The Adaptive Buffer
An Emerging Building Type

Kimberly Drennan, AIA, LEED AP
Assistant Professor
Program in Environmental Design
University of Colorado Boulder

Abstract

Harnessing architecture's potential as a biotic force offers a powerful evolutionary advantage for human and non-human life during times of intense change. This paper seeks to define a new type of architectural product, the adaptive buffer, that has emerged in response to ecological disruptions. It is no longer enough to shelter; architecture needs to also buffer time, space and information. While all buildings manage the environment for inhabitants, the adaptive buffer preserves or provokes structural and/or behavioral adaptation. In concept and embodiment, this type of architecture operates as a physiological extension of its inhabitants and performs work on their behalf.

Distinct from earlier building types, an adaptive buffer is provisional in nature, dependent upon predictive models to remake itself annually, and buffers time based on the inhabitants' progress toward an intended future state outside of its boundary. The evolution of this concept borrows from historical typological frameworks and embraces new technology to explore emerging spatial temporal dimensions. As an example of an adaptive buffer in practice, a mobile, indoor, controlled apiary for honeybees will be discussed.

"The most intense moments in architectural development are those when a new type appears."

— **Raphael Moneo,** *On Typology.*[1]

Introduction

This paper seeks to define a new type of architectural product, the adaptive buffer, that has emerged in response to ecological disruptions. In concept and embodiment, this type of architecture operates as a physiological extension of its inhabitants and performs work on behalf of living organisms. The adaptive buffer preserves or provokes structural and/or behavioral adaptation. The evolution of this concept borrows from historical agricultural building types and embraces new technology to explore emerging spatial temporal dimensions. As an example of the adaptive buffer in practice, a mobile, indoor, controlled apiary for honeybees will be discussed.

Background

The adaptive buffer descends from a line of thought attributing the origins of architecture to the human need for shelter. In Laugier's Primitive Hut,[2] Nature is shaped into architecture in order to protect humankind from destabilizing natural processes. The advent of a mediator between Nature and humankind, architecture, created separate evolutionary and ecological time zones, "ecozones". One ecozone is the uncontrolled environment beyond the architectural boundary and the controlled is the ecozone contained within it. The creation of architecture relieved humankind of certain evolutionary pressures that would

Figure 1. Architecture as edge. The greenhouse is a smartly situated shed whose job is to repeat a growing cycle for a curated set of organisms. Through frame, transparency, orientation and operation, this building type defines a distinct edge between growth and dormancy.[3] https://inhabitat.com/elegant-pirogovo-greenhouse-nurtures-organic-greens-and-vegetables-in-russia/

have been applied from beyond its protective armor. Protection from outside pressures and the ability to design for growth in population has brought with it a pressure of abundance from within our architectural vessel.

The expanding pressure of abundance from within has altered the discrete nature of architecture as shelter. No longer is it enough to separate and protect, architecture needs to also buffer time, space, and information. Buffering can be understood as both lessening the impact of the disruptions from the environment on an organism and, in a more contemporary context, to preload a commodity, to store something at one speed and provide it at another speed.

The expanded role of the work of architecture opens the door for new types to emerge, types that fully embrace their moment in time at the edge, the instance between a world we operate within and a world that is waiting for us.

Typology

While all buildings manage the environment for inhabitants, certain types have evolved specific niches. In the sea of architectural types, several can be called upon to contribute their expertise in managing biological processes at an architectural scale and complexity. Early influencers of the adaptive buffer include architectural building types that are industrial, agricultural, and designed for use by human and non-human occupants. These types of building can be seen as buildings that do significant work for an organism by managing time and place relative to life cycles. Closest relations to the adaptive buffer include the greenhouse (Figure 1) and the commodity storage shed (Figure 2).

These two building types share key characteristics with the adaptive buffer: they are designed to create internal thermal conditions that shift the timing of biological processes, technology can be added to make them “smarter”, and they contain vital resources for human and non-human life. However, the adaptive buffer diverges from these building

Figure 2. Architecture as preservative. Large scale commodity storage sheds house the process of perishing. In this type of building, time is slowed. The building form takes the shape of the content it preserves. [4] https://www.britespanbuildings.com/uses/commercial-warehouse/

types in three ways: 1) the provisional nature of its embodiment, 2) the dependence on predictive models to remake itself annually, and 3) the buffering of time based on the inhabitants' progress toward an intended future state of being outside of the adaptive buffer.

Evolutionary Ecology

The adaptive buffer is the result of a design strategy that accepts and prioritizes architecture as an extension of an organism's physiology and embraces the selection pressures of adaptation - an architecture that probes at how the environment impacts the patterns of various forms of life as they begin, grow, develop, reproduce, age, and perish. Architecture and other animal-built structures play a vital role in the life cycles of organisms in their environment. Moving beyond metaphor or mimicry, a carefully crafted and designed layer of architecture with seasonal transformations can take agency. J. Scott Turner argues that certain animal built structures perform sufficient work for organisms to be considered organs.[5] The adaptive buffer seeks this "organ" level of engagement with the inhabitant such that

In physical form, the adaptive buffer is provisional; built for one specific trip around the sun. Like an annual flower, it has a seasonal purpose then focuses its energy into the next generation. As a perennial prototype, the adaptive buffer is configured and modified every year, informed by its own history and by measurable progress along a trend or pattern. Agility in physical form is a response to a choreography of pattern and improvisation. The impermanence of this evolving edge condition allows it to remain a prototype, a product in service of the next.

Technology

Responding to concerns about resource consumption and ecological disruptions, the contemporary practitioners have focused on integrating knowledge from multiple disciplines to address complex problems and have developed new technologies to measure building performance relative to type-specific benchmarks and achievements. The push to advance architecture as a measured performance has given rise to a goal-oriented technical theater composed of a cast of "smart" players. From smart appliances to smart buildings to smart farms, the ability to collect and analyze information at multiple scales across disciplines is opening up the ability to design within a spatial logic, similar to the algorithms that create it, that is non-linear, dynamic, and complex. A new dimension of architectural space has been made available by the tools that measure and give structure to overlapping processes of life and the variable speed of time. Advances in laboratory research show promise in that they have revealed the hidden life of materials considered abiotic.[6] The next leap in understanding will come with the ability to view, evaluate, and design the multitude of interactions that are constantly occurring between biotic and abiotic factors in large ecosystems.

In concept and embodiment, the adaptive buffer is equipped with tools that capture and evaluate information on the critical interactions in ecological processes. An example of a critical ecological interaction is pollination - the big event that determines the abundance of life to follow. A pollinator needs to make contact with flowers when they bloom. The information needed to support this one interaction requires the measuring of hundreds of seasonal milestones over time in a space that is complex, non-linear, and dynamic. We now have sensing, computing and analytical tools that can be used to monitor, assess, and predict these milestones with varying degrees of accuracy. These new tools provide access to the space between, surrounding, and within these complex interactions. The greatest impact these technologies will have on the environment will

Figure 3. Cluster of honeybees inside hive during winter.[7] http://scientificbeekeeping.com/understanding-colony-buildup-and-decline-part-13a/

not be the control they exert nor the efficiencies they find, but rather the insights into the inner workings of life they will offer.

Case Study

Mobile Indoor Climate Controlled Apiary

The following case study illustrates an adaptive buffer designed for commercially managed honeybees and their keepers.

Paralleling growth in monocropping as an agricultural practice in the United States, the environmental changes and lifestyle pressures on commercially managed honeybees have steadily increased.[8] Because monocropping limits the seasonal availability of nutrition for honeybees in a region, honeybees cannot stay in one location and build up their supply of honey and pollen over the entire growing season. In response to the need for pollination, beekeepers began to move colonies on trucks to various locations as a pollination service for growers. The advent of migratory beekeeping brought new challenges for honeybees: transportation stress, changes in nutrition, and instability in thermal patterns brought by multiple changes in location.[9]

Since the 1990's, more intense changes have added to the complexity of honeybee life: the introduction of a highly destructive parasite, an economic shift toward larger commercial operations with more densely populated colonies, a more chemically saturated environment, and a changing climate that is disrupting previously successful seasonal behaviors.[10] With these multiple stressors on honeybee colonies, it is no surprise that commercial beekeepers in the United States are reporting 40% average winter colony losses.[11] Winter is the most difficult time of year for honeybees because the lack of forage in the outer environment and the spike in parasites at the end of fall.

Over the past several thousand years, however, the honeybee, specifically the Apis mellifera, has developed remarkable adaptations to winter - producing and storing honey & huddling together for warmth (clustering). (Figure 3) Winter is the reason for honey and it is the abundance of honey stored earlier in the year that fuels honeybees to maintain their activity and supply metabolic heat to their hive. Evolutionarily, overwintering in a stable but cold environment is what European subspecies of honeybees have done to survive.[12] When the temperature outside the hive drops below 57 degrees honeybees will form a cluster inside their hive until the temperature rises again.[13] The storage of honey for the winter bees and the clustering behavior are two strategies that have allowed for adaptation of this species to many climate zones and locations. The mobile indoor controlled apiary (MICA) is designed to use these two strategies to advance adaptation to the recent changes and to anticipate future needs (Figure 4).

Architectural Design

Considering the architecture an extension of the honeybee physiology, the MICA works to keep honeybees alive and functioning through the winter season. Similar to the greenhouse repeating spring and the commodity storage delaying decay, the MICA creates a pause. This pause must happen at precisely the right moment

Figure 4. Architecture as pause. Through advances in instrumentation, the application of building science, and research into honeybee biology, modern apiaries improve survival rates by creating an indoor environment that prompts a winter behavior that preserves the strength and resources of honeybee colonies. [14]

– the time when the colony has stored enough honey to last through the winter, reduced its population to the optimal colony size and type, and just prior to the spike in mite population.[15] Inside MICA, the temperature is steadily held below cluster threshold until the spring bloom. Once forage is blooming, the bees return to environment and rebuild their colony.

As adaptive buffer, the embodiment must be provisional. The MICA is a modular panel system designed for disassembly and can assume multiple configurations. The envelope is layered to allow for the addition or reduction of materials based on location, durability, or hygienic requirements.

The embodiment is dependent upon predictive models. The MICA is equipped with an extensive sensor network that measures key biological metrics at the scale of the individual organism (a colony), the aggregation of organisms, the interior environment, and the microclimate surrounding the exterior. In addition to finding health signatures in the honeybees, the performance of the architecture is also constantly reported and assessed. Using the various data, assessment models and predictive models inform the current operation and future configuration of the MICA. The relationships between the organism and the architecture, the architecture to the microclimate, and the architecture to the future climate and future organism set the criteria for the next year's embodiment. The desired future state of being for honeybees is a healthy, strong population that can thrive outside of the MICA during the spring, summer, and fall.

The buffering of time is based on the inhabitants' progress toward an intended future state of being outside of the adaptive buffer. The buffering required in this case is both a buffering against environmental instability and a gathering of information throughout the year to be used in the winter months. Buffering against environmental instability occurs by providing stability in interior environment when the exterior is shifting to longer fall seasons, more intense diurnal temperature swings, and increased parasite loads. The information gathered throughout the year on honeybee health, local weather patterns, spring bloom inform how the MICA will be configured, when it will be assembled, and where it will be located.

Conclusion

Harnessing architecture's potential as a biotic force offers a powerful evolutionary advantage for human and non-human life during times of intense change. The act of design is an act of ecosystem adaptation. The new tools of our information age can offer insights into the complex relationships between the multitudes of biological clocks. The emergence of the adaptive buffer as a new type of architectural product opens opportunities for architects to broadly serve and shape the future space of life.

Endnotes

1. Moneo, Raphael. "On Typology." Oppositions. Summer, 13 1978: p27.
2. Laugier, M. A., An Essay on Architecture. London: T. Osbourne and Shipton. 1755.
3. Totam Kuzembaev Architects. (2011). *Pirogovo Greenhouse*. Klyazminskoe Lake, Russia.
4. Commodity Storage Building [Digital Image] (no date). Retrieved from Britespan Building Systems Inc. @ https://www.britespanbuildings.com/uses/commercial-warehouse/
5. Turner, J Scott. The Extended Organism. The Physiology of Animal Built Structures. Cambridge: Harvard University Press, 2000.
6. I am referring to the work of Professor Neri Oxman at the MIT Media Lab and her conceptualization of "Material Ecology" and fabrication techniques.
7. Oliver, Randy. "Understanding Colony Buildup and Decline. Part 13a. The Physics of The Winter Cluster. "American Bee Journal. v156. 2016/07.01.
8. Steinhauer, N., Kulhanek, K., Antúnez, K., Human, H., Chantawannakul, P., & Chauzat, M. P. (2018). *Drivers of Colony Losses*. Current Opinion in Insect Science.
9. Alger, S. A., et al. "*Home sick: impacts of migratory beekeeping on honey bee (Apis mellifera) pests, pathogens, and colony size.*" PeerJ, 6, e5812. doi:10.7717/peerj.5812, 2018.
10. Jabr, Ferris. "The Mind-Boggling Math of Migratory Beekeeping." Scientific American. 2013/09/01.
11. United State Department of Agriculture National Statistics Service. "Honey Bee Colony Report." 2018.
12. Wallberg, A., Han, et al. "A worldwide survey of genome sequence variation provides insight into the evolutionary history of the honeybee Apis mellifera." *Nature Genetics*, 2014. *46*(10), 1081.
13. Oliver, Randy. (2016)
14. HiveTech Solutions. (2019). *MICA - Mobile, Indoor, Controlled Apiary*. Colorado, United States.
15. DeGrandi-Hoffman, et al., "Population growth of Varroa destructor (Acari: Varroidae) in honey bee colonies is affected by the number of foragers with mites." Experimental and Applied Acarology, 2016 *69*(1), 21-34.