 1990s was considered a leap forward in innovation, with the advancement of technology, architects tried making buildings that could anticipate information. Michael Mozer came up with the idea of a smart house that can program itself for its inhabitants, and make home automation more user-friendly and available. With this aim, Mozer led the development of the "Adaptive House", which can foresee the behavior and needs of the inhabitants by having observed them over a period (Sutton, 1998). The Adaptive House by its system was not only following certain programmed adjustment but mostly making decisions by itself. It monitors the adjustments in the conditions and senses the occupants' practices and investigates them in order to foresee future activities and respond to them. Mozer designed the system as a learning device, which works just like a human brain. This system predicts inhabitants' behavior and movements, controlling the condition as indicated by the forecast. For instance, it can tell which rooms will be used at what times when the user will leave the house and return, and when hot water will be needed in the boiler, making it a flexible interactive type of building (Bellman, 1957). With the escalated social and urban change in modern times, the requests for flexible design arrangements are more requested. The new technologies conveyed new answers to the customary issues of movement, dullness and order. These progressions in innovation prompted to the idea of having buildings and designs that could adapt,

transform or interact with its users. In the recent decades, the concentration of flexible architecture study has moved from the mechanical worldview to the organic one, unlike programming in which the building is assigned to do certain assignments. Now, researchers and architects are endeavoring to make a design that is living and breathing and acting on its own. The reason is that the programming type of buildings is very redundant and predictable while the latter biological ones are evolving as the building imitates life (Grimshaw, 2003).

Currently, unlike adaptive and transformable architecture's practice that can be seen extending from the inside of the building to its outside or even to its urban surroundings, a large portion of the interactive architectural practice is on changing facades, controlling interior conditions, saving energy, or artistic interactive installations. Despite the fact that these are without a doubt are exceptionally huge accomplishments, there is less study on the spatial interactivity of an entire building or, at least, a significant portion of a building.

2.3 ADAPTIVE ARCHITECTURE

With the understanding of the history of flexible architecture, it is clear that flexibility started out with the implementation of adaptive elements and spaces within the building. Moving forward, the following discussion would describe the adaptive building forms and motivations that encouraged architects to design these adaptable buildings. Adaptation could be found in different forms, these forms have been summed up into two categories which are: spatial adaptation and environmental adaptation which are often driven by multiple needs and aspirations.

2.3.1 What is it?

The terms “flexibility” and “adaptability” are very close in meaning that they sometimes overlap. The word "adaptability" points to the characteristic of being versatile and adaptable; to have the capacity to be adjusted; having the potential to fit appropriately (Oxford English dictionary online, 2009), it takes over the meaning of fitting or adjusting for multiple purposes.

An adaptive building is a building that changes its function; adjust its interior and exterior space and form. It can also adapt to the environment, inhabitants and objects

within it. In this case architecture not only adapts to the changes in its content and context but it also can be improved according to the changing needs of its users and its surroundings, or as Kronenburg (2007) stated that adaptive buildings intended to conform to various capacities, uses and atmospheres which can take a wide range of many forms.

2.3.2 Forms of Adaptability

The forms of adaption have been summed up into two categories which are: spatial adaptation which is explained through building and urban scales and environmental adaptation which explains how adaptive architecture has helped in providing internal comfort as well as controlling the temperature expenditure inside the building.

2.3.2.1 Spatial adaptation

One of the most common forms of making an adaptable design is through making the space within the building or its surroundings changeable and adjustable according to its user's needs

2.3.2.1.1 *Building scale*

The Schroder House (1924) in Utrecht is one of the most popular example that demonstrate adaptable space, eliminating all the ornamental components and focusing on making the configurations in the house direct and useful (Acharya, 2013). The house is very compact yet the design plays with vertical and horizontal planes in three dimensions. Individually, the rooms are very small yet stream into each other. The open plan design elements show a blend of clean lines and basic pure forms unlimited by constructional components, with plan arrangements that characterized and portrayed the design. Sliding partitions make it conceivable to change the floor arrangement of the two main levels. The convergence of planes and linear elements and the joining of joints and railings make the house’s interior spaces as hard to perceive from within as they are from the outside. Walls are no longer the single viable components of space. The house was not intended to be a declaration for an aesthetic reinterpretation of local capacities but rather, as indicated by Rietveld, to form a formal clarity and increase the experience of space. Subsequently

adaptation of space is achieved, by making a small house seem bigger, Also the addition of sliding partitions and foldable furniture makes the house a multi-purpose space that is highly adaptable and responsive to the user's changing needs.

Figure 2.3: Schroder House, Rietveld, Utrecht, 1924

Source: http://www.archdaily.com/99698/ad-classics-rietveld-schroder-house-gerrit-rietveld

The idea of having a space that is adaptable encouraged Le Corbusier who was one of the most prominent architects to proclaim the idea of the open plan arrangement where columns are introduced in the floor plan to entirely replace obstructing structural walls, allowing adaptable subdivision of building spaces and the ability to change it to a broad assortment of uses (Acharya, 2013).

One interesting example of the open plan arrangement that explains how a space can be adaptive is the traditional Japanese house. The house is organized by a series of interconnected spaces that could be joined together or separated by partitions and openings. Connections between rooms can be opened or closed through lightweight partitions*(shoji)* making it possible to change the function and size of the space in a matter of seconds; two separate rooms can be joined together by simply opening up the large screens so that the two small spaces become one large room(Tuttle, 1985).

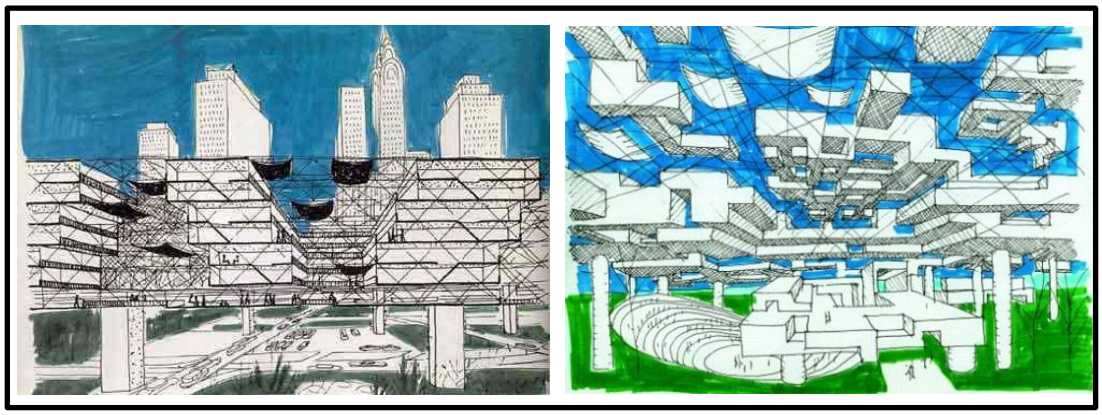
Figure 2.6: Traditional flexible Japanese house, with the shoji screens

Source:https://www.google.com.tr/search?q=traditional+japanese+house

2.3.2.1.2 *Urban scale*

The open plan arrangement was extended to the urban scale as well. Yona Friedman in his manifesto "mobile architecture" suggests that adaptability is mainly not for the building itself but for the people and users who can make the decision of choosing what the need. His theory gives maximum flexibility. In his "Spatial City" idea, he suggested using suspended superstructures and a system of disconnected trusses over the city. This system provides the inhabitants a complete freedom of choice to construct their own dwellings within the structures (Friedman, 2006).

Figure 2.4: Spatial city, Yona Friedman, 1959



Source: http://www.megastructure-reloaded.org/yona-friedman/

The Yokahama Ferry Terminal is another type of urban space that provides spatial adaptivity, only this time without the use of changeable structures. It is designed by Toyo Ito 2002 in Japan. The terminal is constructed as a long-span, arched steel structure which has the sensation of a light and flexible structure. The quality of the materials minimizes the requirement for vertical supports and allows for a mostly open floor plan, while the height of the structure considers an assortment of ceiling conditions in the interior spaces. The basic plane is particularly proficient at adapting with the lateral forces of seismic movements, a vital precondition of buildings of its size in Japan (Moussavi, 2014). The circulation flow of the building works as a continuous looped diagram, specifically dismissing any thought of linearity and directionality. Visitors are taken through ways that wander vertically and on a level plane before landing at any destination. Considering it an adaptable organizational building which can be called as a ' flow management building', it is intended to adapt to the changing stream of individuals by giving an extensive open zone to permit distinctive flood of travelers to separate national from international departures (Langdone, 2014). Moreover, all of the chaotic complexity of the materials, formal gestures and simplicity of this space offers a feeling of clarity and uncovers the procedure from which the building developed. Associating the levels is a progression of gently sloping ramp in which the architect decided, were more effective than stairs keeping up a nonstop and multi-dimensional stream of flow (Moussavi, 2007). The outcome is a flexible adaptable, column-free space with a consistent move between the inside and the outside.

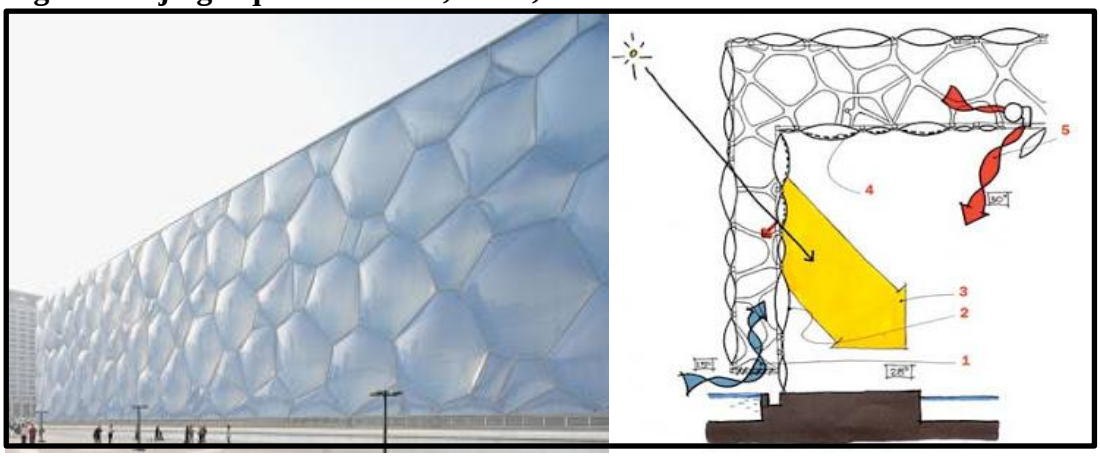
Figure: Yokahama Ferry Terminal, Toyo Ito, Japan, 2002

Source: http://www.arcspace.com/features/foreign-office-architects/yokohama-international-port-terminal/

2.3.2.2 Environmental adaptation

Not only were architects able to design buildings with adaptive spaces, but also they were able to make building environmentally adaptive as well. Adaptive elements are designed to react to the interior environment in order to ensure that temperatures inside are comfortable for inhabitants, and also to control the energy expenditure in achieving a particular comfort level. The Beijing National Aquatics Center's building is a good example of environmental adaptation. Designers used at type of cushion cladding which is the ETFE (ethylene tetrafluoroethylene) which can give warm protection with diminished introductory expenses and less structural supports, the space between the air-pillow walls has been totally closed off creating a layer of insulation. Amid summer, a 1m-high vent controls the indoor temperature of the building through heat exchange by drawing out the inside warm air and letting in the outside cool air. The vent is closed during winter and keeping the warm temperature inside the venue (Anon, 2013). Environmental adaptability in which the cladding adjusts its interior according to the environmental conditions was achieved by placing simple cladding to the whole building that could provide comfort for its users.

Figure: Beijing Aquatics Center, PTW, 2013



Source: http://www.dezeen.com/2008/02/06/watercube-by-chris-bosse/

2.3.3. Impact of Technology

The integration of technology has somehow helped in the changing and adaptation of spaces in the building according to the users' needs.

Technology mainly had an impact on achieving comfort inside the building and adapting it to its inhabitants by creating climatically controlled insides. Like the electro-chromic windows which minimize solar heat inside the building by controlling the amount of light and heat by making the window to lighten or darken using voltage applied to the windows. This offers opportunity for windows to be used as energy saving devices. Similarly, there are window shades and lights to brighten in response to the amount of day light available. The "BASF house" constructed in 2008 by Nottingham University in UK, is an example of making an adaptable house to the climate while keeping up low carbon discharges. Technology helped accomplish two important factors in the house, first it made the house energy efficient, with as close as possible to nearly zero carbon discharges, and second integrating technology in it helped in making it highly economical and affordable. The house's system joins various components such as; shading, buffer zones, minimization of design, insulated building fabric, double glazing windows, an earth-air exchanger for cooling and preheating of air, and natural ventilation by stack effect to achieve its desired performance, making it highly adaptive to its surrounding climate and adapting it to its interior (Bodart, Evrard, 496).

2.4 TRANSFORMABLE ARCHITECTURE

2.4.1 What Is It?

Transformable Architecture is closely related to than adaptable architecture. According to the Oxford English Dictionary, transformable architecture implies that an object that is equipped for change and physical adjustment. It is a kind of architecture intended to change shape, space, form and appearance by physical modification of their structure, skin or internal surface. Transformable structures are physical constructions consisting of movable interconnected parts that can readjust their positions either manually or through input systems according to demand. The

outcome is an overall change of the physical arrangement of the structures that is determined by the set of interior parts and their inbuilt transformable mechanism. The mechanisms of transformability tcan be utilized to accomplish real development take after seven essential standards: that of folding, rolling, tension, nesting, scissors, tensegritic, and pneumatic (Yiannoudes, 2016).

The principle capability of transformable structures is that they can suit various circumstances, topographies and can take various desired forms on the premise of the user's needs. Transformability in nature could be viewed as way for advanced adaptation. In other words it is a flexible architecture with the capacity to quickly take on new shapes, forms, functions or character in a controlled way. Additionally it empowers dramatic change in the character of the whole architectural environment (Maziar Asefi, 2010).

2.4.2 Forms of Transformability

With the understanding of the meaning of transformable architecture, it is clear that architects tried to develop architecture not only to adapt as seen in the previous section but to transform as well. Moving forward, the following discussion would describe the transformable architectural forms and motivations that encouraged architects to design these transformable designs. Transformability could be found in different forms, unlike adaptive architecture which is categorized in only two forms transformable architecture is considered a more advanced type of flexible architecture, these forms have been summed up into now three categories which are: spatial transformation, structural transformation and environmental transformability which are often driven by multiple needs and aspirations.

2.4.2.1 Spatial transformability

2.4.2.1.1 *Building scale*

Transformability tries to fuse dynamic space capabilities inside the building. By embracing such an approach, the created spaces get 'freed' from the altered and inflexible connection between its structural and morphological components. Therefore a dynamic condition rises where the thoughts of 'conceivable position', 'range of movement' and 'degrees of opportunity' are incorporated into the structure (Calabrese, 2008, 106). Atelier Philéas designed a room in the workspaces of the

Hub Créatif d'Euro that can rapidly change and transform from an area with stadium seating to a meeting room with a table that appears from the floor. The space may take various distinct configurations totally clear for entire sessions or gatherings or with dim blinds for viewing projector presentations (Hespel 2009). Similarly the ' House Bordeaux' designed by Rem Koolahas is a house that contains a hydraulic floor which is mainly an office floor and is capable of moving vertically through the house creating a spatial dynamism within the house that is always changing and redefining the space of the office as well as the space where it stops (Kroll, 2011).

2.4.2.1.2 *Urban scale*

Architects have been trying to figure out how to maximize use of an urban space. They envision a space's purpose by making it change easily and evolve to meet the users' needs. Unlike adaptability, transformability is not applied very much on an urban scale. However one design hast that has helped in solving an urban spatial problem is the "Transformable Playground" designed by Studio B.U.S in Seoul. Due to the high level of population and lack of space in Seoul there's little room for parks making it difficult for people to practice their daily sportive activities. In order to give people more access to practice and play, designers found a way to make more sport activities fit in the city: They designed a mini sports field playground which can be folded up, transformed or moved according to its users, converting any public space into a playground area. The project has room for a game of mini soccer on one side and basketball on another. It also features a wall for practicing tennis, space for a game of target practice with flying discs, and a snack bar. Unfolded, it makes more room for soccer, and adds space for hammock-like hanging beds on the back. This not only solves urban space problems, but also in encourages outdoor activities (Peters, 2016)**.**

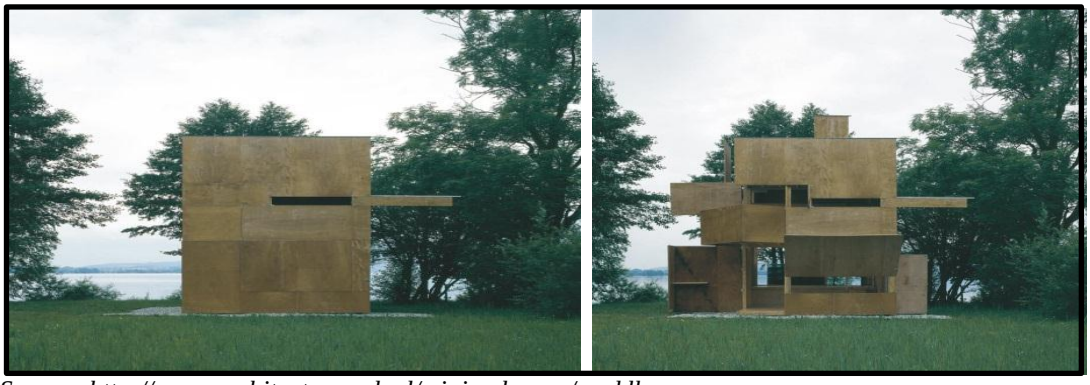
Figure: Transformable playground for tiny space, Studio BUS, Seoul

Source: http://www.psfk.com/2016/06/transformable-playground-invents-games-for-tiny-spaces.html

2.4.2.2. Structural transformation

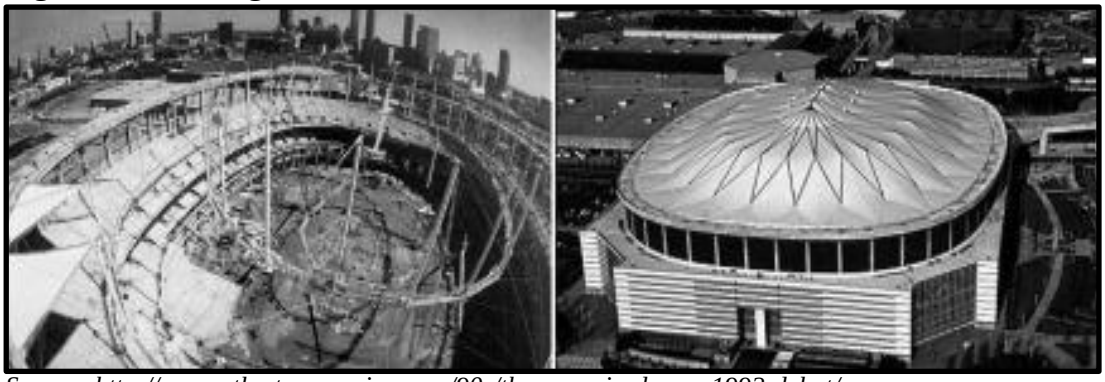
Designing transformable structures requires special techniques and considerations including construction techniques, materials, structural performance, which make their design more difficult and complex in comparison with conventional static architecture. The most widely employed techniques of transformable structures are the folding techniques. The GucklHupf by Hans Peter Wörndl is designed of folding the whole structure; the objective was to provide the inhabitants with the ability to modify their living space, the lighting conditions within and the views of the surrounding environment according to their needs and wishes. By pushing, folding and shifting walls, the house transforms from a solid box to an intricate lookout. Not only do the views and lighting shift by moving and closing partitions in different settings, but also the interior spaces can therefore become the exterior (Castle, 2000). Another common transformable structure is the opening and closing of the roof. The Georgia Dome designed by Chuck Hoberman in Atlanta, is considered the largest dome in the world and consequently indicates the great potential of tensegrity structures which is a strategy that utilizes both tensile and compressive elements to reduce the overall weight of the roof. The integration of the structural elements, the translucent membrane covering, help in transforming the building from a football stadium to other uses as well (Ishii, 1999).

Figure 2.10: GucklHupf, Hans Peter Wörndl, 1993



Source: http://www.architectenwerk.nl/minimalspace/gucklhup

Figure 2.11: Georgia Dome, Atlanta, 1992



Source: http://www.atlantamagazine.com/90s/the-georgia-domes-1992-debut/

2.4.2.3 Transformability for environmental purposes

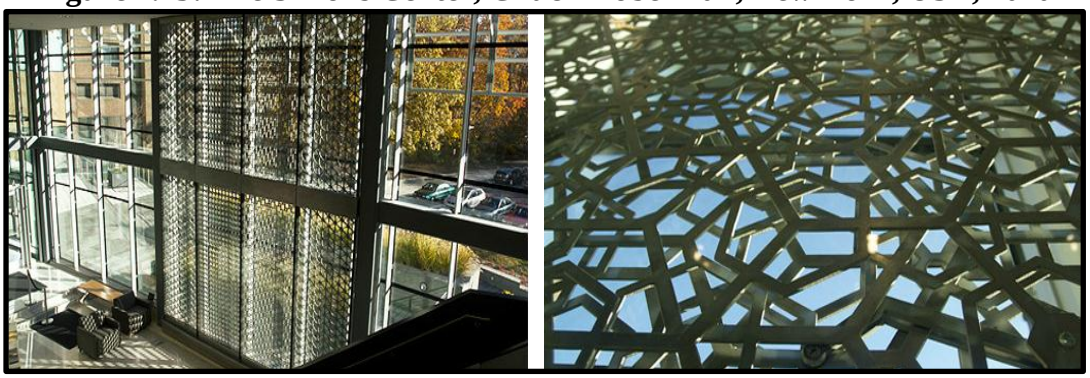
The environment is constantly changing providing a complex set of stimuli for transformable architecture. The sun's movement is the most obvious, however, changes in temperature, humidity, and wind pace and bearing give critical strengths that could be utilized favorably rather than seen as an issue to overcome. One such project is the Medina Mosque folded umbrella structures by Bodo Rasch in Saudi Arabia completed in 2010; these umbrellas change their geometry from an open and dynamic state to a shut and inactive position that work as a shading device for the pilgrims. The umbrellas cooperate to constitute the convertible shading roof for the mosque's court. In order to have the expected result and provide pilgrims with ideal shade and environment, the high tech sunscreens are made of a specific material called PTFE fabric, which resists the forceful ultraviolet radiation. Like sprouting blooms, they all are customized in minutely postponed arrangement to open and close simultaneously to avoid collision between their moving parts. Other than that, the material has to a great degree of resistance to wind force, and imperviousness to fire, most extreme flexibility, as well as powerful shading and suitable light transmission (Designer, 2013).

Figure 2.12: Medina Mosque transformable umbrellas, Rasch, Saudi Arabia, 2010

Source: http://www.sefar.com/data/docs/en/7238/AS-PDF-Architecture-Exterior-Medina-sunshades-EN.pdf

Façades also can be intended to transform its shape according to its environment, like the Simons center for geometry and physics by Chuck Hoberman which serves as both the building's masterful centerpiece and as a functional shading device. Hoberman designed every board to have a special geometric design pattern of punctures that mirrors each examination room of the building. As these patterns adjust and veer, the visual impact is of scanty geometric examples like hexagons, circles and triangles that change into a hazy cross section. The outcome is furnishing the building with the useful ability to progressively change its opacity and shape the nature of light inside (Hoberman, 2010).

Figure 2.13: The Simons Center, Chuck Hoberman, New York, USA, 2010



Source: http://www.hoberman.com/cv-c-hoberman.pdf

2.4.3 The Impact of Technology

Technology specifically helped in the improvement of materials that can physically change, modify their appearance as well as their dimensions. For instance the "transparent concrete" is solid material with changing properties that have a level of transparency embedded in them. This material has the capacity to make a transparent structural system which radically changes the levels of light and opacity of itself according to the environment in which typical structures of today take into consideration (Fortmeyer, 2009).

Technology additionally helped transformable architecture to meet environmental needs and even to generate unexpected situations. For example, designers can reach out to the public by conveying historical, social and political messages through transformable facades.

The advancement of simple geometric design software played a great deal in the development of transformable architecture. Examples like Rhinoceros 3D and Grasshopper have helped in producing a wide range of complex structures, and tolerating extra plugins for live physics. Not only is parametric modeling great for easily creating geometries, it also instantly evaluates the kinematic conduct of structural mechanisms (Tibert, 2002).

2.5 INTERACTIVE ARCHITECTURE

2.5.1 What Is It?

Interactive architecture is the sort of design that performs interaction between the building machines and individuals. It is designed with the aim to create spaces and objects that can address the changing needs with respect to evolving individual, social and environmental demands (Michael fox, 2010). Intelligent building systems are utilized to create intuitive architecture that responds to the users' needs in modified or instinctive ways. It is the kind of design that alters itself according to people's actions and requirements with the assistance of technology that can trigger a broad assortment of activities such as, dynamic systems that physically change space, services that change the environment, in a programmatic or instinctive ways making both the building and the user participate in a progressing discussion. Interactive environments give the people the opportunity to engage with space not as inactive individuals

existing in a static arrangement of conditions but as proactive individuals influencing the space they use (Kronenburg 2007).

Interactive architecture is an advanced multi-disciplinary kind of flexible architecture which mainly depends on the incorporation from the world of; architecture, mechanical configuration, computer programming and physical computing in order to reach maximum flexibility (Jaskiewicz, 2013).

2.5.2 Forms of Interactivity

With the understanding of the meaning of interactive architecture, it is clear that architects tried to develop architecture not only to transform as seen in the previous section but to interact and respond as well. Moving forward, the following discussion would describe the interactive architectural forms and motivations that encouraged architects to design these interactive designs. Interactivity could be found in different forms, these forms have been summed up into three categories which are: spatial interaction, environmental interactivity and interactive installations.

2.5.2.1 Spatial interactivity

2.5.2.1.1 *Building scale*

Currently, a new interactive development is starting to take place in architecture whereby there is an expended yearning to make a space that can progressively collaborate with users. Most of the places designed in general are to a great extent inactive and passive. Interactive spaces attempt to explore how new technologies, materials, and methods can be used to accomplish creating active and evolving places that respond to the intricacies of life (MIT 2005).

One example of interactive spaces that interacts with its users is the Bill Gates house, Paul Reuber claims that "a house is not a home until a resident makes a personal imprint on his or her own space." This, he believes, prompts "user-oriented architectural design" (Reuber 1992, 7). In the Bill Gates house, a personal tag is worn which distinguishs every person inside the house and adjusts the temperature, music and lighting according to the individual**,** as one moves, speakers hidden in the walls of the house permits music to trail the user from one room to the other. Also the house has computer screens that are hung on the walls which act as artwork, displaying the

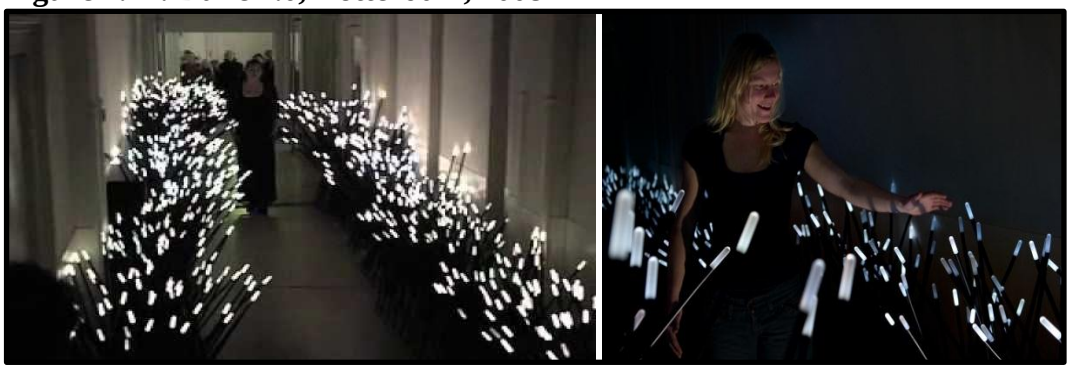
user's favorite picture or painting and can be easily changed according to the user. The whole composition of the household and conditions change in according to the users which makes it particularly a "user oriented" house (Sommerer, Mignonneau, 2008).

2.5.2.1.2 *Urban scale*

In the urban scale, there are spaces that are called "in between", these spaces are found in between buildings or neighborhoods. These spaces are most of the time considered as uninteresting spaces. Their primary goal is to take the individual from one point to the other. They can have different forms and spatial structures yet all those spaces share two mutual features: they are public spaces and they behave as transitional spaces. Examples of this sort of spaces are usually found in below ground passages in public buildings. In this segment, the upcoming example demonstrate how designers of interactive systems saw these spaces as spaces of opportunities in which the expansion of an interactive computerized layer was utilized to deal with an architectural problem (i.e. flow and movement); an urban issue (i.e. infringement/safety measures); diverge the way of the space (i.e. spontaneous social intercommunication); by merely making urban wandering a more lively encounter.

The Dune 4.0 is an example of an underground urban interactive space which reacts on the presence of people. It is situated in the pedestrian tunnel of the Maastunnel in Rotterdam. Dune explores nature in a revolutionary connection with urban space by means of looking, walking and interacting. The mixture of nature and technology occur out of large amounts of fibers which are illuminated depending on the sounds and movement of passing visitors (Roosegaarde, 2008). Dune's main interaction strategy evolved around the idea of play, playful interactions which would enliven and transform the dark and uninteresting nature of the space into a lively one.

Figure 2.14: Dune 4.0, Rotterdam, 2008



Source: https://peppermindac.files.wordpress.com/2008/10/9-dune-40_-studio-roosegaarde.pd

2.5.2.2 *Interactive environments*

There is a wide ranging necessity for an architecture that is 'environmentally respondent' (Von Hoffman, 2005) or designs that act in response to the frequently extensive needs of atmospheric conditions, place and society (Slessor 2006). When talking about the environment, one perspective is the climatic conditions, which contains the occurrence of regularly ever-changing sun angles, course of the wind and power, temperature, rain fall and humidity. The Institute du Monde Arabe designed by Jean Nouvel in France is a climatically interactive example in which a developed responsive metallic brise soleil is installed on the south façade. These metallic structures which correspond to the design of a 'mashrabeya' are efficient from an environmental control perspective, where solar gain is easily relieved by closing or contracting the opening structure. The system combines various light reactive rings that control the quantity of light that is permitted to penetrate the building. During the diverse stages of the lens, an ever changing symmetrical design is formed and displayed as both light and void. Squares, circles, and octagonal shapes are created in a smooth movement as light is controlled at the same time. (Radford, 2009).

Figure 2.15: Institute Monde du arabe, Jean Nouvelle, 1987

Source: http://www.archdaily.com/162101/ad-classics-institut-du-monde-arabe-jean-nouvel

2.5.2.3. *Interactive art installations*

In recent years, human-oriented technology has been leaning to subcultural, stimulating and tangible human interactions (McCullough, 2004). An increase of improvement in interactive provisions has encouraged augmentation of a wide range of spatial art installations with both installed and built in computing. Due to the complexity of embedding interactive designs in a building, to date, only a small amount of interactive designs exist. Designers have focused more on creating interactivity mainly on the facade or other small elements inside the building rather than the entire architectural work. The most commonly used interactive designs are materials particularly textiles, with the help of sensors these materials can now change their appearance, illumination, position, contract or enlarge in response to human contact and sound (Thomson, pp.35-42). These investigations are seen as "art" instead of being considered as actual architectural or building engineering research. Consequently most of the interactive endeavors and designs are considered experimental, primarily designed with the aim of reviewing it in a social context. An example of a "building to user" interactivity is The Son-O-House by NOX 2004 in Netherlands. The installation creates an interactive sound architecture that gets its information from sensors to produce a live soundscape that is dependable on the presence and behavior of people using it. The installation gives people the opportunity not just to hear sound playing in a musical construction, but also to contribute in the making of the sound. The main purpose of this environment is to generate an everlasting interaction between the sound, the architecture and the users

(Heide, 2002). The sound contemplates to persuade and get involved with the experience and the movements of the users in which the presence, activity and location of the visitors is being detected by sensors in the building. This information is simultaneously induced and specified and therefore used to operate the nature of the sound, and by that, challenges the visitors to reprise their relationship with the environment.

Figure 2.16: Son-O-House, NOX, 2004, Netherlands

Source: http://www.arcspace.com/features/nox/son-o-house/

2.5.3The Impact of Technology

One of the main purposes of interactive designs is to play with human experience and therefore to greatly shape the spatial experience of people. Digital media systems are the most efficient means since such systems are being broadly used in art installations, captivating and alluring people's attention and appeal. The core of interactive computational technology can allow buildings or spaces to exemplify correspondence of information technology, respond to human and environmental contribution and obtain sensitivity to behavior (Saggio, 25). These include the ability for continuous formal and visual change, reconfiguration and personalization. Embedded computing has also provoked tangible interaction with physical world in real time against physical and social settings (Dourish, 102).One of the most common production of technology in interactive architecture is the attempt to make a structure alive, that could memorize react and respond. One example of this type of advancement is the Hylozic Ground by Philip Beasley where a huge number of lightweight digitally-manufactured segments were fitted with microchips and proximity sensors that responds to human nearness. This responsive environment

works like a big lung that inhales in and out around its users. Varieties of touch sensors and shape-memory compound actuators (a kind of non-mechanized active system) make floods of empathic movement, attracting its guests into the ghostly shining profundities of a legendary scene, a delicate forest of light (Beasely,2010).

Technology also helped in the development of materials such as the 'Shape Memory Alloys' or 'Nickel Titanium Alloys'. These alloys have the distinct feature of repositioning their molecular connections every time they are exposed to a specific trigger-state of energy, usually provided by heat or electricity. When this occurs, the alloys change their shape in two or more pre-programmed forms. This type of transformation can be used directly, as an architectural effect, or indirectly, as an element of mechanical amplification (Widberg, 2011).

3. EVALUATION

Flexible architecture is considered a broad field that incorporates many types of architectures including adaptable, transformable and interactive in which their purpose is to accommodate and adjust to the user's needs. Flexible buildings are designed to accommodate the different needs defined by users' activities. Through years of architectural progression, changes have taken place step by step in how buildings are conceived and built. Architectural ideas adapt to time, in which they are established and realized. These flexible concepts result from time changes, society, financial situations, the requirements of users and environmental conditions. In one case the overall climatic change, that happens over a period of time, produce forces for architectural object to change over the years in order to maintain and sustain itself. Adaptation in architecture on one hand is an enduring process where adaptive buildings as explained before endeavors to use less energy, offer more occupant comfort, and feature better overall space efficiency to the building. The merit of designing an adaptive building at one point is that it is utterly independent of technology where a simple building with the basic principles such as natural ventilation, spatial and thermal comfort inside a building could be considered a highly adaptive building.

Transformable is a more developed kind of flexible architecture which allows the revaluation of the enclosure of buildings by changing shape, space, and form by physical alteration of their structure in order to react to the architectural or structural requirements, or to modify itself to various environmental circumstances. While typical traditional architecture may only include the users of the building in the design development, a transformable building can involve its user before, during and after the design procedure. The degree of success of this type of architecture is highly reliant on the capability of the structure to handle the active loading conditions and circumstances and to transform into a steady shape that can meet both architectural and structural requirements. Transformation doesn't only mean expending the space of a building from indoor to outdoor that occurs by means of sophisticated structural transformation; rather it can change architectural spaces by implementing movable elements using simple transformation patterns. These buildings create a dynamic

architectural space that gives the users opportunities to extend their creative, social, environmental and aesthetic knowledge.

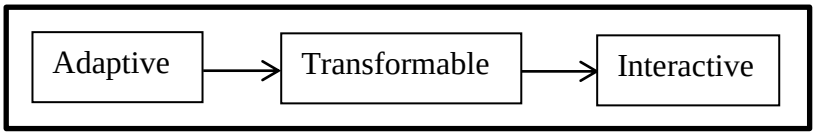
Interactive architecture on the other hand is an evolving design practice that tries to combine advanced technologies & computer simulated spaces with perceptible and substantial spatial occurrences. This idea has to be realized in the technological level of computer systems installed in the structure of the built environment, unlike both adaptable and transformable designs in which the building can be changed or adjusted either manually or automatically in response to provide user comfort.

Interactive architecture is the type of architecture that responds to the user's requirements in an instinctive way. Interactive architecture is completely dependent on technology and computation in order to uphold a going conversation between the building and the user and its surrounding environment, to the extent that intelligent spaces are now applicable for many tasks, unfortunately it hasn't reached the point in which it could be applied completely on a whole building.

What is common between them all is that they all include variable elements in order for the building to modify and accommodate itself according to how it is perceived; these types of buildings make room for spaces to be used for diverse purposes, grants liberty of use, and encourage responsive social and cultural interaction.

Figure 1 presents the levels of flexibility based on the level of sophistication, which increases from left to right

Figure 3.1: Level of flexibility in order of technological sophistication.



Adaptive is the first step in flexible architecture. With adaptive architecture the prospect of modifications on certain compositions or elements of a building are aimed. This undertaking is in complete control of the user to personally change to what is needed. The ways of having change occur are limited and technological utilizations are unimportant. Transformable design is based on either mechanical transformation which existed since the 1920s or with computer technology that has been available since the 80s. A step further is taken with interactive architecture in which the building

components can have a two way conversation with the users and/or environment. A conversation is established between the user and structure. A cohesive setup is necessary for interactivity to take place in which digital censoring was within reach since around 1994.

This is a brief explanation of flexible architecture which has transformed from being functional to intelligent with changing needs of time. Social environment is continuously changing and architecture needs to adjust itself and change with it as well. Since its very origin, architecture has been evolving to provide the requirements of its inhabitants. However, in recent times with the changing conditions of the environment, it is therefore inevitable that architecture reacts and responds to all the diverse conditions and accomplishes the aim of its existence.

4. EVOLUTION

In the two decades it became clear that flexible architecture connects many different fields, like the fields of arts, cybernetics, mechanics and technology and many more. Whether buildings in this perspective are expressed as adaptive, transformable or interactive, they preserve the idea of architecture being flexible rather than fixed.

Within this standpoint, the main purpose in this chapter is to find out how flexibility gives the architect the chance to express creative substitutes that will react and respond to the varying demands of the users throughout tenancy. Also to understand the scales and boundaries of flexible designs over selected three cases of the last decade: Sandai Mediatheque in Sendai-shi, Japan, designed by Toyo Ito in 2001; Sharifi-Ha house in Tehran, Iran, designed by Next office architects in 2013; and The BIX, a communicative light façade in Austria, designed by Realties architects in 2003.

Figure 4.1: Sandai Mediateque; Sharifi-Ha house; The BIX in the evening

Source: http://www.archdaily.com/118627/ad-classics-sendai-mediatheque-toyo-ito
Source: http://www.archdaily.com/522344/sharifi-ha-house-nextoffice
Source: http://www.archdaily.com/89408/bix-light-and-media-facade-at-moma

These case studies have been investigated in this research in order to gather facts and examine the theories behind flexible architecture. These case studies have been selected due to: The three case studies are thought of to be entirely flexible structures in which some of them are designed for public use and others for private use, the three projects differ in how technology interferes to achieve. The Sendai Mediateque is a cultural media center designed for the

general public, it is an adaptive building that doesn’t mainly depend on technology for achieving adaptability and flexibility in its design. The Sharifi-Ha house is a private house designed with a transformable exterior leading to the building's volume to open and close.

The BIX project was built as part as the European Capital of culture, it is a museum which specializes in contemporary art. It is considered an interactive type of design, in which the building translates what is happening inside the building onto its façade, this is achieved with the help of advanced technology.

These case studies depend on demonstrating the use of technology and its importance to get a hold of a specific level of flexibility; the first in Sandai Mediateque in which flexibility was achieved without the help of technological interference, in the Sharif-ha House, there is a moderate use of technology and mechanical structure were used in order to reach flexibility, and finally the BIX completely depends on its technological interference which make the building a flexible one. This comparative analysis investigates the principles of evolution of flexible architecture and its effect on its users; also they will give the opportunity to answer the questions asked previously with the information collected, and gives the chance for conclusions to be put down. These case studies would be based on five dimensions: Intention, Form, Structure, Function and Technology.

4.1 SANDAI MEDIATEQUE

The preparation to build the Sendai Mediatheque started out in 1994 when a competition took place for the design of the building. The preparations for the building called for a building that is multifunctional which contains many facilities. The span of the project was modified to encompass a more extensive circle of abilities that would permit it to work as full mediatheque representing the necessities of a continuously changing information and innovation environment. The competition was won by Toyo Ito who thought of the space as liquid and imagined the columns as seaweed skimming through an aquarium (Sveiven, 2011). The design of the Sendai Mediatheque took a sequence that without a doubt was not the same as traditional structure. Firstly, the buildings was originally deigned within the early years of the information age. With so much uncertainty concerning the definition of that time, what it would contain and manage, the building needed to be firmly integrated. "It needed to be the presentation of a new urban function space for an age" (Ito, Sendai Mediatheque, P.9), merging digital media with audio and visual electronics while making a space which manages connections on multiple levels. In short, it needed to be a building with no specific program (Witte, Sendai

Mediatheque, 29). The outcome of this study suggested a way to a conception of space that was not similar to most space designs of the postmodern time and still one of a kind in many ways today.

Structurally, Ito was inspired by the Domino system (which uses the method of vertically stacking columns and beams) from Le Corbusier's "catalogue" of modernist architecture. Ito got the possibility of the stacking domino effect with floor slabs, by supplanting the columns with structural components, put in a symmetrical form in which mirrors the buildings connected nature. The resulting structure was composed of three architectural components, plates that acted as the building's floors, tubes which are the columns that looked like trees and the skin of the building. Ito considered these components as the vital basics of any architectural building.

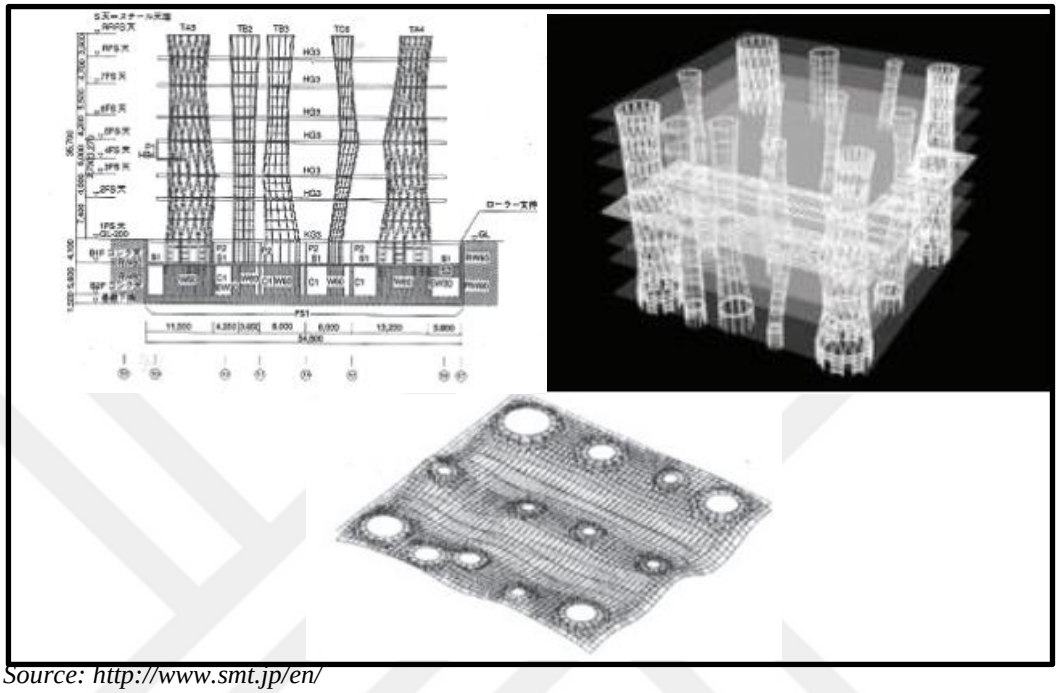
Figure 4.2: Sandai Mediateque, façade and exterior

Source: http://www.smt.jp/en/

"Connected to one another, the Mediatheque's basic elements operate within a different rule-set from those propounded by the rules … which were modern architectures arbiters of control" (Witte, 2001). This is demonstrated in various parts throughout the whole building. For example, the supports within the floor structure are organized according to the structural requirements to transmit loads to the erratically designed columns that are located all around the building rather than the traditional method for load transmitting. Moreover, likewise, the circulation and flow system on each floor is organized around the furniture pieces, partition walls and information areas, in which each area is separated to what is close to five meters from each other. The effect this has on the building is that each floor are instinctively different in terms of organization that every floor could be thought of as another building as they connect to their present program, yet the whole building is

connected to each other through the tree like tubes structurally controlling the form of the building.

Figure 4.3: Sandai Mediateque, structural system (tubes) and plates (floors)

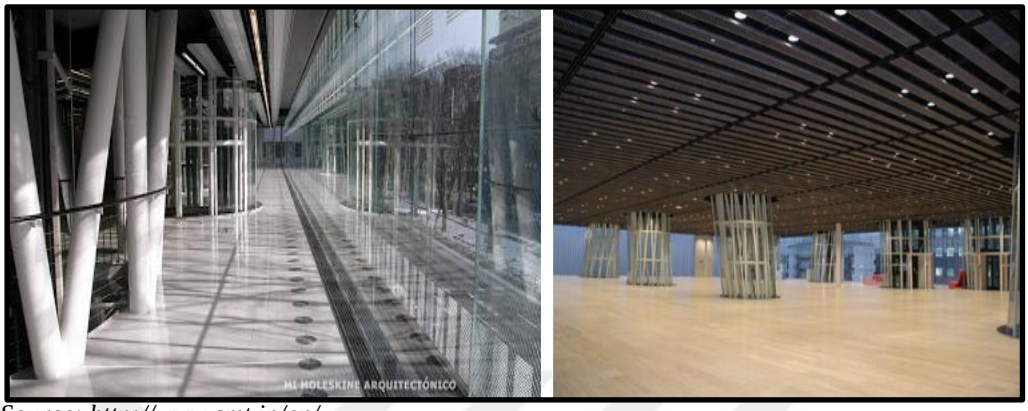


Source: http://www.smt.jp/en/

The building contains specific natural and dynamic potentials; the building is barrier free, whether between people with and without impairments, or between languages or cultures and traditions. As tubes are the principle aspects, they are equipped of great enhancements and are intended for energy absorption in case of the high probability of having earthquakes in the seismic region of Sendai. Furthermore, Witte states that elevators go up and down to electronic tones; the tubes (structural columns) are most of the time obfuscated with condensation, clearly from a ventilation system, and filled with faintly changing daylight that emerged from the inside. It was as though the building itself was beginning to breath (Huxtable, 2011). The representation of the building explains its potentials as a single substantial body as it responds to its environment. On a smaller scale, the Mediatheque contemplates the association between the general public as a body to the building. According to the intentionally proposed concept of the Mediatheque, it demonstrates that it is effortlessly accessible and useful to anybody within the surrounding environment. That is a space for the audio and visually disabled a completely practical library which would be useful to all age groups, and an urban exhibition. The building

would then serve as a space for combination of these elements. Therefore, the integration of these elements with the building results in a foundation for components to interact (Svieven, 2011)

Figure 4.4: Sandai Mediateque, interior space



Source: http://www.smt.jp/en/

The building serves as a space that bears diverse activities for various individuals. On one level of form, the unsymmetrical size of the tube structures, the various spatial qualities on every floor and the building's diverse façade, all help in drawing attention to the building deficiency of functional program. Ito allowed the form to be an agent of program and created a building which represented a non-program building, in which any type of program could effortlessly engage with. On a smaller scale, the main idea of the Mediatheque itself was focused around connecting the diverse spaces together. A new building for the Sendai urban exhibition, a substitute framework for the building's public library, and enhanced an education and communication service centers for the audio and visually disabled. Subsequently the building itself functions as a working body which adopt the combination of these service centers (Pogoson, 2011).

Figure 4.5: Sandai Mediateque interior mixing of spaces

Source: http://www.smt.jp/en/

The conceptual mixture of spaces and integration of people and the surrounding community to the building, change the building itself into an open and desegregated flexible body that suits all functions (Albert, 2003). Sendai Mediatheque is a precisely constructed, adaptable body, for it to work for its intended function, first, its structural abilities should be integral. Second, it has to contain a system which will adopt interoperability alongside with the structural components which are integrated to the building. Therefore the building reaches maximum adaptability through integration of information, combination and alteration of spaces, connection of people with each other and with the building and the existence of transparency throughout the whole building, all of this with minimum use of technology to achieve adaptability in the building (Sakamoto, 2011).

4.2 SHARIFI-HA HOUSE

The Sharifi-Ha house is a residential building for a single family designed by Next architects in Tehran, Iran. In Tehran the summer climate is somewhat warm and the winter is rather cold, a typical type of weather conditions in which architects came up with a distinct solution. The house is built on a considerably confined location between two other buildings, forcing the building to have a narrow façade, with a deep lot. The architects were inspired by the opening and closing idea of the building from the conventional Iranian houses that have both a summer living room (Taabestan-Neshin) and winter living room (Zemestan-Neshin) which would actively work well for seasonal changes. In summer, The Sharifi-ha House proposes an open, translucent and crenellated body with broad and large terraces. The contrary happens during the cold, snowy winters of Tehran, in which the body of the house shuts itself,

offering the least possible amount of openings, removing the wide summer terraces. In this project, the demand to for an open and closed concept (introverted and extroverted character) required a stimulating spatial transformation of an ever-changing residential building (Jahangiri, 2015).

Figure 4.6: Sharifi-Ha house narrow façade and movable boxes

Source: http://www.archdaily.com/522344/sharifi-ha-house-nextoffice

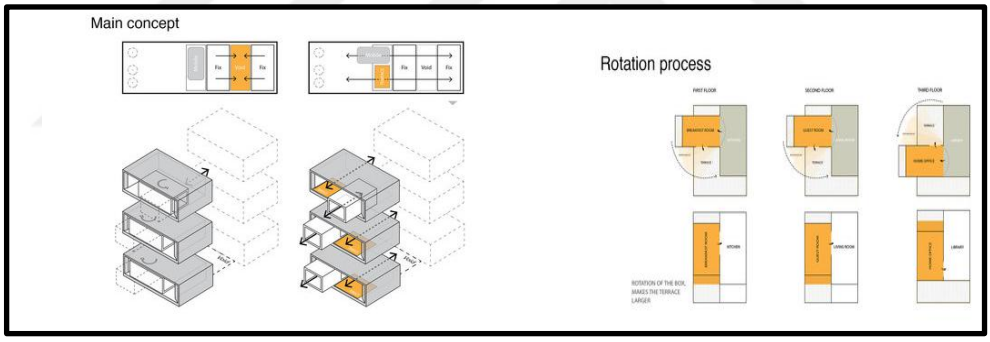
The house is divided over seven floors: the two basement floors are entertainment floors which contain a gym and other leisure facilities, while the ground floor contains the parking and housekeeping rooms. Most of the activities are done on the first and second floors, and on the third and fourth floors is where the family practices their private life (Ames, 2016).

The house contains three boxes that look like drawers that fit into a simple concrete structure, each box rotates separately which gives the house opportunity to be partially opened and partially closed. A door is placed on the side of each box which opens onto the terrace when the house is open, and into the interior of the house when closed. Having a space that can rotate means that the forms and composition of these three specific rooms can be changed at any time and giving an opportunity to benefit from multiple qualities of light and views according to the season. The impressive, spatial characteristics of the interiors, as well as the unconventional structure of its exterior, instantaneously react to the movement of the turning boxes that drive the building's volume to become open or closed, introverted space or extroverted one (Moreno, 2015).

Figure 4.7: Sharifi- Ha House, transformable boxes opening and closing

Source: http://www.archdaily.com/522344/sharifi-ha-house-nextoffice

Figure 4.8: illustration of the main concept and the relation process of the boxes



Source: http://www.archdaily.com/522344/sharifi-ha-house-nextoffice

The house accommodates itself to the functional needs of its users. For instance, depending on whether or not there is a guest in the house, the guest room that is located on the second floor can be adjusted for different purposes. Also, the home office and breakfast rooms which are placed in the rotating rooms in the first and third floors can change the form of their according to the how the inhabitant wants it to be.

The constructing technique used for the rotating process is an uncomplicated one; it is the same technique that is now used in rotating stages in theaters and rotating of floors in car museums. Details of the handrails and the controlling of air that enters the house were major problems that were put in consideration in the design of the

rotating boxes. Designing foldable handrails, improving and refining the corners of the boxes were the utmost solutions (Ames, 2014).

4.3 The BIX Kunsthaus Graz

Kunsthaus Graz, a museum for worldwide exhibitions of modern and contemporary art, was introduced in September 2002 in Austria. The building's design idea came from the winning competition design by Archigram Peter Cook and Colin Fournier in the 1960s. The unevenly formed, living organism shaped like building structure hangs by itself like a single handed body, which looks like a balloon, over a glass foyer. The shimmering blue façade is the main feature of this building, crystalline glass panels, covering the whole volume of the building like a skin. The Berlin-based design studio 'Realities United' in 2002 proceeded to develop the building's skin more and transformed it into a huge media screen called BIX. The BIX was an advanced installation element that was added later on to dominate the riverside front view of the building, by this means completely redefining the architectural idea of the building's skin (Kolarevic, Malkawi, 2005).

Figure 4.9: The BIX Kunsthaus Graz, a new standard in architecture and technology

Source:http://designtoimprovelife.dk/bix-communicative-display-skin-for-the-kunsthaus-graz/

Underneath the glazed surface facing the river and the city center, the architects used a grid of fluorescent light rings casing, an area of around 20 m high and 40 m long.

Each light ring acts as a pixel, in which its illumination can be computer-controlled and varied at a speed of 18 frames in a second. This means, the generated light patterns are of low-resolution but can be visible all over the façade and can be seen from a reasonable distance all over the city. Each individual pixel is a typical 40W fluorescent bulb with a 40 cm diameter. The reason for using these economic components illustrates the irregular design feature of the BIX idea which is to blend with the river front context. The matrix's display resolution is considered to be very low. There are 930 monochrome pixels installed. On one hand, this low image resolution puts on strong limitations; on the other, however, it gives both the flexible structure and the large size of the installment, an opportunity to be combined into the design and its surrounding environment (spacelab, 2000).

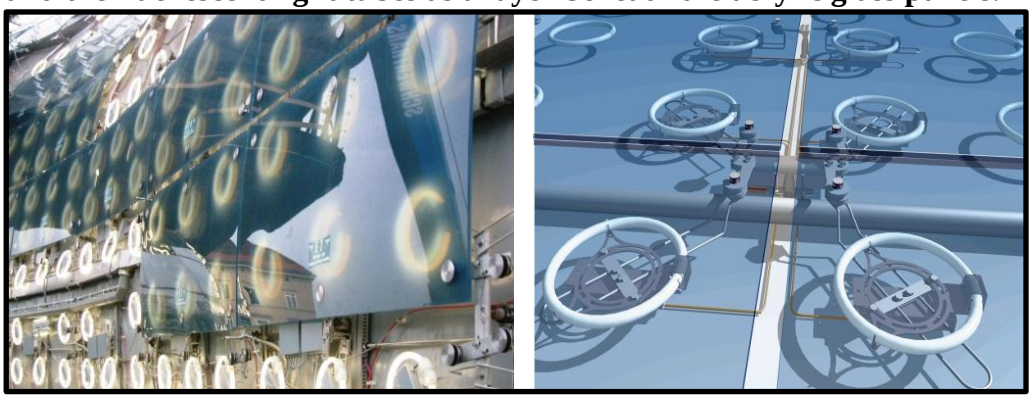
Figure 4.10 the BIX communicative skin

Source: http://designtoimprovelife.dk/bix-communicative-display-skin-for-the-kunsthaus-graz/

Sharing the same scale, the architecture and the media installation establish together new, creative and artistic effects. The installation is not viewed as a distinctly fixed display wall but as if it is part of the Kunsthaus building that the whole building gleams images and characters; the installation and the building attain a very high level of integration as a single individual body (Pakesch, 2005). The light grid does not compose a rectangular image with straight edges, but instead a vague zone, customized to the complicated form of the building and bit by bit diminishing away as it comes closer to the edges. Concealed behind the tinted covering glass façade, only the functioning light rings are apparent, while the rest of the inactive light rings remain unseen behind the skin so that the installation’s edges are not always detectable. Therefore the building gives the sensation that the blue bubble itself displays light displays from the inside (Ruby, 2000). In the nonexistence of an

absolute boundary, it seems as though the light images could dance freely on the outside skin of the building. BIX, moreover, gives the Kunsthaus Graz amazingly more opportunities than just an impressive aesthetical touch; the installation also acts as an architectural facilitator, realizing the envisioned concept of the building's skin. Most of the installation is vague, but from time to time there are exposing slivers of translucency of the presence of action inside the building. Different things appear and disappear within the skin: announcements, short parts of film or images: viewed for moments, only to disappear again. The BIX project fostered these architectural fantasies at the time when it became obvious that the main concept of a mostly translucent skin would have to change for technical reasons. The installation keeps a hold of the main design purposes, even if in a considered way. In this way, BIX did not only achieve the original architectural concept but the installation became an indispensible argument in explaining the reason behind the expensive tinted covering façade boards to be placed in front of the inner non translucent, covered and hidden, bubble-like shell structure (Pakesch, 2003).

Figure 4.11: The BIX installation of the acrylic glass panels over the light tubes and the fluorescent light tubes as a layer beneath the acrylic glass panels.



Source: http://designtoimprovelife.dk/bix-communicative-display-skin-for-the-kunsthaus-graz/

The façade working as a display expands the communication range of the Kunsthaus Graz, achieving its program of organized friendly communicative aim. In a conceptualized and well-chosen form, the media façade translates the processes happening inside of the Kunsthaus Graz out into the public, by forming a synergy between art, architecture and media all together. BIX, therefore, becomes an identity, and an image-building feature of the Kunsthaus Graz. Peter Pakesch, Director of the

Kunsthaus Graz, considers the BIX as a new level of art intervention, in which he sees that the architects have successfully presented a new sort of transparency which is not like the shallow kind of transparency that is found in a glass house, but it is considered more an informational transparency and the translucency of content, for which it still has a long way to be developed. It is considered a challenge in architecture for achieving this high level of transparency (Pakesch, 2003). If a cultural establishment like the Kunsthaus Graz is a way for artistic expression, the BIX installation increases its power by making the whole Kunsthaus Graz into a "power tool", where its power is not seen in a physical point of view but most of all by the ability to translate and spread information and meaning. The communicating skin is a one of a kind exploratory working display place for art projects reviewing how the media and space can communicate together (Edler, 2011). With BIX, artists can investigate different cultural and artistic ways of presentation, whose application on commercially used advertising displays is widely carried out. The massive size and the low resolution of the installation in contrast with the showcase display systems aim at the main parts of artistic examination: diminution and intensity are powerful approaches of contemporary art to develop towards the inner fundamentals. In this way, BIX not only expands the Kunsthaus Graz's communication dimension spatially as well as temporally but the installation renews the overall program of the Kunsthaus Graz (Herre, 2010).

Utilizing low tech fluorescent light rings as the fundamental module for the showcase which concentrates on the problem of technological maintainability over time in which in high tech ones to become outdated at a fast pace. The BIX installation however functions by especially developed specific software tools, which are absolutely critical for the effectiveness and accuracy of the innovative preparations that are to be shown on the façade. There are two fundamental programming modules: the "BIX Director" and the "BIX Simulator". The BIX Director application gives the user the chance to create and arrange a program to be displayed on the façade. The application's interface is like those of famous video-altering situations. Four distinctive video tracks are accessible for arranging and blending various "occasions" on a 24-hour course of events. Along these lines, the Kunsthaus Graz can set up complex 'shows' for specific days or for a few weeks in succession. The second programming module: the BIX Simulator is much more

essential for artistic preparations. It empowers artists to analyze the outcomes in a constant three-dimensional (3D) computer stimulation of the Kunsthaus Graz in its notable connection. By exploring through the city as though utilizing a 3D "shooter" diversion, artists can guarantee that their creations adjust to the vast scale complex shape and the rough resolution of the façade display (Rotsztain, 2011).

4.4 RESULT ANALYSIS

Table 1: Overview aspects of the previous case studies

Name of project	Method of Flexibility	Intention	Form	Function	Level of Technology for achieving flexibility	Conclusion
The Sandai Mediateque	Free floor plan for flexible furnishing.	A building that could act as a social area for the city, a place where people could exchange information freely	A glass Façade that reflects the city and invites entry. The solid elements reflect the people on the street.	• Changed the flow of people in this part of the city, people use it as a destination • Each floor has different uses, and used as multipurpose spaces • It acts as a center of multiple activities serving as a public facility to help people freely exchange information with each other and learn how to use that information	the over reliance on digital communication tools has resulted in an increasingly poor interpersonal communication therefore low to nearly no technology used	An adaptive building with An open plan With various activities and lots of contact between the people and their activities
Sharifi-Ha House	Motor controlled apertures like room rotation Electronic driven elements, like opening and closing of the boxes and Folding handrail.	Designed for a single family. Limited construction site. An open and closed concept due to weather conditions.	Contains three boxes that open in the summer and close in the winter	• The rooms change according the users desire • The building volume becomes extraverted or introverted • Rotating rooms gives the opportunity to benefit from multiple qualities of light and views according to the season	Moderate, mainly mechanical systems as used in theaters and car floor exhibitions	A transformable building which Changes the building's volume from the inside and outside. Provides environmental comfort and functionality
The BIX Kunsthaus Graz	Adjustable translucency and image of façade. Possibility of motion pictures on	To transmit internal processes of the art institution to the public.	An irregularly biomorphic building structure with acrylic glass panels, wrapping	• The façade extends the communication range of the Kunsthaus Graz, • Artists can explore alternative cultural and	High level of digital technology and computer software	An interactive building that communicates with the public outside the

	the facade.		the whole volume of the building like a skin.	artistic modes of production.		building Technologically sustainable by using 'low tech' fluorescent lights, that way doesn't need to be constantly saving time, energy and cost

This table shows that the studied projects are all flexible and adjustable to their environment and to the circumstances in which they are designed for. Whether technology had an impact or not, technology used in a building depends mainly on what type of flexibility the building aims to achieve.

The Sendai Mediatheque as a building, structures a space which encapsulates the possibility of multidimensionality and interconnectivity for the most part through making people and the building interact with each other without the help of any technology, just by occupying the building. The mediatheque creates a space that develops and reclassifies space, its motivation as a building cultivates the rising above of space, with the vehicle being multimedia and the sound of the web. Toyo Ito at first remembering the vital element in the structure idea, that the wonder of design must be molded by the unstable, fluctuating society of the information time (Witte, 2002).

The Sandai Mediateque not only has a solid association with its context, but it is also a completely open building that contains multi-practical spaces with movable furniture that could be modified by the users, as indicated by the contextual analysis.

The physical space has seem to become an antidote to the world of digital technology since the over reliance on digital technology in general has resulted in an increasingly poor interpersonal communication. The Mediateque on the other hand has helped in improving a person to person communication by creating a place that is incredibly adaptive, open and friendly which has all these different activities available to use at any purpose.

The Sharifi-Ha house uses simple technology to achieve flexibility in design. By applying mechanical and electronic devices, the building can easily transform its outside shape, as well as expanding and contracting its interior spaces according to its user. Not only does it provide flexible use of space, but it also provides environmental comfort and functionality by the boxes that could rotate in summer time when the weather is hot. The box works a terrace and provides ventilation and transparency in summertime, while in winter, the house closes up to provide warmth and minimal openings.

The BIX Kunsthaus Graz on the other hand is totally reliant on technological obstruction. By utilizing conventional, round glaring lights for the BIX acts an open display, in which the public outside could have an idea on what is happening inside the building. Artists also utilize the BIX to show their art for public acknowledgment and for showing messages on occasions. Not only does the building communicate with the general society and users, it likewise communicates with its urban context.
What makes it a more flexible building is that the subject of being technologically up to date does not cause a problem since it uses low tech florescent lights as the fundamental module for the showcase which concentrates on the problem of technological maintainability overtime in which high tech ones to become outdated at a fast pace. By utilizing the glaring light rings, i.e. an "obsolete" innovation, the BIX display takes care of the architectural demand of consistency. This focal trait of the establishment is technological maintainability which spares the administrator steady redesigns and ensures an operational harmony amongst architecture and technology at similarly low expenses (Latherbarrow, 2003).

5. CONCLUSION

The focus of this thesis has been on flexible architecture, which explains that flexible architecture often reorganizes, and reflects the way users seize the possibilities and standards for living. Flexible architecture attempts accommodate the needs of the present time, such as social, spatial, cultural and environmental issues. Also it aims to push architecture into a more effective and maintainable stimulating product for the society. Flexible architecture is based on buildings with embedded adaptability and reacts to various circumstances and needs.

Flexible architecture has shown through cases in the early and late times and overviewing its history, that although the materials, technologies and needs of society change continuously. The idea of flexibility itself is still constant, which is to accommodate its user's needs. Based on the gathered information the term 'flexible' is commonly used in architecture in accordance to the changing forms of the architectural object. These changing formations are due to changes happening by time and development of architecture as a social entity, technological product and as a practice. Through years of architectural progression, changes have happened slowly of how buildings are thought of and built. These flexible formations are a result of social form, economic support, user needs and environmental changes occurring over a course of time and user occupancy. Creating forces for architectural object to change over the years, in order to survive and sustain itself. Many projects dealing with flexible architecture can go under the name flexible such as adaptive, transformable, or interactive architecture. These three types of flexible architectures were established to be the most dominant in this kind of architecture. It started out with adaptable buildings, in which the main concern was to make spaces adapt to certain circumstances by changing the layout of its interiors to accommodate different functions. Then by gradually adding advancements to the design, an adaptable building could by then transform its shape, color, skin or structure in response to its environment and users. With the advancement and help of digital technology buildings were now not only adapt and transform but could also interact and respond to its users actions and demands as if it is a living design.

According to the case studies and illustrated examples discussed, adaptation in architecture is a long-term process that occurs with time and generations, the environmental changes that occur in a given time such as a day and spatial constrains can be a continuous drive of changes that happen to any architectural building, leading

to local adaptations. Adaptation is easily applicable and can be applied in any building type or form, it and doesn't not require any complicated technology or structures for it to be achieved, as long as it abides the basic design principles such as; user comfort, functionally adaptable to the changing needs and environmentally sustainable. Transformable architecture on the other hand requires more complex assembly procedures. There are three main issues that transformable architecture should respond to in order to be as effective as possible, these are: flexibility and response to change, operational conditions, maintenance and management. Consideration of the different types of transformable architecture introduced previously reveals that their success is directly related to the degree of integration of structural elements, transformation mechanisms and the flexibility of operation. It can be argued that the compatibility of these three factors determines the effectiveness and success of transformability. However, these structures have problems such as: maintenance, cost, aesthetics architectural issues, non-smart, appropriate covering materials, massive pieces (not modular) and unstable during the different states of constructing.

Technological improvement, economic supports and human integration operation has participated in the making of interactive responses. Interactive architecture is still in a study phase which is still under development. Most of the interactive designs are applied on a small part of a building or an art installation, hasn't reached to a full interactive building yet. However, interactive design depends mostly on the use of technology, sensors and actuators in order to respond and interact with its users and environment. That being said, it also contains a great deal of transformability as well, where a design has to transform either its shape, function, color, light or material in order to give a response.

Flexibility as a process has been conceived in various disciplines which presents a straight forward interpretation into architectural conceptualization. The building can be considered to be a system which adapts its behavior according to information gathered about its occupants. Information gathered from the outside of the building could also be integrated into the process, like weather data, energy savings, demands of neighboring buildings, etc. Adaptive architecture thus has the capability to respond, transform or adapt to a number of parameters with time. Time is an important aspect influencing adaptability in architecture. Thus adaptive architecture can be said to be a responsive and transformable Architecture evolving with time.

The comparative case studies of three projects that were investigated: Sandai Mediateque; Sharifi-Ha house; and The BIX Kunsthaus Graz, were used as a research

strategy to test the research hypothesis and draw conclusions objectively. They provided answers to the questions asked in Chapter 1 that flexible buildings can identify a specific need and set out to meet it both satisfactorily and efficiently. They can be flexible in function, require a minimum technological use (Sandai Mediateque), use a small building site (Sharifha house), and can communicate with the public and its surrounding environment and architectural context (The BIX). The case studies demonstrated that the role of technology is an aiding role when attempting to design a complicated and innovative design, but the integration of technology is not essential when desiring to design a flexible building. The case studies also demonstrate that flexible architecture is multifunctional, it leaves room for more innovations and changes, it could work for various purposes and under various circumstances without having to relocate or demolish or reconstruct. They can be used by the designers and project owners to promote their business in creative industries.

Architecture has changed through time from being formal to functional to intelligent, with the altering requirements of time. Social environment is also a continuously changing factor and architecture needs to adjust, modify and change with it too. Architecture has always been progressing and developing to respond to the needs of its users. In today's complex lives however, with the uncertain factors and conditions of the changing environments, architecture needs to respond and adjust to various diverse functions through its life cycle and serves the purpose of its existence.

There are potential benefits when designing flexible buildings which would solve a wide range of architectural problems more than the conventional responses ; flexible buildings could stay being used for a longer time. Since flexible buildings can modify itself according to its users experience and involvement, the building could correspond to its aim better and stay compatible to social needs. Flexible architecture also encourages the implementation of the most recent technological developments in technology and building materials, this way buildings could be more cost effective and environmentally more feasible and practical.

Categorizations like the one proposed here between (adaptive,
transformable and interactive); in many cases show that there are potential overlaps and examples easily fit into multiple categories, showing that there are various strategies that architects have at their disposal. They are flexible in the way that they adjust themselves according to the surrounding environment and its inhabitants 'needs. They also overlap in having changeable elements either manually, mechanically or

through advanced technology. A building can first adapt itself according to the user and Transforms its form/function/skin then interacts with the user.

The case studies demonstrated a major benefit of designing a flexible building, the role of technology is an aiding role for a more complicated and innovative designs, but not essential when desiring to design a flexible building. The case studies also demonstrate that flexible architecture is multifunctional, it leaves room for more innovations and changes. Flexible designs could work for various purposes and under various circumstances without having to relocate or demolish or reconstruct and they can be used by the designers and project owners to promote their business in creative industries.

By demonstrating the participation of flexible architecture within a social and historic context, the thesis aims to contribute to viewing architecture as having cultural importance both aesthetically and in terms of it being an architecture that is ever responding to the changing needs of its users.

The thesis has helped in providing a comprehensive examination of flexible architecture; it has concentrated precisely on making a comparative analysis between adaptive, transformable and interactive designs, Further research might focus on more subcategories such as deployment, mobile, transportable, kinetic and more. The focus was mostly on architecture created by architects from the “western” world. Further research might be interesting to examine flexible architecture in other cultures and developing societies to see how they might compare and provide a wider range of examples which might contribute more nuanced representation of varying aspects of flexible architecture.

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