Towards an Adaptive Architecture

ROBERT FRYER
Philadelphia University

Introduction

Human comfort is typically considered during the development of building systems in the architectural design process. Architects rarely consider issues of comfort as a conceptual design tool, with perhaps the exception of light. Light, especially since the modern movement, has been explored and employed as a device to organize and define space. However, other elements of which human comfort is composed, such as thermal, visual and acoustical means are much less frequently used to such ends. Is it possible, however, to reconsider human comfort in all of its constituent elements as a primary architectural design tool?

Reyner Banham has documented the impact of thermal comfort on architecture in *The Architecture of the Well Tempered Environment* [1]. The development of mechanical systems has undoubtedly had significant impact on how architects conceive and design buildings. It has created the illusion of decoupling a building from its environment by permitting the use of forms and materials without regard to climate, since any comfort conditions that are not met by the architecture are handled by the brute force of the mechanical system. However liberating of a design force this may have been, it does have its failings as well. The experience of many people with the most common type of system used to address thermal comfort, namely the mixed air VAV system, is often unpleasant. It has been shown through experience to hardly provide consistent thermal comfort and has been linked to poor indoor air quality. Typical means of controlling thermal comfort are enormous consumers of fossil fuels, too. Some architects are adopting the concept of high performance buildings, and with it they are employing high performance systems, which use more sophisticated and energy efficient means of maintaining comfort. However, these buildings do not aesthetically nor programmatically express their sophisticated approach. The expression of the mechanical devices and ducting has been explored, most notably at the Pompedieu Center, but human comfort is not defined nor best expressed by the articulation of machines. Rather, comfort is a dynamic *process* regulated by the human body. The body is a complex organism that is not kept perfectly thermally satisfied at a single specific degree Celsius or Fahrenheit, but rather self-modifies its behavior at different scales of operation (biological, behavioral, social). Is it possible through deep investigation into this process to create the potential for architectural expression? And what would the characteristics of such an approach be?

Human Comfort

Human comfort is typically comprised of thermal, visual and acoustical comfort. However, studies have suggested that levels of comfort are influenced by the *perception* of comfort, as well [2]. Even dummy thermostats have demonstrated the ability to create the perception of comfort, although their manipulation does not cause a change in the environment. The opportunity for behavioral changes, such as closing blinds, having access to hot or cold beverages or moving into or out of direct sunlight significantly impacts one's perception of comfort.

Comfort exists within a range of conditions. The conditions are based upon the interaction of body and environment (both natural and artifact). The comfort range of conditions is dynamic. It changes daily, seasonally, climatically and culturally. People do not tolerate the same environmental conditions year round. The comfort band tends to shift upwards along with higher temperatures in the summer, and downwards in winter (see Figure 1). People also tend to tolerate different conditions in different climates. Often while traveling, one may find their arrival in a very different climate from the one they just departed to be a very uncomfortable experience. However, after some time the body adapts to the new climate. Likewise, different cultures tend to tolerate a different

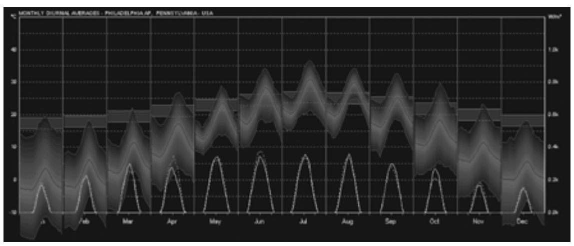

Figure 1: Comfort Zone Varying Over the Year [2]– *Comfort shown as horizontal band*

range of conditions. It could certainly be argued that the US has a developed a culture that tolerates an increasingly smaller range of environmental conditions, as we spend more than 90% of our times indoors in mechanically treated spaces, often after driving in an air conditioned automobile [3]. Comfort ranges also vary from individual to individual. This has led to inaccurate predictions of how comfortable occupants may be in a space, and has led to the development of the Predicted Mean Vote method of determining what percentage of occupants may be comfortable in a given situation [4]. Comfort ranges also vary according to activity, as one's metabolic rate is altered. Because of its highly dynamic nature, human comfort requires the ability to adapt, and by so doing alter the process between body and environment.

Adaptability

Adaptability is the opportunity to modulate one's behavior, perception and environment to tolerate a variety of situations that are created by the interaction of a single body or a group of bodies with one's environment. The environment is composed of the surrounding space and the factors that affect the different elements of what defines human comfort; that is built environment, equipment, and climate. The notion of adaptability can also be extended to artifacts and their ability to be modified to accommodate a variety of situations over time (ie adaptive re-use, tools that are able to multi-task). An adaptable building has also been termed "loose-fit". Buildings that are easily adapted often share the characteristics of a regular shape and plan with a robust primary structural system that enables easily changeable partition locations. These spaces often have multiple exposures with operable windows on each façade at regular intervals. A common example of this typology is the warehouse.

Thus, what seems to be implied in adaptability is a non-specific design that enables extreme specificity. That is, the creation of a space that is neutral but enables the opportunity for an *interaction* that is customizable to an individual at a specific time. Because of the focus on the dynamic nature of maintaining comfort, adaptability can meet these needs with proper design rather than relying on mechanical systems. By optimizing the mediating artifact (architecture) to negotiate comfort, the mechanical systems have the potential to be minimized. Depending upon the climate, the system may be eliminated altogether. In fact, projects in mild climates, such as San Francisco and in the UK, have recently been proposed that nearly or completely eliminate the need for mechanical systems. Adaptability thus has the characteristic of energy efficiency.

Material efficiency is also is essential to adaptability. Responding to variable bodily and environmental interactions requires agility in the design of an artifact. These variations are more easily mediated through changes in the properties of materials, or through changes in the form of materials. The notion of lightness is thus a characteristic of adaptability.

Associated with issues of materiality and efficiency is the opportunity to make adjustments to the body-environment situation by acting in only those areas that require it, rather than changing entire systems. This is the characteristic of specificity, or locality.

These characteristics are applicable to sustainable architecture. Issues of material, energy and resource efficiency are central to sustainability, as is re-use of the embodied energy already expended in existing constructions. Adaptability thus fits into the context of sustainable architecture.

Lightness

Adaptability implies the minimum use of materials. As discussed in *Lightness*, the need for efficient use of materials is essential to continue human's trends of speed, mass transportation and the flow of goods [5]. What is crucial in this approach to lightness is the pursuit of novel means of designing across traditional discipline boundaries; a blending of art, science and construction, or as the author states it, "the trinity of material, shape and process, since the balance between them becomes more delicate, proportional to the lightness required for the resulting structure" [5]. The transport of goods, or dynamic resource allocation, is a trend of globalization which has the potential to transform the design of urban centers, which is discussed later in this paper.

Lightness involves more than simply making use of materials with less weight, and more than redesigning a small component of a structural system with material that weighs less, since this may lead to an overall increase in weight as any weakness created by the redesigned component requires additional structure elsewhere to compensate [5]. Rather, it is an holistic approach that incorporates materials based upon their performance criteria and acting as a complete system.

Adaptability relies on such an approach to succeed. Not only do more efficient primary structures provide for more efficient use of space and materials, but subsequent layering of structure in the form of partitions or other means of controlling one's environment, whether it be spatially, thermally, acoustically, or visually, depends upon the rapid deployment and re-deployment of layers.

Locality

At the scale of materials, locality includes interaction between body and artifact in a way that is directly applicable to comfort. Here, the use of the concept of boundaries provides a better means of understanding and using the notion of adaptability. As Addington describes in *Smart Materials and Technologies*, current conceptions of discrete boundaries in architecture hinder the architect from realizing the full potential in advances in material properties. Rather than seeing boundaries as reference to lines on drawings, thermodynamic boundaries "are not legible and tangible things, but instead are zones of activity . . . [and] we see that the boundary demarcates the *difference* between the material at its identifiable state and the immediate surroundings in a state that may vary in temperature, pressure, density and/or internal energy. While diagrammatically this boundary appears to be a discontinuity or a border, physically it is where the mediated connection between the two states occurs. All change takes place at the boundary" [6]. The boundary may be conceived of as a zone of interaction with variable thickness. The envelope may then be seen as having a system of cooperative layers that may deployed throughout this zone, thus potentially increasing the distance between each layer. If adaptability implies a neutral place and perhaps a typical exterior envelope, than the notion of boundary permits the creation of additional layers to mediate thermal (thermodynamic), visual and acoustical comfort separate from the neutral envelope. Comfort can thus become a local phenomena that are employed at a location and time that is derived from the architectural program. Comfort is related to locality, and thus enables the specificity and adaptability that is its characteristic.

Acting at a different scale, the notion of adaptability can impact the city and its local towns. A criticism to the notion of speed and transport discussed by Beukers and van Hinte is the notion of Locality as described by Thackara in *In the Bubble* [7]. Instead of increased speed and transport, he argues for a notion of locality where urban centers and their surrounding smaller towns be seen as an aggregate that replaces intense international shipping with more local distribution centers. This is essential, he argues, because technology by itself will not solve issues without the integration of the face to face interaction of humans. Business, society and progress ultimately rely on social interactions and trust to succeed. For design, this leads to notions of more intense and integrated resource allocation based upon flexibility of spaces to accommodate various occupants and uses over different lengths of time, and has profound implications of how urban spaces may be conceived and designed. Again, this will be discussed later in this paper. Indeed, flexibility, lightness and adaptability are characteristics that relate to the notion of locality.

Responsive Architecture

Material and structural efficiency (lightness) combined with the characteristic of specificity (locality) creates exciting possibilities for the architectural expression of human comfort through adaptability. One such possibility is the design of architecture or assemblies that respond to body-environment situations as they vary. Such responses could occur within material properties themselves, or through assemblies that deform. The ability to change properties of materials or assemblies has not been within the reach of architects before, but with investigations into pneumatic structures and smart materials these characteristics are now within the reach of designers. For example, a deformable lightweight fabric structure could deform to effectively alter its U value to correspond with the heat transfer across its boundary. This has exciting formal potential in that architecture may be seen to visually register its behavior (see Figure 2). It also has the ability to significantly reduce fossil fuel consumption as the mechanical heating and cooling load could be nearly eliminated, as a study for the UK climate suggests [8].

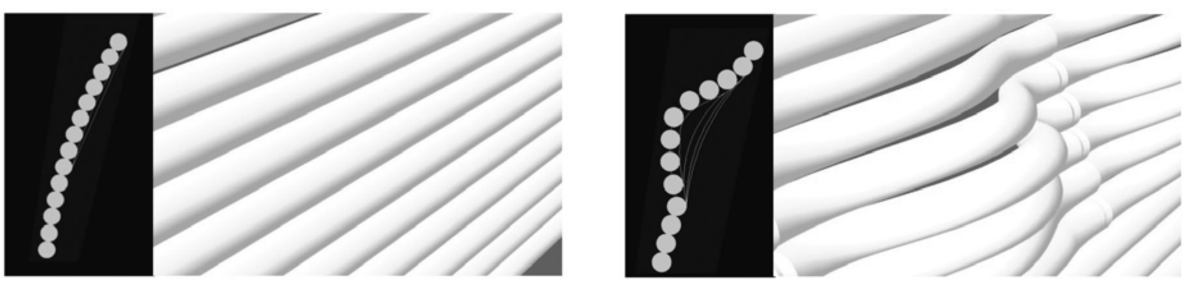

Figure 2: Visual registration of heat transfer through a proposed building skin in closed and open positons [8]

Potential Models

Few, if any, precedents for the type of proposed adaptable design currently exists. However, architects could look to other fields for models.

Biomimicry is a rich source of models for the notion of adaptability. The human skin alone possesses several models. For example, the assembly of human skin alters its heat transfer by means of arteriovenus anastomosus by altering the interaction of a heat source (heat being carried by blood flow) and its environment (air flow around the body) [9]. In essence, the human body uses the surrounding air as a heat sink for surplus heat. This transfer is visually registered in the skin by means of bulging veins and blushing. Another means to expel unwanted heat from the body is through the process of direct evaporative cooling. Here, the body sweats, and this liquid evaporates on the body's skin. This exchange of energy via a phase change in the liquid effectively removes heat from the skin surface. The human skin has also adapted over time to accommodate different environmental conditions through altering the production of melatonin. This alteration in its properties permits or inhibits solar radiation of varying wavelengths to penetrate the body. This is visually registered through skin color. Examples beyond the human skin exist, as well. Penguins have a unique feather structure that enables the quills to compress [10]. This compression expels air from the center of the quill. This action allows the animal to dive underwater for two reasons. Firstly, it reduces the buoyancy of the feather. In fact, the penguin would otherwise float. Secondly, it creates a fluidly dynamic surface that increases the efficiency of its swimming motions. Upon exiting the frigid water, the penguin immediately fluffs its feathers, injecting air back into the quills. This action increases the insulating properties of the feather, without which the animal would undergo thermal shock. In all of these examples, the characteristics inherent to adaptability are demonstrated elegantly and efficiently; from a change in form to a change in the properties of material to the rapid deployment and re-deployment of different states of operation.

Another potential model can be found in extreme expeditions. The equipment and clothing required for exploring, camping, surviving and eating in extreme climates demands several of the characteristics of adaptability. Among these is lightness, albeit in the sense of less weight and high performance materials. An explorer is capable of carrying only so much weight and the provisions and equipment brought for the expedition must be carefully chosen. Much of the equipment must also be able to multi-task, that is perform multiple operations. Additionally, the clothing and tent must be able to handle various climatic conditions, and must be able to deployed and re-deployed in minimum time with little effort. Fabric for clothing and tents is driven by high performance characteristics, such as wicking away water, providing insulation and controlling air flow. These characteristics are heightened by the property of locality, that is different materials are distributed in different locations where they are needed most to provide comfort. For example, air flow control is located near the armpits while wicking properties are distributed over the majority of surfaces.

As mentioned previously, the concept of dynamic resource allocation can be viewed as the notion of adaptability acting at the scale of cities. Thackara predicts that “speed is a cultural paradigm whose time is up. Economic growth, and a constant acceleration in production, has run up against the limited carrying capacity of the planet” [7]. Instead, he proposes that “it is within our powers to reverse engineer the spatialization of time and to separate time, speed and distance. One way is to change the word ‘faster’ to ‘closer’ in our design briefs for cities and transport systems. . . Dynamic resource allocation . . is the basis for a speed-time situation better adapted to the rhythms of individuals” [7]. This can be done by enabling “situations that support an infinite variety of fast and slow moves,” a characteristic of adaptability. Much of our time is spent waiting for services, whether it be a doctor, delivery or business appointments. However, precision in appointments is not very common because of the flux that people, products and services constantly undergo. Rather than predict precision and then wait for services, flexibility may be added to the system by the integration of technology in the form of pervasive computer networks that provide real-time updates of the availability of services. Wifi and GPS can be coordinated with services to permit “users [to] flexibly arrange and adjust their appointments by coordinating their own schedules with the availability of the services they are seeking” [7]. The integration of these technologies into our daily lives could lead to enhanced resource ecologies in a city with embedded information tags on maps alerting individuals to available services in their locality. This could impact the way we design cities by distributing different services throughout a city where they may be of most use to individuals at whatever time they may need them. The spaces for these services may be interlinked or may be transformed, allowing different services to occur in a single location at different times. Adaptability would need to be designed into the dynamically available spaces.

Conclusion

Adaptability seems to be an increasing characteristic of this new century. Limited energy resources, demands upon individuals’ time and attention, international business and travel require a new approach to notions of speed, resource allocation, patterns of consumption and technology. People find themselves awash in technology that seems to make more demands on them, rather than doing what they had promised: making our lives easier. Refocusing technology upon individuals can create a new approach to design. Human comfort is one approach to the notion of adaptability that has the potential to address some of architecture’s current concerns, such as energy consumption, material efficiency, uses of smart materials and climate-specific design. Adaptability and comfort hold the potential to be central design forces as they become powerful, useful and poetic means to find form, define space and respond to programmatic demands.

Endnotes

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