INTELLIGENT ARCHITECTURE:
The Way to Design Intelligent Buildings

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ABSTRACT

With the enhancement of Informational Revolution, the transformations in our lifestyle demand the space around us to have interaction modalities that support new as well as old communicating ways. Therefore, it becomes a challenge for the designers to blend the informational space with the physical space through technology inspired architecture, which helps to incorporate the design application in the digital as well as real world context. Intelligent Architecture is a new design process that perceives and interacts with the built environment by applying recent advances and implementing new technologies to architectural practice. The concept of Intelligent Architecture started as an interest in the latest integrated building systems and technologies which can communicate and exchange information.

The paper is based on the conceptual research done to give the overview of Intelligent Architecture in general, its application in the world of information system with all of its multi-dimensional viewpoints and explore the criteria determining intelligent building technologies. The focus of the paper is to gain an insight phenomenon of Intelligent Architecture and its responsiveness to fulfill the demands of human needs and to understand the technologies through which Intelligent Building systems can be achieved. The selection criteria of case studies are based on the advance technologies which are used to promote the idea of Intelligent Architecture.

Keywords: *Informational Revolution, Intelligent Architecture, Intelligent Building, Built Environment*

INTRODUCTION

Since the 1970s, computer and telecommunication technology have been changing human life. These changes have outpaced the theories guiding such technologies. Also the concept of physical spaces and their definitions, as human aspects, have also been affected. Meeting rooms, for example, have become *virtual*[1] as their physical elements have been computerized. This is simply integration between the computer's abilities and the physical world.

In late 70s, the technology of HVAC systems controlled with the computer chips and localized by sensors were enabled to fast and more precise response to changing environment conditions. This electronically enhanced technology had led to the initial development of an Intelligent Building. The word *"intelligent"* was initially used to describe architecture at the beginning of the 1980s, when the automation of occupant-safety, security and lighting systems was followed with refinement in coordination of components within individual systems (Chan and Wong).

Intelligent Buildings simply represented an attempt to portray and exploit the prevailing trend for incorporating increasing quantities of information technology into buildings. The new development of *Intelligent Building* is the idea to use the information technology and control

1 Virtual is a concept defined in philosophy as that which is not real but may display the salient qualities of the real. (http://en.wikipedia.org/)

system to make the functioning of the building more useful to its occupants, in relation to its management, and in respect of the building's operational purposes.

With the rise of global hazards[2], the impact of architecture on the global environment became a matter of concern and the recent trend of Intelligent Building design is concentrated on both economic and environmental sensitive developments. Flexibility and low energy become the issues to cope with the fast growing technology, which promote the concept of *Intelligent Architecture,* to contribute in the environmental quality and hazards prevention. (Youseef and Khaled, 2005).

INTELLIGENT ARCHITECTURE

With the advancement of technology, the perception and interaction of human mind with the built environment can be defined as *Intelligent Architecture*. Intelligent Architecture cannot be defined by any single definition. There are a number of concepts introduced under the title of Intelligent Architecture.

The concept of Intelligent Architecture is not very new. The definition of Intelligent Architecture has been evolving with different emphasis, mainly driven by the development of relevant technologies and the changing needs for the built environment. In 1980s, the building was considered to be Intelligent when it had the latest building systems and it accommodated the high-tech installations and latest technology. Mainly, three broad phases can be associated with Intelligent Building concept. First phase (till mid of 80s) emphasized that the Intelligent Buildings are collection of innovative technologies and automatically controlled to function. In the second phase (till 90s), emphasis was on responsible buildings, and Intelligent Buildings were supposed to be capable of responding to the changing needs. Third phase focused on the buildings with features effectively satisfying the changing needs (Intelligent Building Concept).

According to EIBG[3], "Intelligent Building is one that maximizes the efficiency of its occupants and allows effective management of resources with minimum life costs". According to IBI[4], "Intelligent Building is one that provides a productive and cost effective environment optimization of its four basic elements – structure, systems, services and management and the interrelationships between them" (Smart Accelerate Project).

With the rise of Informational Revolution[5], the technological systems brought changes and easiness in human life. Along with high comfort and safety levels, the technological systems integrated into building systems such as, communication system, security system, system which supplies energy control, building automation system, etc.

Information is the central theme of new sciences, which emerged in 1940s, including Shannon's[6] (1949) Information Theory and Wiener's[7] (1948) Cybernetics[8]. Fang Irving[9] (1997) also identified that the term, Informational Revolution is used to describe trends in communication media. People have been also introduced to new abilities and efforts to draw the first idea of Cyber Space[10] had been initiated.

2 Global hazards include climatic change, loss of diversity, changes in hydrological systems and the supplies of fresh water, land degradation and stresses on food-producing systems which may effects human health. (http://www.who.int)
3 European International Building Group.
4 The International Building Institute, USA.
5 The term Information Revolution describes current economic, social and technological trends beyond Industrial Revolution, having social, economic and technological role of information as the main features. (http://en.wikipedia.org)
6 Claude Shannon: (1916-2001), an American electronic engineer and mathematician, known as the father of Information Revolution.
7 Norbert Wiener: (1894-1964), an American and founder of Cybernetics.
8 "Cybernetics is a theory of machine and deals with all forms of behavior in so far as they are regular, determinate or reproducible". Ashby and Ross, 1957).
9 Dr. Fang Irving: is a Professor in the School of Journalism and Mass Communication at the University of Minnesota.
10. Cyberspace, the term was coined by science-fiction novelist and author William Gibson (1948) in his novel "Neuromancer" (1984), means the entire world of computer networks especially the internet. (http://www.britanica.com)

In 1990s, the term *Intelligent Architecture* was used to embrace creating architecture in an anti spatial context to be accessed via networks, celebrating the concept at a global scale such as The *"Network Society"*[11] criticized by Manuel Castell's[12] and *"e-topia-lean, green cities work smarter not harder"*[13] by William J. Mitchell[14].

CHARACTERISTICS OF INTELLIGENT ARCHITECTURE

The circumstances of a global economy, require blending of knowledge of specific values and beliefs with 21st Century to understand that how human intelligence affects the artifacts i.e. buildings and places that we create. Intelligent Architecture depends upon the human Intelligence that how one can relate and interact with the built environment. By uncovering how the foundations of the architectural experience through science lead towards the process of human cognition and intelligence, the discipline of Intelligent Architecture has been discovered. Intelligence is not an exclusive domain for architects. This is about which process the information to make it meaningful, provide an integral link between humans and physical reality. This is all about the knowledge that is essential for architects to have to know how the built environment connects to humans (Salingros et.el. 2oo4).

Intelligent Architecture needs to be supported by three forms of intelligence. First is the "perceptual intelligence" which captures people's presence and movement in the space in a natural way. Second one is the "interpretive intelligence", which understands people's actions and is capable of making informed guesses about their behavior. And the third is the "narrative intelligence", which presents us with information, articulated stories, images, and animations, in the right place, at the right time, all tailored to our needs and preferences (sparacino, 2005).

Initially, the concept of Intelligent Architecture was considered as futuristic and fanciful. Now it is a reality. During the last century, till 1900, buildings had static structure. Till 1945, electric appliances were improved and having electric machines inside buildings started to become common. After 1945, the number of appliance and electronic systems, from automation to communications, has been increasing continuously (Intelligent Building Concept). Different control, monitoring and supervising strategies have been implemented, directly associated with the improvements at the electronic devices level. The concept is much more than lighting and temperature control automation.

To the user, an Intelligent Building offers economic and efficient environmental systems: heating, lighting and air conditioning. Also, it enhances safety and security. Moreover, it improves business potential with integrated data communication systems. To the manufacturer, Intelligent Buildings offer a profitable market, particularly if they are able to exploit both the commercial and consumer markets (Morsy and Sahar, 2007). Intelligent Architecture suggests buildings which are capable of making "intelligent" decisions or respond "intelligently" to changes. For example smart home or intelligent home are the terms commonly used to define a residence that uses a control system to integrate the residence's various automation systems. Integrating the home systems allows them to communicate with one another through the control system.

In short, the Intelligent Architecture is the one which is designed with intelligence and talent

11 According to Manuel Castell, Networks have become the basic units of modern society based not only on technology but also on cultural, economical and political factors that make up the Network Society. (http://www.geof.net)
12 Manuel Castell: (1942), Professor of urban geography in Barkley, is a sociologist, especially associated with information society and communications research.
13 The theory describes that by five basic principles i.e. Dematerialization, Demobilization, Mass Customization, Intelligent Operation, Soft Transformation, we can potentially meet our own needs without compromising the ability of future generations to meet theirs. (E-topia by Wiliam J. Mitchell available at http://homepage.mac.com)
14 Dr. William J. Mitchell: a Professor of Architecture and Media Arts and Science, Dean of the School of Architecture and Planning at MIT.

i.e. a building which is safe and secure which can automatically adjust to naturally varying light, temperature and humidity changes, where occupants can customize themselves to individual preferences and finally a building which operates efficiently and assists with its own maintenance—a building of distinction that reflects its owner's character. Therefore, ideally, a building is judged intelligent when the building subsystems provide the occupants with productive and comfortable conditions by responding to and enhancing the workplace environment.

CLASSIFICATION OF INTELLIGENT ARCHITECTURE

There are a number of viewpoints related to the term Intelligent Architecture, applying a wide range of knowledge to architectural theory and practice. *Smart Architecture, Smart Cities, Intelligent Cities, Digital Cities, Soft Cities, Smart Communities, Intelligent Buildings, Smart Buildings* etc. are the related terminologies used. There is not one standard definition of Intelligent Architecture.

The first viewpoint describes *Virtual Architecture*, which defines the first broad perspective of Intelligent Architecture. Virtual Architecture redefines architecture in anti spatial and soft terms, promoting stimulated environment. Virtual places and e-activities take the priority over spatial peers. Unlike a simple 3D model on a computer, the Virtual Building contains a great deal more information about the building's materials and characteristics. It is a 3D digital database that tracks all elements that make up a building (Balogun and Odeyale, 2006). Virtual Architecture exploits Information Technology and the connectivity to broad band networks to create anti spatial, Tele-served, soft architecture, promoting the idea that the physically built environment be supplanted by e-activities, supported by e-agents, and closely integrated with networks in a global context (Youssef and Khaled, 2005).

The second viewpoint promotes the concept of *Automotive Architecture*. This concept enhances physically built spaces in terms of improving performance, saving energy, minimizing cost, supporting users' comfort and productivity via high tech installations and automation system. Automotive Architecture enhances the physical architecture in terms of self-responding to external changes and internal demands, improving performance, saving energy, minimizing initial and running cost, and supporting users' comfort and productivity, by means of technical installations, cabling solutions, and automation systems (Youssef and Khaled, 2005).

Third viewpoint introduces *Sustainable Architecture*. According to this group, the outward aspect of Sustainable Architecture is to achieve durable, green and environmentally responsible architecture that exploits free, renewable and recyclable resources. Sustainable Architecture creates durable, green, environmentally oriented and responsible architecture that exploits free, passive, sustainable, renewable, bio-degradable and recyclable energy resources, to guarantee the environmental quality, the intergenerational equality, the quality of life and the intended symbiosis with nature (Youssef and Khaled, 2005).

By reviewing all the viewpoints regarding Intelligent Architecture, the main common aspect which covers all the concepts is the technological advancement and application of computer systems. The variety of concepts shows the gradual technological advancement and its impact in human life. The advance technological applications which are used in Intelligent Building arrange the relationship between humans and environment.

In 1980s, the buildings which accommodated the high-tech installations were termed as Intelligent. But in late 90s, after Informational Revolution, the concept of Intelligent Architecture, related to creating architecture in an anti spatial context and promoting the informational mode as an integral part of the architectural Intelligence. This shows the shift of technology from automation towards digital. With the rise of global hazards, the pressure on energy resources and massive environmental degradation have occurred and the foot print of architecture on the environment became the matter of concern. This shows the travel from digital to sustainable approach. Therefore, there is no single definition and single application which is sufficient to define Intelligent Architecture. In recent developments, all viewpoints need to be brought under one roof and should acknowledge and support each other.

CRITERIA FOR INTELLIGENT ARCHITECTURE

Intelligent Architecture is not prescriptive. It is responsive to human needs and sensibilities through adaptation to existing buildings and nature. It represents evidence based result rather than expressing visual ideology. The science behind Intelligent Architecture supports distinct new developing architectural movements and practices. It provides common theoretical support for Sustainable Architecture, New Urbanism, Environment Friendly Architecture, and Automotive Architecture throughout the world. In short, this is a new way to view the world i.e. the way of connecting it to ourselves.

Intelligent Architecture applies technologies to improve the building environment and functionality for the benefit of their occupants or tenants while controlling costs. The benefits were touted to include cost savings for cabling and long term maintenance, plus a future potential for inter operability between systems. It also improves user safety, comfort and accessibility. The vision was to share building telecommunication as backbones with energy management systems, fire alarms, security systems and even office automation (Morsy and Sahar, 2007).

Various ideas are presented and discussed about the features that give buildings intelligence, the building has potential to serve future generations, maintain the sustainability or adaptability over its life cycle and safeguarding the earth and environment resources. A series of design criteria which include elements like site planning, settlement decisions, building form, building envelope, space organization, usage of ecological materials, usage of ecological energy resources and waste control direct the design phase (Smart Accelerate). Therefore, the built environment should be productive, safe, healthy, thermally, aurally and visually comfortable.

TECHNOLOGY AND INTELLIGENT ARCHITECTURE

Intelligent Architecture applies technologies to improve the buildings' environment and functionality for occupants or tenants controlling costs, improving end user security, comfort and accessibility help user productivity and comfort levels. An efficient integrated system enables a modern comprehensive access and security system to operate effectively and exchange information with other building systems. The information is used to manage the local environment and the resulting energy usage. An effective energy management system, for example, provides lowest cost energy, avoids waste of energy by managing occupied space and makes efficient use of resources, through centralized control and integration of information from different sources (Technology Roadmap for Intelligent Buildings, 2002). Widespread use of computer-based processing enables the automation of all basic building systems. These systems primarily support and operate its infrastructure including lighting, heating, ventilation and air conditioning (HVAC), energy management, security, elevators, life safety systems and building condition monitoring.

RESPONSIVENESS OF INTELLIGENT BUILDINGS TO HUMAN NEEDS

The strategy to proposed application of Intelligent Architecture, is firstly, to point out the current unsustainable trends in architectural practice to justify the objectives needed to achieve sustainable future development and secondly, to explore the selective alternatives to refine the architecture theory and practice.

The most important business driver for Intelligent Buildings is the ability to reduce cost, optimize manpower utilization and improve service levels by the use of latest technologies in building management to control environment, access, safety and costs. The energy efficiency of buildings combines many technologies including:

1. Passive heating and cooling
2. Efficient daylight
3. Efficient appliances that reduce the electricity consumption and cost
4. Increased thermal insulation
5. High efficiency windows
6. Natural ventilation for indoor air quality
7. Improvements in building services of HVAC technologies
8. Building Energy Management and Control (Morsy and Sahar, 2007)

The use of these technologies may open the presence, in architecture, of a new spatial, temporal and wider spatial environment that allows you potentially to connect with the rest of the world, gain information that may have value to you in your present surroundings or lets you to act back upon the physical space by changing it to soothe your needs. Architects used to consider the following characteristics of the building in order to define it as an Intelligent Building:

1. Provide Spatially Flexible Environment
2. Provide Individually Conditioned Environment
3. Provide Individually Connected Environment
4. Provide Social Environment
5. Provide Healthy Environment
6. Ensure Low Energy/Low Resource Environment

From the above it is obvious that in order to grasp features of individuality and sociality, the Intelligent Architecture must be flexible and adaptable. Flexibility secures the appropriate environment for diverse needs while adaptability caters to changes in needs or occupants. Third main sustainable feature of Intelligent Architecture is cost efficiency. Productivity is highly linked with comfort which affects human performance and also productivity (Morsy and Sahar, 2007).

CASE STUDIES OF INTELLIGENT ARCHITECTURE

1. The Rotating Home

The concept of Rotating Home (Figure 1), is initiated by Al and Janet Johnstone, who are the owners of RotatingHome.com. Al designed and researched the house, as well as founded or built all the special parts required to make the house rotate. To fulfill the concept of Rotating Home into reality they hired several different engineers to verify and sign off Al's work (Johnstone and Janet, 2002).

Rotating Home can be built in any size or shape in which all or part of the home rotates. A Rotating Home can also be multi-level, with the ability of all or any of the stories to rotate. By using a motor, the building rotates 360 degrees. The speed of rotation varies from one revolution in 30 minutes to one revolution in 24 hours and can be selected by direct control concept where rotation starts and stops by using a switch. Conceptually, all walls in this house can change their location to change the view. Sensors rotate and change bedroom location to avoid sun, heat or light; noise on the other hand can be avoided and view at certain time can be seen from specific spaces in the house. A Rotating Home is perfect for an upscale beach house or large mountain cabin. Steep mountain terrain is not a problem as the Rotating Home can be built up on a central steel column (Figure 2). The building can take any shape in design (Johnstone and Janet, 2002).

2. The Environmental Building (BRE), Watford, UK

The Building Research Establishment (BRE) (Figure 3) is a former UK government establishment, now a private organization, funded by the building industry that carries out research, consultancy and testing for the construction. Environmental Building provides a model for offices for the 21st century. The new Environmental Building has been built as a demonstration building for the Energy Efficient Office of the Future. Innovative and environmentally advanced, it demonstrates the way for the future based on a platform of new low-energy targets. The building aims not only to provide a working office with low energy consumption in use, but also to serve as a large-scale experimental facility for evaluating various innovative technologies (The Environmental Building).

To make maximum use of available daylight the building has a large glass area which optimizes to provide high light levels but low heat loss and solar gain by moveable external louvers (Figure 4). The use of a novel ceiling slab (Figure 5) allows the building to be flexible in terms of space layout without hindering the natural ventilation pathways. A fully integrated, intelligent and efficient lighting system has been installed which automatically compensates for daylight levels and occupancy, controlling each light separately. The operation of the building systems is controlled automatically using the latest integrated technology (http://projects).

The most striking feature of the building when seen from the south side, is the five distinctive ventilation shafts running up the façade (Figure 6). These form a key part of the energy-saving natural ventilation and cooling system. Air-conditioning has been avoided by exposing the ceiling slab. The slab absorbs heat during the day and is cooled down by ventilation at night. Pipes embedded in the floor can provide additional cooling utilizing groundwater (The Environmental Building) (Figure 7). Occupants also have a high degree of control over their local environment by overriding automatic control of the lights, louvers, windows and heating. In addition they can manually open mid-level windows.

The 47 meter square Building Integrated Photovoltaic (BIPV) array incorporated in the Environmental Building provides non-polluting electricity directly to the building (Figure 8). Utilizing thin film amorphous silicon cells, the array seeks to explore issues associated with the integration of photovoltaic into vertical walling, building on previous demonstration installations within the UK (http://projects).

3. Blur Building, Switzerland

The Blur Building (Figure 9) is a media pavilion for Sixth Swiss National Exhibition 2002, designed by the New York architectural team of Richard Scofidio and Elizabeth Diller, in Switzerland (Diller and Scofidio, a, 2002). It’s a beautiful concept; the primary building material is water, pumped from the lake and vaporized around the promenade deck. The attempt to construct a 60x100x20 meter metal building that sprays countless tiny drops of lake water from thousands of jets. The building can approach via 400 feet long ramped bridge which deposits visitors at the center of the fog mass on to a large open air platform where movement is unregulated (Figure 11).

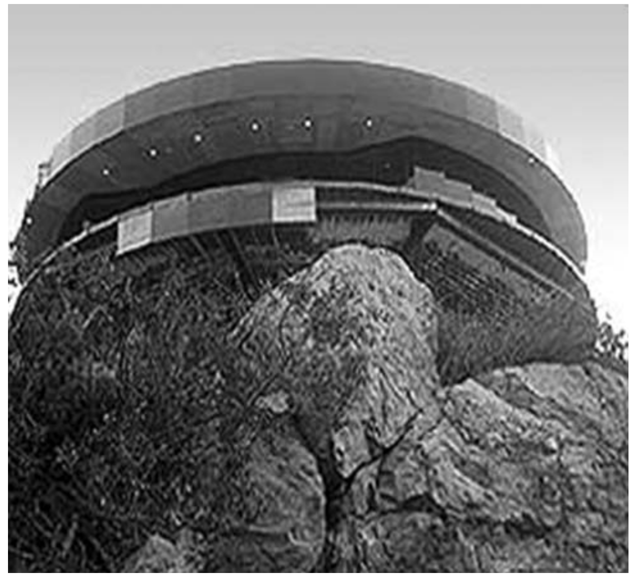

Figure 1: The Rotating Home.s
Source: A. and Janet, 2002, Maximize your view with rotating home available at http://www.rotatinghome.com/

Figure 2: The Rotating Home on Central Steel Column.
Source: A. and Janet, 2002, Maximize your view with rotating home available at http://www.rotatinghome.com/

Figure 3: Building Research Establishment, Watford, UK.

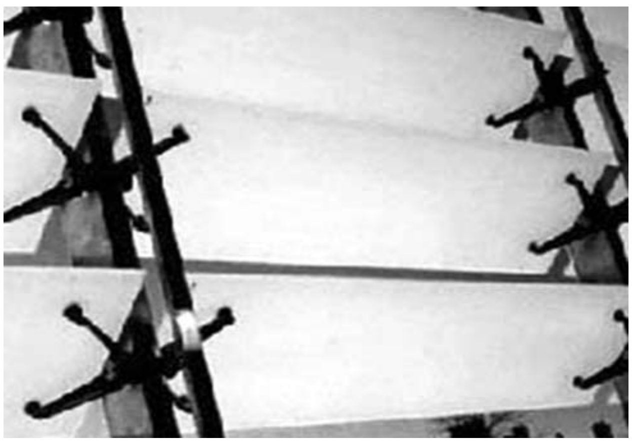

Figure 4: Moveable External Lourvers can also operate mannually.

Figure 6: Ventilation Shaft.

Figure 5: Good level of daylight is achieved throughout the day.

Figure 7: Low energy cooling system.

Figure 8: The South facing photovoltaic facade.
Source for Fig 3 to 8: The Environmental Building: A Model for the 21st Century, manual by BREEAM).

Figure 9: The Blur Building

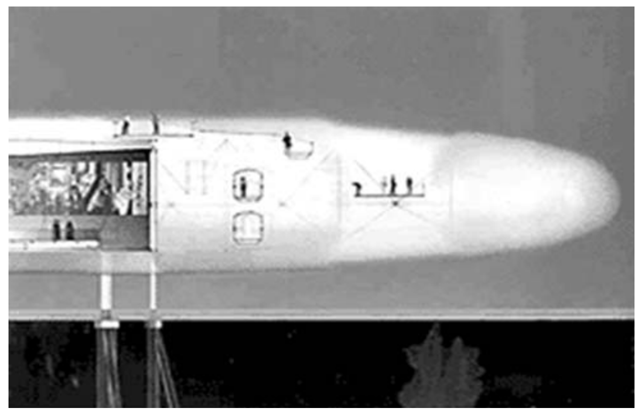

Figure 10: The Longitudinal Section

Prior to entering in the clouds the visitors received a brain coat i.e. smart rain coat which was used as protection from water environment. The space was surrounded by glass on six sides so that visitors could experience a sense of physical suspension. At the top of the structure was the Angel Bar, serving glacier water as well as commercial and municipal water from around the world (Diller and Scofidlo, b, 2002).

The Blur Building gave the basic idea of liquid form in architecture that is supposed to respond and be formed according to its users' needs. They used computers to adjust spray strength according to the different climactic conditions of temperature, humidity, wind speed and direction (Scofidio, Ricardo and Diller, 2002).

4. Topotransegrity – Non Linear Responsive Environments

Topotransegrity (Figure 13) is an award-winning and widely published research design project, designed by 5subzero, a building group of architects from London. The Barbican Arts Center is used as a testing ground to explore how an adaptive spatial organization can be introduced to public spaces and challenges long held assumptions about architecture as a passive spatial arrangement. Since the public spaces are the only place where all different programs connect, it became an ideal testing ground for Topotransegrity (http://5subzero).

Topotransegrity is an inhabitable interface running in a constant feedback loop which can react to and interact with the users and anticipate and adapt to their behavioral patterns. It relies on contextual and internal parameters derived from its environment and works according to different modes of operation that influence different parts of the structure and add up to a series of emergent user dependent spatial configurations (Senagala and Mahesh, 2005).

Topotransegrity constantly evaluates its surroundings and reconfigures according to the changing conditions. It investigates today's networked ways that enable architecture itself to operate as an intelligent interface that connects spaces, users and performance criteria (Figure 14). Topotransegrity is a pneumatic piston driven system. The possibilities and limitations of this system were examined in a series of physical and virtual models. The

Figure 11: Aerial view of the ramped bridged.

Figure 12: The basement.
Source for Fig 9 to 12: Diller & Scofidio: The Blur Building available at http://www.designboom.com/

structure is capable of various transformations, which range from small-scale surface articulations to large surface deformations, which can generate temporary enclosures. Sensors, input devices and wireless networks are integrated into normally dead building materials to transform architectural space into complex intelligent operating systems (Neumayr, 2006).

Different types of responses are superimposed on the structure but act in different time frames, operating in three parallel modes. These three modes of operating act independently but are always interrelated since they are based on the same data input. The entering movement of visitors is recorded and displayed through the memory mode. The crowd mode also interprets this data and influence the temporary structures established by the program mode which acts in relation to the given event schedule. These three parallel modes of operation run simultaneously and add up to the structure's complex, unpredictable user-dependant spatial configuration. The constantly changing three-dimensional space envelope, interacts with its visitors in a permanent feedback loop, where the users' reactions to spatial adaptation are fed back into the system to update the spatial arrangements and individually customize the built environment to requirements at any given moment for any given pattern of use (http://5subzero).

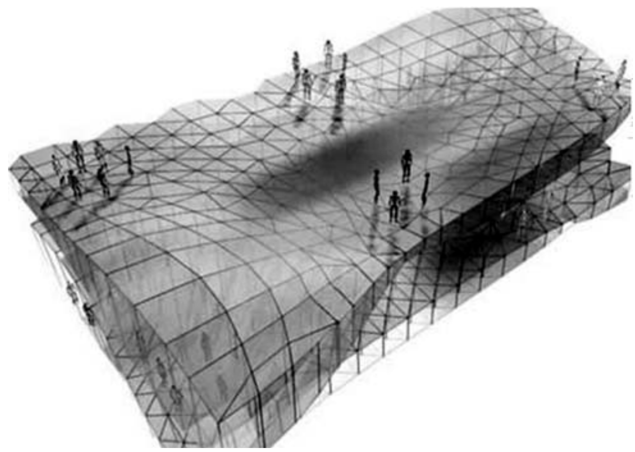

Figure 13: Topotransegrity

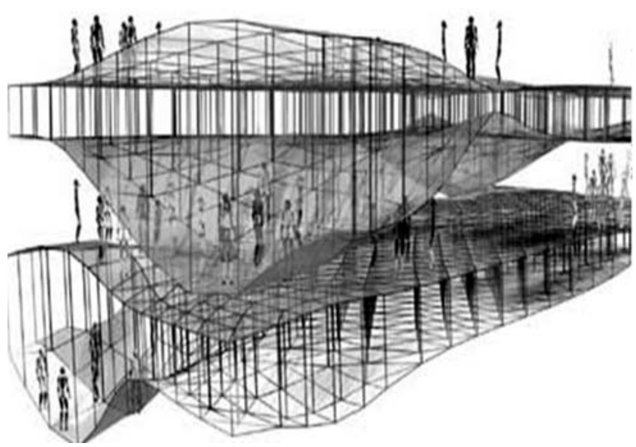

Figure 14: The non linear envrionment.

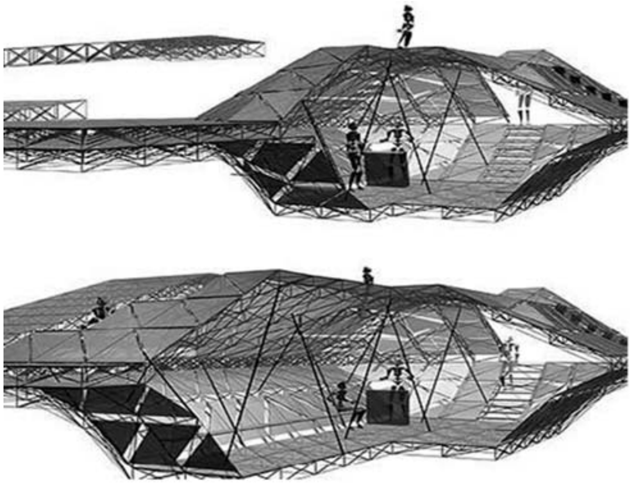

Figure 15: Visitors movement inside the topotransegrity.
Source for Fig 13 to 15: Neumayr, Robert, 2006, Topotransegrity - Non-Linear Responsive Environments, available at http://www.interactivearchitecture.org/

CONCLUSION

Figure 14: the non linear environment.

As a result, new definitions and identities will appear in connection with the technological improvements in buildings. Nowadays integration of technology systems into a standard building which has been designed without analyzing the physical and social systems of the project field carefully is not enough to describe a building as "intelligent". The major "actionable" conclusions to promote intelligent architecture are:

1. There is a significant number of intelligent building technology products currently in the international market that are capable of automating and integrating all major building systems.

2. Building automation systems can both reduce costs and increase productivity and comfort.

3. The degree of confidence in intelligent building technologies is inadequate largely because of a lack of awareness and understanding, of its value.

4. There is a lack of properly assessable intelligent building technology reference projects.

5. Reduced energy costs are seen as a major benefit of intelligent building technologies equated to HVAC. However, other benefits, e.g., reduced staff levels and improved occupant satisfaction, are often overlooked.

6. Economic analysis of intelligent building projects are often flawed. Typical errors: construction cost increases but not the savings, incorrectly reflecting operational cost savings over the project's expected life, and ignoring additional rent and sales revenues.

7. Widespread use of the Internet and wireless communications improves worker productivity and increases the cost effectiveness and market of intelligent technologies.

8. Air quality measurement and other sensors work well to control HVAC and other building automation systems.

9. There is a significant shortage of trained, knowledgeable and certified professionals in the design, installation and integration of intelligent building systems.

10. Intelligent building technologies require the co-operation of the entire design team including owner, developer, architect and engineers.

11. An integrated communications infrastructure is the essential foundation in the effective deployment of intelligent building technologies.

12. New and evolving technologies enable the gradual enhancement of functions and features, via upgrading of the electronics, throughout the life of an intelligent building.

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