Adaptable Architecture

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Abstract

In this paper a framework is created for categorizing adaptable architecture. The term adaptable architecture describes an architecture from which specific components can be changed in response to external stimuli, for example the users or environment. This change could be executed by the building system itself, transformed manually or could be any other ability to transform by an external force. Different levels of adaptation are determined to pinpoint the relations between the different connotations of adaptable. Realized adaptable projects are studied to define the relation of innovation and realization. To generalize the outcome of the analyses the different components of the building are categorized.

1. Introduction

Adaptation and flexibility have played an important role in experimental architectural projects in the last decades. Visionary projects and ideas were developed to link the architectural buildings with new technologies and possibilities. Inline with innovations of that time, a clear connection is found with experimental architectural projects and ideas. During the Industrial era, machine and technology played a very important role in the experimental projects of the Avant-garde. The comparison of architecture with a machine is typically for this period (Corbusier, 1924). With the era that followed, Futurism and Situationists developed imaginary ideas based on multimedia techniques and the free state of mind. Realization of the projects wasn’t the main goal (Archigram, 1972). With mobility and mobile parts, a step further was taken in the relation with machine. Today’s period can be seen as the electronic era, an information society; individualization, commercialization, globalization and personification are characteristics of today. Next to the pace of the development of advanced electronic devices, and the growing commercialization on this field, the customization of these products plays a very important role. Individualism and the adaptation of the building on the personal wishes of the users and environment is, in relation to technological developments, a current subject of research.

This paper is part of a PhD research, in which the realization of an adaptable architecture with the use of dynamic materials is the main subject. The aim of this paper is to come to an extrapolation of the technology based on realized projects. In this research it is important to clarify the definitions of adaptable architecture to pinpoint the position in which the thesis research is found.

Various definitions of adaptable architecture are used in literature, but coherence between these is lacking. Different connotations are given, which are related to different levels of adaptation. Dekker (2006) stated
that interactivity is specially used as an indicator of change in an installation or environment that a person can enforce, taking into account the mechanical, physical and psychological implications. According to Edler (2006) dynamic architecture or structures adapt to the varying needs of the users, to changing environmental circumstances or to the designers desires and imaginations. In the literature of Kroner (1997) intelligent architecture refers to built forms whose integrated systems are capable of anticipating and responding phenomena, whether internal or external, that affects the performance of the building and its occupants. Intelligent architecture responds to its occupants and the local and global environment in a sensitive, supportive and dignifying matter. Another connotation is given by Kronenburg (2002), in which the ultimate flexible interior may be one that is completely amorphous and transitional, changing shape, color, lighting levels, acoustic, temperature, as the inhabitants moves through it—abandoning flat horizontal surfaces and demarcations between hard and soft, warm and cold, wet and dry. It seems that there are several technicalities involved when defining aspects of adaptation.

2. Method

Various realized adaptable projects were analyzed to determine the stage of adaptation of the current building stock. Only projects that have the special ability of a relatively simple adaptation on the level of time and effort were analyzed. The focus in this research lies on projects that have the special ability of adaptation on re-appearing scale.

To categorize the different methods and levels of adaptation in the analyzed projects, a general overview of the building components was set. This overview gives an idea on what level in the building system adaptation is found. Various categories of the building are used in past research (Brand, 1994). In this research the categorization is based on adaptable components in architecture.

Next to the categorization of the building system the different levels of adaptation are given. According to developments in technology, science and application, adaptable architecture has the ability to get more sophisticated. The different levels of sophistication are concluded in a scheme. The case studies will be analyzed according to the levels of adaptation and concluded in a table. The table gives the overview of the method of adaptation of the different projects. On the hand of the method of adaptation the level and component of adaptation are concluded.

The outcome of the table was analyzed according to the general development of technologies. Therefore, it will give an insight into the realization of adaptable architecture with the use of new technologies in relation with its time. With this overview of the adaptable projects it will be possible to set the framework for the research of the PhD subject.

2.1 Categorizing building system elements

In this paper the categories of the building are important guidelines for the analysis of the projects. The categories can be divided in subcategories, which are the elements of the building. These elements can be divided in parts and the parts in pieces. To illustrate the different categories, examples of elements are given. These elements do not take part in the research and are only used to explain the different categories.

The fist category of the building system is the structural part, the construction of the building, which establishes the shape of the building and maintains its stiffness. The next category is the infill of the building. The infill includes all finishing components of the interior of the building; examples of elements of this group are walls, floors and ceilings etc. This group includes also non-bearing walls. The interior parts were excluded from the infill. The term interior in this research means the added components which are used to decorate and inhabit the building. Elements of this category are products like chairs, desks,
closets etc. Finishes like paint and carpet are included in this group, as these aspects belong to the decoration of a house which can be renewed rather easy. In the fourth category the technical aspects of the building are assigned, this group consists of the technical installations of a building. As an example, central heating, air control and wiring and piping, could be given. The last category of the inside of the building is the ambient aspects. This category is not commonly used in the category of building systems. The ambient component of the building is focused on the emotional experience of the building spaces on a sensorial level. The intensity and color of lighting which will be related to the atmosphere of a room is a specific example. The skin of the building is included in the outfit category. This group includes the façade element, the roofing and elements like balconies. The overview of the categorization is presented in figure 1.

![Figure 1 Overview of building system, category (components) and subcategory (elements)](image)

### 2.1 Adaptation level

In this research the term adaptable architecture is used as a general definition of an architecture from which specific components can be changed in response to external stimuli (the user and/or the environment). Figure 2 presents the levels of adaptation based on the level of sophistication, which increases from left to right. The definition of the different terms of adaptation is explained below.

![Figure 2 Levels of adaptation in order of sophistication](image)
The first step in adaptable architecture is flexibility. With flexible architecture the possibility of adjustments on specific components of the building is aimed. This action is in direct control of the user, which means that the component doesn’t have the ability to change itself. The components of the building are changeable, with an external force. The different possibilities of change are limited. As an example the Delfts Blauw apartment building in Delft from architect firm “de Architecten Cie.” could be given, in which the façade could be changed by the user with sliding shutters. Flexible adaptation requires mechanical techniques such as bearings, which were developed in the middle ages.

Active An active building component will give a set reaction on a specific change; the action must be undertaken by the user or environment. An example of active components is a light switch. The building component responds on an action of the environment/users with a specific reaction. Active adaptation requires electricity as basic technique, what is available for housing since around 1900.

Dynamic Dynamic architecture has the possibility to give different output on a certain input. The action-reaction relation is not a closed relation. More possibilities and settings are possible within one system. These possibilities are bordered and set in advanced. For dynamic adaptation computer technology is essential, this technology was ready for use in housing since around 1980.

Interactive A step further is taken with interactive architecture in which the building component has to ability to have a two way conversation with the users and/or its environment. A dialogue is set up between the user and system. An integrated system is needed for interactive relations. An example could be found in the saltwaterpavilion by ONL (www.oosterhuis.nl), in which the relation between virtual and real-time are visualized with projections. The projection reacts on external data input. The behavior and reactions are set by the programmer; this will mean that interaction will take place within a specific framework. Interactive adaptation needs digital sensoring what is available since around 1995.

Intelligent Intelligent according to Collier and Thelen (2003); “Users experience a system as intelligent not only if it accepts natural language input rather than just specific commands, but also if it allows the user to take initiative. If the system adapt itself to the users’ interests and interaction preferences and works cooperatively with the user to accomplish specific goals with the use of additional sources of knowledge to meet the needs of the user, a system is considered intelligent”.

With intelligent architecture the adjustment or transformation of the building component is selected by the system as a reaction on the external stimuli. The building can take its own conclusions for certain situation. Reactions on re-appearing situations will not logically lead to the same change or adaptation. The system has the ability to learn from its environment or users preferences. As an example the Chess computers Hydra (www.hydrachess.com) and Deep Blue (www.wikipedia.org) could be given. The Chess Computers have the ability to calculate indefinite possibilities of positions. This means that it can calculate faster as the human brain, and could therefore play chess with master chess players on a very high level, and actually win. Due to the fact that the machine is “thinking” during the turn of its opponent, the computer can react faster. According to master chess players the computer plays chess on a level which is nearly human, and also makes human mistakes. The only task the chess computer has is chess playing; therefore this computer can not be smart, according to this research. Intelligent adaptation requires more sophisticated computers with advanced software. Future developments based on the Law of Moore (1965), gives promising visions.
Smart architectural components have the ability of self-initiative. The smart system is completely integrated in the life and behavior of the users and environment. The system is self-learning. As Vincent (2001) describes it precisely; “the ultimate smart structure would design itself”. Smart systems are pervasive systems with knowledge. Ambient Intelligence has the ambition of a smart system. In Ambient Intelligence a full integration of technology and knowledge should lead to systems which fully collaborate but have also the possibility to take over task when other systems drop out. Ambient Intelligence should anticipate on the users’ desires or environment without conscious meditation (Collier et al., 2003). Ambient Intelligence should be an open tool, could be customized by the user, and could learn itself. Smart architecture will mean that ubiquitous computing will lead to digital relationships. These relationships should be parallel to human interaction, based on emotion and intuitive. To create smart adaptability new techniques need to evolve that are not yet available. Promising developments on this field lie in quantum mechanics and DNA computers.

The subsequent stages of adaptable architecture in figure 2 include the lower stages. This will mean that the different stages of control will be part of the higher steps in technology of the adaptable architecture. In for example intelligent architecture the users have also the possibility to set new changes by hand, and tune preferences to their own ideas.

2. Results and analysis

Table 1 Overview of aspects of existing housing projects

<table>
<thead>
<tr>
<th>Architect/designer</th>
<th>Name Project</th>
<th>Place</th>
<th>Year</th>
<th>Component</th>
<th>Method of adaptation</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Rietveld-</td>
<td>Utrecht</td>
<td>1924</td>
<td>Infill</td>
<td>Manually reconfigurable sliding walls.</td>
<td>Flexible</td>
</tr>
<tr>
<td>Rietveld-Schröder</td>
<td>House</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Villa Savoye</td>
<td>Poissy-sur-Seine, France</td>
<td>1929</td>
<td>Infill</td>
<td>Free floor plan for flexible furnishing.</td>
<td>Flexible</td>
</tr>
<tr>
<td>C</td>
<td>Rohe, Mies van der</td>
<td>Brno, Czech Republic</td>
<td>1930</td>
<td>Infill</td>
<td>Draperies on ceiling tracks.</td>
<td>Flexible</td>
</tr>
<tr>
<td>D</td>
<td>House of the Future</td>
<td>Prototype</td>
<td>1956</td>
<td>Infill</td>
<td>Manually reconfigurable folding walls.</td>
<td>Flexible</td>
</tr>
<tr>
<td>E</td>
<td>Becket, Welton</td>
<td>Mc Cullough House</td>
<td>Palm Springs, USA</td>
<td>1956</td>
<td>Infill/Interior</td>
<td>Electronic driven elements, like doors, drawers.</td>
</tr>
<tr>
<td>F</td>
<td>D’Angelo, Floyd</td>
<td>Aluminum House</td>
<td>Snow Creek, USA</td>
<td>1962</td>
<td>Structure</td>
<td>House structure on motorized rotating pole.</td>
</tr>
<tr>
<td>G</td>
<td>Prouve, Jean</td>
<td>Villa Seynage (Maison Alba)</td>
<td>Prototype</td>
<td>1962</td>
<td>Structure</td>
<td>Changeable modular structure.</td>
</tr>
<tr>
<td>H</td>
<td>Nouvel, Jean</td>
<td>Institut du Monde Arabe</td>
<td>Paris, France</td>
<td>1987</td>
<td>Outfit</td>
<td>Motor controlled apertures in facade.</td>
</tr>
<tr>
<td>I</td>
<td>Holl, Steven</td>
<td>Fukuoka apartment building</td>
<td>Fukuoka, Japan</td>
<td>1992</td>
<td>Infill</td>
<td>Manually pivoting elements.</td>
</tr>
<tr>
<td>J</td>
<td>Ban, Shigeru</td>
<td>Curtain Wall House</td>
<td>Tokyo, Japan</td>
<td>1995</td>
<td>Outfit</td>
<td>Curtain wall.</td>
</tr>
<tr>
<td>---</td>
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</tr>
<tr>
<td>K</td>
<td>Ban, Shigeru</td>
<td>Nine Square Grid House</td>
<td>Kanagawa, Japan</td>
<td>1997</td>
<td>Infill</td>
<td>Manually changed walls.</td>
</tr>
<tr>
<td>M</td>
<td>Atelier Brüchner</td>
<td>CycleBowl</td>
<td>Hanover, Germany</td>
<td>2000</td>
<td>Outfit /Structure</td>
<td>With pneumatic pressure the facade and the roof could be changed.</td>
</tr>
<tr>
<td>M</td>
<td>Ban, Shigeru</td>
<td>Naked House</td>
<td>Tokyo, Japan</td>
<td>2000</td>
<td>Infill/Interior</td>
<td>Manually movable units.</td>
</tr>
<tr>
<td>O</td>
<td>Colani</td>
<td>Rotorhouse</td>
<td>Germany</td>
<td>2000</td>
<td>Infill/Interior</td>
<td>Electrical rotation room.</td>
</tr>
<tr>
<td>P</td>
<td>Peter Marino Associates</td>
<td>Chanel Ginza</td>
<td>Tokyo, Japan</td>
<td>2004</td>
<td>Outfit</td>
<td>Adjustable translucency and image of façade. Possibility of motion pictures on the facade.</td>
</tr>
<tr>
<td>Q</td>
<td>UNStudio</td>
<td>Galleria Department Store</td>
<td>Seoul, South Korea</td>
<td>2004</td>
<td>Outfit</td>
<td>Image on façade can be changed. Also movies.</td>
</tr>
<tr>
<td>R</td>
<td>Herzog &amp; de Meuron</td>
<td>Allianz Arena</td>
<td>Munich, Germany</td>
<td>2005</td>
<td>Outfit/Infill/Ambient</td>
<td>Pressure of façade can be adjusted to weather circumstances. Suspended ceiling. Adjustable color of façade.</td>
</tr>
</tbody>
</table>

The projects presented in table 1 are all characterized by the year the project was realized and the technology used to create adaptability. In figure 3 a graph is presented that combines the information in figure 2 and table 1. Figure 3 also shows when the different stages of flexibility were technically possible. From this graph it can be seen that most of the studied projects used aged technology and that the trend to use “old” technology has increased in the past years. Based on the currently available technology it should be possible to develop interactive adaptability. For intelligent and smart adaptability new technology needs to be developed.

Both figure 3 and table 1 show that none of the studied projects concerns interactive adaptability, even though this should be feasible with current technology.
3. Discussion and conclusion

Even though the projects are only a small selection of the realized adaptable buildings it could be concluded that most realized project are found on the level of flexible and active adaptation of buildings. This outcome is logically inline with technological developments. The integration of new technologies with old elements of the building is interesting. The electro optic windows of the Chanel Ginza building are an interesting example of material innovation (www.privalite.com). With the use of integrated material technology regular glass will get more possibilities.

What can be seen in realized adaptable projects is that elements of the building are integrated with existing technologies to get to the level of adaptation. Hardly any new elements are introduced. Adaptation is realized on a one-dimensional level. Different elements of adaptation react individually. A good example is the Allianz Arena, in this project all three aspects have their own change of input, and react independently. Most of the adaptable aspects concern the transformation of a room. This is an interesting outcome as space saving is a logical fact in city houses, in which space is limited. In relation with the traditional Japanese Washitsu rooms this level of adaptation has a very interesting history.

The Open Building theory is not specifically mentioned in this paper, as in the opinion of the writers Open Building is a subject of Flexible architecture, and not a specific level of adaptable architecture. Next to the fact that Open Building has its basics in building processes and systems, flexibility and variation are a common result of the involvement of the user in the building process (Kendall et al., 2000). The systems have the possibility to be renewed more easily compared to conventional houses, but this takes considerable effort.

Even though the scheme in figure 1 differs from the scheme used by Brand (1994) it has a lot of resemblance. The most impressive difference lies in the word Ambiance. Brand uses the word Environment, to refer to the outside area of the building. Because the research presented in this paper has no relation with the outside area in terms of adaptation, this term was changed to Ambiance which is much more relevant in the context.

It could be argued that the definitions and the related level of adaptability are not fully based on existing schemes. In some aspects the definitions presented differ from those used by for instance Holland (1992)
and Negroponte (1970), for a general framework of levels of adaptation these definitions were refined to fulfill its purpose.

For the decision on the level of adaptability only the body of the building was considered. Interior aspects and technical as well as ambient aspects were not considered, as subject of research on its own. This was an attempt to narrow the subject of analysis.

The division of the timeline of the technical possibility to achieve a specific level of adaptability depends on the specific definitions presented in this paper. If the definition would be different this would possibly influence the division in level of adaptability. Furthermore the assumption that the named techniques are mainly responsible for the possibility to create a certain level of adaptability could be discussed. However, it is expected that the time connected to those techniques will not change significantly if further research proves that other techniques where in fact more decisive.

Based on the results presented here it was concluded that it is feasible to make an interactive adaptable design with use of dynamic materials (materials which have the ability to change their physical appearance and characteristics, with the change of an external output, for example temperature and electronic current). Then it would meet the requirement of new techniques and a new level of adaptability as can be concluded from this paper. Dynamic materials offer the possibilities of an integrated system. The first goal of the Ph.D. research is to take the next step of adaptable architecture on the level of interactive adaptability, with the use of dynamic materials.

8. References

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