RESEARCH ON BUILDING LAYOUT DRIVEN BY ENERGY FLOW IN HUMID TROPICS

Take the living space of HALE KUAHINE Dormitory in Honolulu
as a thermal comfort simulating object

A DARCH PROJECT SUBMITTED TO THE GRADUATE DIVISION OF THE UNIVERSITY OF HAWAIʻI AT MĀNOA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

DOCTOR OF ARCHITECTURE

MAY 2016

BY

RUYUN XU

DArch Committee:

Joyce M Noe

Willian Chapman

Scott Inatsuika

Keywords: Building Layout, Energy Flow, Thermal Comfort, Sustainability, Hot-humid

ABSTRACT

Building, which can be defined as a “container of life”, should not only be analyzed for expressing visual beauty of architectural language, but special attention related to living quality indoor and outdoor also must be asserted. The desire of comfort is usually satisfied by some mechanical equipment with high energy consumption in modern architecture; however, facing the current crisis of environmental pollution and energy shortage, it is urgent to blaze a trail and to find an architectural approach that is energy-efficient to enhance the life quality.

As a part of the Shanghai-Hawaii Global Track Project, this doctoral research has been launched in University of Hawaii at Manoa (UHM), by selecting the non-air-conditioned dormitories in East-West Center (EWC) as an object to study the relation between the comfort level of daily activities and the building programming, which is one of the main architectural design contents once linked too much to spatial accessibility but lacking of considerations from a performance perspective. In order to find appropriate strategies for building programming in such a climate of humid tropics, the paper will blend the lessons of architectural history with the future-oriented technological progress, presenting in two major research clues ---- one is “experience” and the other is “evidence”. Specifically, the clue of “experience” will commence in studying the ancient ingenious ideas from typical human dwellings and vernacular settlements in hot-humid areas and then move to those salient

modern regional explorations sparked by their ancestors' wisdom. Meanwhile, the clue of "evidence" will serve as an evaluation system to demonstrate the feasibility of certain sustainable design concepts, with the assistance of computational simulation data and new credible discoveries from relevant disciplines such as environmental psychology, thermodynamics, neuroscience and behavioral economics on man-environment interaction.

By mixing these expertise, architects can take the role of traditional engineers to fabricate a well-tempered "living machine" and figure out some constructive design techniques, which, if applied to mold the campus dormitory, would create a sense of well-being and encourage more students to enjoy the space for a longer time.

KEY WORDS

Building Layout, Energy Flow, Thermal Comfort, Sustainability, Hot-humid, Dormitory

CONTENTS

Abstract ..... **i**

Contents ..... **iii**

A Trigger of Research ..... **vii**

1 Introduction **1**

1.1 Question and Motivation 1

1.1.1 Question: Value the significance of Invisible Energy Flow in interior spaces 1

1.1.2 Motivation: Energy issue & Technical Support 3

1.2 Trends of the Correlational Study 5

1.2.1 Climate-responsive design and Limitations 5

1.2.2 Climate & performance; Collaborative & interactive 8

1.3 Research Focus and Relevant Factors 9

1.3.1 Focus on Layout and Indoor Thermal Condition 9

1.3.2 Relevant Factors 10

1.3.3 The concept of "Energy-Programming" 13

1.4 Object and Purpose of Research 15

1.4.1 Research object: Living space 15

1.4.2 Case Selection by Research Logic 15

1.4.3 Purpose: Sustainability & Well-being 18

1.5 Scope of Research 18

1.6 Research Methodology 20

1.7 Significance of Research 22

1.8 Research Framework and Structure 24

2 Cognition of Energy Effect on Thermal Comfort **26**

2.1 Thermal link between life and natural energy 26

2.1.1 Climatic forming 27

2.1.2 Thermal Strategies of Organisms 29
2.2 Influential Factors in Thermal Comfort 34
2.2.1 Metabolic rate of human body 34
2.2.2 Clothing Insulation 35
2.2.3 Air Temperature 35
2.2.4 Radiant Temperature 36
2.2.5 Air Pressure & Speed 37
2.2.6 Humidity 37
2.3 Thermal Sensation and Comfort Evaluation 38
2.3.1 Relativity of thermal sensation 39
2.3.2 Graphic & Analytical Comfort Zone 39
2.3.3 Evaluation methods 42

3 Redefining the Role of Energy in Architectural Evolution 44
3.1 Primitive Period --- Energy and Construction as two independent survival options 46
3.2 Pre-industrial era --- Energy as a part of the Construction 49
3.2.1 Site Planning 52
3.2.2 Building Programming 53
3.2.3 Spatial Form 57
3.2.4 Natural Material and Component Design 59
3.3 Modern time --- Energy Quantification and Mechanically Isolated architectural system 61
3.4 Sustainable age --- Generalized Mechanization and Fine Control of Energy Flow 63
3.5 Chapter Conclusion 65

4 Precedent Study in Humid Tropics --- Impact of Energy on Layout Design Experience 67
4.1 Climate characteristics, and Representative locations 67
4.2 Ancient Wisdom Study in Vernacular Dwellings 69
4.2.1 Houses in Thailand --- A unique icon in tropics 70
4.2.2 Other tropical vernacular houses 71
4.3 Modern Architects' Practice towards the hot-humid climate 73
4.3.1 Wind Vault House in Singapore 73
4.3.2 Parekh House in India 74
4.3.3 Liljestrand House in Honolulu 75

4.3.4 Stacking Green in Vietnam 76
4.4 Induction of Programming Characteristics 77
4.4.1 Proportion of modules 78
4.4.2 Location of inner buffer 78
4.4.3 Form of outer buffer 79
4.4.4 Interspersed dynamic zones 80

5 Thermal Comfort Parametric Simulation --- Kitchen and Living Area in HALE KUAHINE 81
5.1 Site & Climate Data 81
5.2 Experiment Organization 83
5.3 Simulating Target & Zone Creating 86
5.3.1 Orientation influence 86
5.3.2 Relative position influence 87
5.3.3 Courtyard influence 89
5.4 Analytical Diagrams of Testing Results 90
5.5 Predesign Studies for Proposed Improvement 92
5.5.1 Change the current layout 92
5.5.2 Sunshade Components 93
5.5.3 Wind Pathway: Increasing openings on windward side at the ground level 94
5.5.4 Landscape Assistance 95
5.6 Summary and Extension 95

6 Recommended Layout Design Procedure under Energy Perspective 97
6.1 Grouping Zones 97
6.2 Locating Zones 98
6.3 Organizing Principles 101
6.3.1 Grouping Zones by similar energy requirements 102
6.3.2 Coordination: Thermal Zone—Schedule 103
6.3.3 Heat source as a Dynamic Factor 108
6.3.4 Buffer & Filter 110
6.3.5 Interstitial space as wind pathway 112
6.3.6 Auxiliary Landscape 114

6.3.7 Thermal Delight as a Spatial Identification 116
6.4 Simulation & Adjustment 119
6.5 Supplement Strategy 119

7 Epilogue 120

8 Graph Index 122
8.1 Source of Images 122
8.2 Tables 122

9 Bibliography 123

10 Appendix 126
10.1 Data setting during the experiment process 126
10.2 Other case study in humid tropics done by author 130

Acknowledgement 141

A TRIGGER OF RESEARCH

Architecture always pay attention to the orientation, to where the wind comes from… However the essence of these attentions has not been strengthened --- energy. In the following example of “Housing and studio for Dominique Gonzalez-Foerster” leaded by Philippe Rahm, the way of locating programs is totally different from ever before, which, is based on the energy flow (thermal condition) in particular position or the thermal impact of adjacent zones.

Figure 0-1，Housing and studio for Dominique Gonzalez-Foerster

The building creates its interior climatic phenomenon and air convection by two thermal polarization with 7 ℃ difference in temperature. After importing the digital model into the simulating software, the variation of temperature and its distribution in all the space will become visible. Designers then find the proper places for different programs based on the equilibrium in the exchange of heat between the users' body and the simulated temperature. It can be seen that even the bathroom is separated into several parts: the bathtub is put on top of the warm pole (22 ℃) while the commode is moved close to the cold pole (15 ℃), which is because people are nude when taking a shower, but wear light clothing when using other sanitary wares. The floors and the open spaces are cut out from the shapes of the thermal flow in the entire height of the building. Although this form will have some practical problems, it no longer needs to heat up all the rooms to the same temperature, which results in an ecologic and economic gain by creating a low average of temperature at 18 ℃ in the whole house instead of 20 ℃ in a normal heating system, without sacrificing thermal comfort.

This ideal attempt generates an unprecedented layout mode which breaks the limitation in architects' minds. It shows the potential of the new layout methods in saving material & energy consumption. All of these achievements are realized owing to a concept which is the purport of this paper --- Layout follows energy.

Layout is the way of organizing various building functions. Influenced by the modern trend of thought, architects have been engaging in discussing the relation between form and function for a long time. Someone believed that form should follow function, while others argued that form evokes function. Actually, these opinions are one-sided. Form and function

are two equal elements: forms can change the micro-climates on the building edge which are the constraints of locating functions, and functions should in turn be reflected on the form. In this dialectical and unified relationship, energy is their link.

1 INTRODUCTION

1.1 Question and Motivation

1.1.1 Question: Value the significance of Invisible Energy Flow in interior spaces

For over one and a half centuries, research in energy has furnished a main thread of classical knowledge through the history of natural and social sciences. In the field of architecture, there also exists a long discussion about “built order or combustible disorder”. As a matter of fact, architectural speculations on tectonics and energy have shared almost the same period, however, the latter has been neglected by the dominant ideology for ages because of its invisibility. Just as we warm-blooded animals are capable to control the speed of our body heat loss aided by inner energy but without awareness, energy is always the crucial factor for sound operation of every system, even being intangible. Unfortunately, the continuous emergence of electric appliances has established a paradigm of isolation and machine-control between natural and built environments, resulting in unprecedented weakness of building interior: the demand for air circulation is satisfied by air-conditioning and the need for light is realized by artificial illumination. Even those architects who are experienced in manipulating the natural light quality of a space, are still more likely to focus on the light-shadow rhythmical aesthetics, rather than the heat entering the building along with sunlight. The indoor thermal comfort then became a relinquished package thrown to machinery and

equipment. Nevertheless, the interior is, after all, an architectural category instead of a mechanical assembly. Long-term evolution of conventional building modes have mirrored some great constructing techniques to guide internal energy flow, and this original pursuit for better thermal qualities has generated a degree of continuity in pre-modern material culture, which yet disappeared in much of the world after the industrial revolution. Thus, it is the right time to recall the public attention to the architectural thermal condition----warm or cool, humid or airy, which not only closely related to our spatial experience, but also directly affect the building energy saving. This attention will lead architects to seek for an alternative construction based on the tectonic and thermodynamic behavior to cope with the built spaces, amending the erroneous division between envelope and structure in modern projects. Here, the design target -----'interior' is more than a location inside a building, it is about certain modes of spatial organization whose form and materiality facilitate the regulation of the environmental conditions and screen out useless external climate elements before penetrating the room. As the Spanish architect Alejandro de la Sota mentioned, "Architecture is the air we breathe, an air laden precisely with that: architecture", those aeriform resources like air are today's one of the single most valuable materials of architecture, and designers should learn the mastery to balance the different thermodynamic factors in their energy-oriented programs.

Define the categories of Energy Flow related to building design:

- **Interior energy**

Heat gain from indoor appliances --- equipment schedule

Heat dissipation from occupants --- schedule & activity

- **Exterior energy**

Natural wind; solar radiation

1.1.2 Motivation: Energy issue & Technical Support

1.1.2.1 Introspection of the energy issue caused by the contemporary building design

A report from "Building Green" has shown that 41% of U.S. energy consumption attributes to buildings, which also account for 40% of total greenhouse gas emissions in the U.S. ----- Energy issues are alarming the world community and present profound challenges to architectural designers who must find solutions. Tracing back to the industrialized history, the biggest problem lies in people's attitude towards energy. Much is talked about the contemporary buildings' dependency on limited supplies of non-renewable energy sources (e.g. burning fossil fuel to generate electrical power), most often combined with calls for new technologies. Non-renewable resources will be completely consumed in the foreseeable future, while industrialized society has caused an acute pollution problem and is forced to cope with global warming and its consequences. An article in TIME called the air-conditioner "a more pertinent symbol of the American personality than the car", which pointed out the abuse of mechanical equipment in the construction over the past decades. In one sense, the neglect of natural renewable resource is a great loss to modern architecture. The misconceptions that architecture belongs in one place and energy service in another has crippled building performance and divorced the art of architecture from the practice of operating buildings. Rather, the building layout drawings tend to be an aesthetic expression of architects' spatial control, seldom showing the storage or delivery routes of energy source,

and therefore render those energy systems unannotated and uncommented, falling out of all subsequent studies of architectural history. Although most schools require courses that introducing the dynamic thermal performance of a building, the knowledge are generally taught from the perspective of a mechanical engineer, so architectural students still do not have conscious of regarding energy as a design object. In fact, pre-eminent scientists now unanimously concur that emphasis on energy issue is not only embodied in the macro word "sustainability", but also effects the micro physiological reaction of the human body. That is why the matter is worth taking seriously. In order to assume this an intrinsic and urgent responsibility, an architect should transcend himself of being a pure space designer only using existing building languages, but become an experimentalist or a craftsman in order to adapt to discipline transition.

1.1.2.2 Development of architectural technology theory

Sciences are associated with each other and the end of one discipline can sometimes be the rise of another subject. Rooted in the age of BIG DATA, architectural design becomes more complicated and must rely on the technologies from other collateral industries. For example, digital simulation platform, 3D modeling & fabrication, pipe network integration, and monitoring sensor device, are all useful tools for carrying out and making the overall design process better, including analyzing before sketching a draft, immediate feedback during form-finding, and maintaining comfort & health when putting into use.

What is developing is not only technology itself, but also the way we apply these techniques. Take "modular management" as an instance which is popular in many realms today. People

may know that this concept can simplify a sophisticated problem by restructuring a mixing sequence into several separated subsequences and prioritizing them. The manner is still helpful when dealing with energy issue in architecture: the energy operating system can also be packaged as an indispensable module assembled in the construction, maybe an independent structure along the building edge, or a thick service layer between the floors.

In short, the dissertation is adding to the core sustainable design principles with the results of well-focused theorizing, careful testing and research, intelligent new applications in actual design and construction, and rigorous performance monitoring.

1.2 Trends of the Correlational Study

1.2.1 Climate-responsive design and Limitations

To respond to the building energy problems, a climate-suitable design is a crucial approach to construct a cozy thermal condition, meanwhile, save energy. However, a building is, a rigid structure placed in the environment of continuously changing pressure, wind movement, temperature, humidity, and cloud cover, and to provide a relatively constant internal environment over a wide range of these external variables. How to solve the contradiction between architectural inflexibility and unstable weather, has been a long-standing discussion, which could date back to the times before energy was plentiful and cooling machine omnipresent. By relearning those techniques shining for centuries, some of the modern pioneering explorers have made their own contributions in this domain, both theoretically and practically.

As early as the 1950s, Victor Olgyay & Aladar Olgyay first proposed the combination of energy and architecture design and invented “Bioclimatic Chart” and “Shading Mask” in their research of “Design with Climate”. Then, Ralph Knowles’ study on “Form and Stability” and Richard Stein’s “Building Energy” both demonstrated the architectural scenario under the tooling condition at that time. Besides, Wilhelm Wundt was the earliest physiologist to note the energy issue from a physiological aspect; while Richard Neutra published a book “Survival through Design” in which he expounded the physical & mental connections between human body and environment, and how comfort and energy affect the nervous system. Apart from these groundbreaking ideology, there have been three important publications and researches around the 1970s established as landmarks in the process of research in energy and modern architecture on the theoretical levels. In 1972, Howard T. Odum, the founder of modern system ecology, put forward the concept of energy flow which inherited the early ideas of Alfred J. Latka, and also created a toolbox of “Diagram Energy Flow” and “Emergy Diagram”. Buckminster Fuller, famous for a series of thermodynamic conceptions and installations such as the Domed City in Manhattan, promoted the research of energy in the field of architecture with his personal utopic passion and deep insight into the technological society. In 1969, Reyner Banham offered the first theoretical summary for environmental control of architecture as an exosomatic artifact in the era of modern architecture through his book “The Architecture of the Well-tempered Environment”. After 1990s, some new research associations like OCEAN, CASE sprang up to expand design knowledge by focusing on a collaborative and interdisciplinary network where thermodynamics act as a scientific tool.

At a practical level, our predecessors also showed concerns for energy in some of their projects. The well-known “Fallingwater Residence” by Frank Lloyd Wright in 1935 mixed a metaphor of energy flow by means of an openable ventilation device interlinked with the active waterfall beneath the house, and a raised fireplace. Le Corbusier’s exploration on sun louver in Carpenter Center for the Visual Arts at Harvard University poetized the interaction between architecture and nature. Coincidentally, in Louis Isadore Kahn’s Esherick house, a T shape window separated its functions into two parts ----- the upper glass fixed with thin frame was designed much bigger and only used for lighting while the opening below with thicker border was for ventilation. The intention of Kahn with this window type was continued in his other buildings to beautify the form and make the energy service more eye-catching.

Still later, as the supremacy of building functions established gradually, the innovations on climate-responsive strategies went away from the center but trended to the surface, especially the material construction within the interface system. A professor in MIT named John E. Fernández suggested in his book “Material Architecture” that one should distinguish “structural materials” from “barrier materials”, for the former transfer loads and the latter control flux (such as heat, air, liquid water, solar radiation, visible transmission, etc.), energy or mass. More and more young architects grow interests in the latest material inventions, and keen to play some adaptive components to mimic the living organism who adapts itself to the flux of its environment. Admittedly, it is a promising direction for research, but no matter how far they go, or how successful they are, there still remain some limitations. Even if the designers can produce many different forms on the skin structure, they won’t be able to

change their original design essence of "form following function", because all these variations are done after the inner functional order constructed. Nevertheless, what is required in the future design is remodeling rather than remediation. The idea of this paper is not to attach local deformations to a fixed structure, but instead, to set up a fire-new form that evokes function, i.e., to fit programs to a well-calculated and energy-efficient form. This does not mean that we could care less about the function, yet make the organization of program units more logical and reasonable. Using a form to order the disordered energy in advance manifests the important status of energy transferring laws in sustainable building design, and will bring about a high-performance interior.

1.2.2 Climate & performance; Collaborative & interactive

- Climate & performance:

The climate is an important driving factor during the natural evolution of life, and thus it should also be a formation factor of the "architecture life". The performance of architecture is like the wellness of the human body, which is based on the information exchange of the inner parts, and can remain in a healthy state purely through self-regulation when the outside environment changes within a certain range. Similarly, if the architectures want to remain promising comfort feelings without using "external forces" such as high energy-consumption air conditioners, it should also have the ability of "self-regulation" – in other words, it should have a perfect energy exchange mechanism.

- Collaborative & interactive:

Not all the energy issues can affect the building forms, contrarily; the shape of the building and its components can not only respond to but have a profound influence on the energy utilization.

The environment in which the architecture resides are often diverse and complex, so we can no longer focus on single and independent factors, but to treat those systems in a global site of view, focusing on the connections between each other, constructing the adaptation process with interactions and feedbacks. The “interactive” design process which is based on the adaptation mechanism of the architecture and environment is consisted of two meanings: the first is that the design should make certain change and adaptations based on the boundary conditions of the environment, while the second is that the form mode of the architecture should go back from adaption to the optimization of the environment simulation. It is a dynamic balance and the adaptation and the optimization between them is the final pacing factor.

1.3 Research Focus and Relevant Factors

1.3.1 Focus on Layout and Indoor Thermal Condition

- How to organize building programs

- Layout not only pay attention to the outside climate influence, but also attach more importance to the relationship (energy flow) between the adjacent program zones.

- The interior microclimate is more complicated than exterior.

- Both of interior & exterior needs to be concerned. Also, include the users.

- The relationship between different zones and the thermal impact on each other. How to interlude buffer zones into the functional circulation.

1.3.2 Relevant Factors

1.3.2.1 Research basis: how energy channels

- Thermal convection

Thermal convection refers to the process in which the fluid moves because of the density difference caused by the temperature change. Heat will transfer from the surface to the air when the temperature of the surface is higher than that of the air, and thus change the density of the air. In still air, gravitational effects caused by the density difference will result in air currents. They can cause heat transfer from the surface that is larger than conduction in still atmosphere. Even in a closed compartment, variations in the temperature of the walls and other surfaces set up air currents, so that there is some air movement.

- Thermal radiation

All matter emits electromagnetic waves that are generated by the thermal motion of molecules composing the material. This process is called thermal radiation. A perfectly opaque material with a totally absorbing and therefore totally non-reflecting surface, which is usually called a black body, emits radiation at the maximum possible rate for any given

temperature. This black body is a convenient concept used as an idealized standard, but which should not be confused with an actual object with a black surface. In this case the rate of radiation emission depends only on the fourth power of its absolute temperature.

- Thermal conduction and resistance

Conduction is the process by which heat flows through a material, or from one material to another with which it is in contact. Thermal conductivity is a specific property of a material and is a measure of the rate at which heat will flow through a material when a difference in temperature exists between its surfaces. The thermal conductivity varies with the density, porosity, and moisture content of the material and also with the absolute temperature. The quantity of moisture contained in a material can have a considerable effect on the thermal conductivity of the material; the higher the moisture content, the greater the thermal conductivity.

1.3.2.2 Constituent Parts

Ordinary module, dynamic module, defense module (buffer zone) ---The three types of modules can be interconverted to each other.

1.3.2.3 Indicators

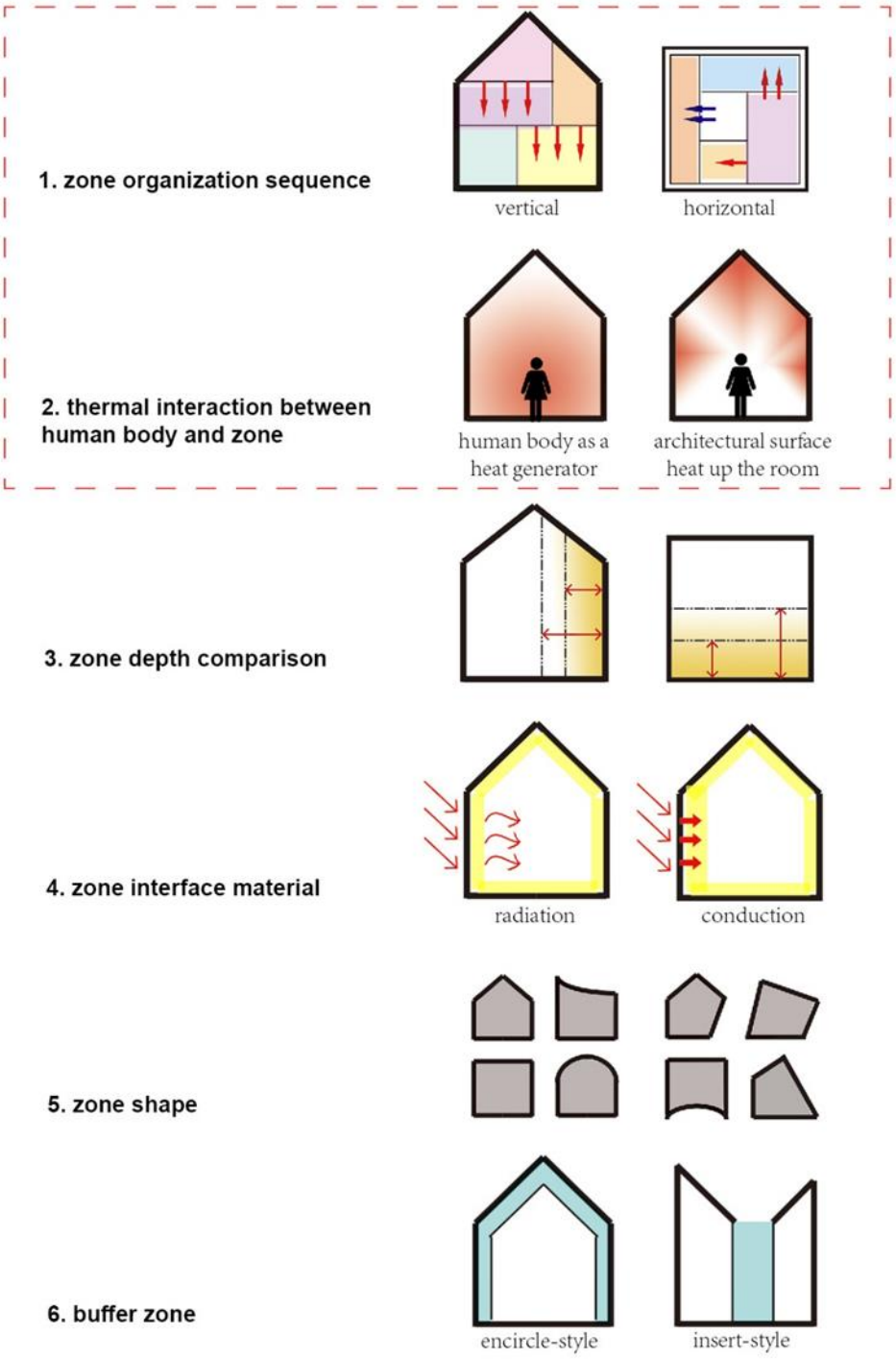


Figure 1-1, factors related to layout (drawn by author)

- Location/Orientation of the zone
- Energy transformation between adjacent zones
- Partitions (materials/spaces)
- Depth of zones
- Heat production by Activities and Equipment
- Extra protections: shading, tree, fan

1.3.3 The concept of "Energy-Programming"

Building is a complex system incorporating numerous subsystems, each system has its own organizing logic and influences the architectural performance to varying degrees. Looking back to our design experience, one may deliberate over the layout orientation, the bodily form, and the type of adumbral components quite often when taking passive energy saving into account. But for building programming, the ways people divide a space are usually more about dry-wet separation and quiet-noise parting, which seems to have a weaker link to the interior energy flow. Actually, grouping spaces with thermal knowledge also contributes a lot to the increase of building energy efficiency. Thinking out of the conventional box ----- what spaces are used for, how to determine their dimensions and characteristics, and their relationships to the adjacency, the paper aims at adding drivers of energy use and occupancy to the architectural program's analysis. That is to say, a building that houses a range of activities with ranging thermal needs cannot be treated as a single energy zone, otherwise it

would be unable to adapt to meet different temperature criteria of the hybrid rooms during the less hospitable seasons. Whereas multiple zones with specific thermal demand level, if well-arranged, can plan out a systematic path for the energy flux and reach various comfort standards without much non-architectural hands. In the process of "energy-programming", two indicators can be drawn on to discover and develop correct zoning strategies: 1) occupant schedules, and 2) thermal requirements for the using space. Besides, a Bubble Diagram will be a good choice to demonstrate the energy zone types for each space and some important functional connections among each other. With the help of the above-mentioned means, architects can finally produce a fine-new plan system or section system. Then the research is going to implement this rational methodology of programming in both case study and scheme remolding.

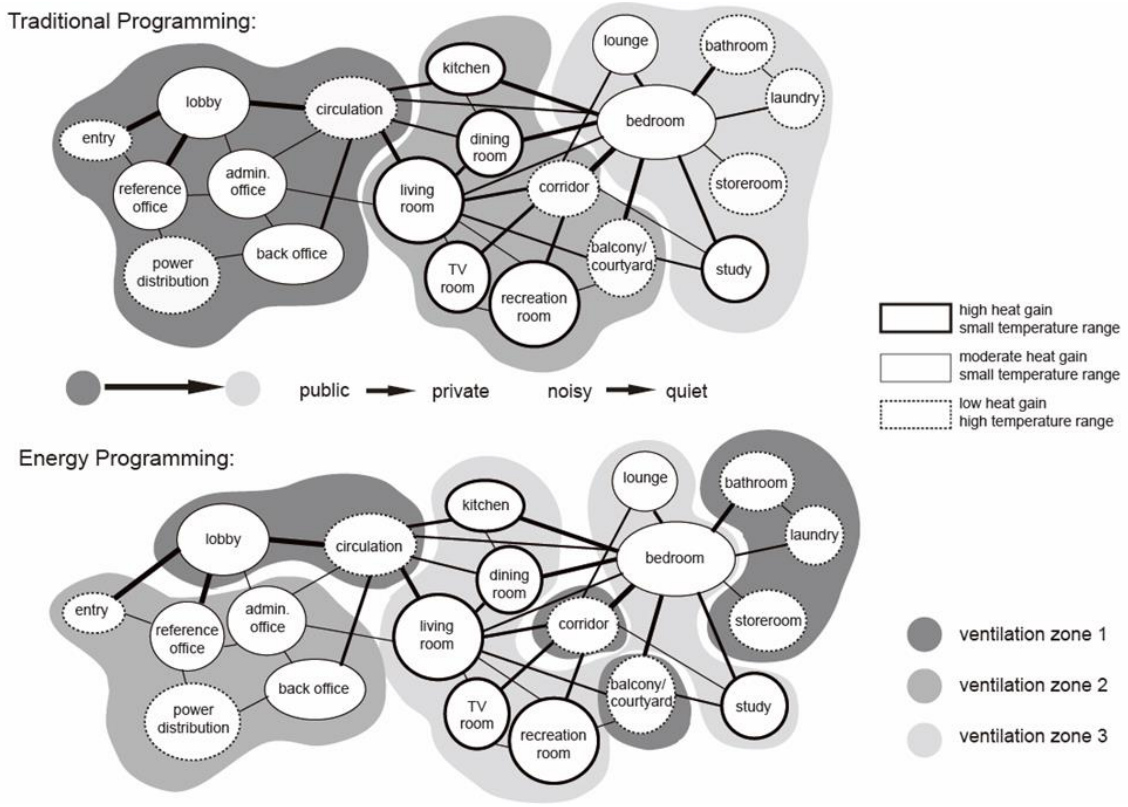


Figure 1-2, concept changes in building programming (drawn by author)

1.4 Object and Purpose of Research

1.4.1 Research object: Living space

Why living space: architecture has begun from living space. Living spaces is complicated and has different thermal zones gathering together. Comfort is a great issue in living space.

1.4.2 Case Selection by Research Logic

- Experience conclusion from precedent study (vernacular & contemporary cases)

- Metric: PPD-PMV

1.4.2.1 Experience precedents

By bringing together written records and on-site research, the "experience study" will invoke precedents of two types ----- residence and dormitory, to analyze their functional organization with colored identification labels, to calculate the percentage of climate-modulating spaces in a building, and to generalize prototypes of spatial patterns and summarize into design philosophy.

Having the common function of dwelling, ancient human settlements where separate units sharing communal utilities, are the preferential samples for collecting good experience used in future dormitory study. There are two things worth in-depth discussion: 1) architectural modes of vernacular dwellings, 2) lifestyle of the ancestors.

- In a great many cultures, dwelling is a large artefact built to satisfy people's physical and spiritual needs when they interact with the environment. World architecture history has

provided obvious differences in architectural characteristics of different regions. These features, regarded as a "gene" inherited from immemorial creations, can be retained in the long-term "architectural evolution" because the ancient occupants benefited much from them to lead a relatively comfortable life in those days without any temperature-controlled machines. In this paper, a serious effort will be launched to compare the old building modes in tropical countries like Singapore, Thailand, and Malaysia, and to find architectural solutions that optimize natural energy utilization in hot-humid climate.

- As dwelling is a theatre of our "life dramas", it is also important to learn how ancient people enacted a succession of scenes of daily lives according to the building programs, such as when and where to have social activities, and whether the programs were fixed in one place or change over seasons. The goal is to illustrate that architecture is always a coordination between human behavior and spatial feedback.

Apart from the ancient cases, modern architects' practices in these specific physiographic regions are another way to reflect the developing trends of the climate-respond building modes. This paper will give some analysis-based interpretations about how architects take advantage of vernacular traditions and local programming models and to create innovations in both residential buildings and campus dormitories.

1.4.2.2 Evidence study

Technical limitation with insufficient scientific information prevents the use of intangible environmental elements in vernacular architecture. Fortunately, the current breakthroughs in computer application field has invented tangible quantitative methods to measure those

features and developed human capabilities to use natural sources of energy far beyond what has been achieved by previous generations of builders. These invaluable contributions to human civilization also benefit my research as a technical support or a design evidence. To make them play a greater role in this paper, it will involve four aspects of efforts:

1. Make a summary of the basic knowledge on the regulating methods and parameters related to thermal sensations. Moreover, update the information from the latest experiments done by the world's top arch-environmental laboratories, and see how modern science revitalizes architecture in a sustainable way.

2. Apply the scientific software modules to evaluate architectural heritage critically, judging whether certain strategies or hypotheses can make a big difference or just a negligible one in efficiency performance.

3. Carry out necessary assessments on EWC dormitories with simulating technologies after making digital models, through examining the pros and cons of two programming types, and comparing the computational test outcome with in-situ observation & cutaneous sensation, which, lays a foundation for subsequent conceptual design of space reforming or program reorganizing in EWC dormitories.

4. The last step is a data-driven design process, to run thermal, ventilation and energy simulations throughout the schematic design course ----- make sure that data are sufficient when making key decisions.

1.4.3 Purpose: Sustainability & Well-being

Targeting the campus dormitory in hot-humid area, the fundamental goal of this doctoral dissertation is to excogitate an intelligent design to combat the negative climatic influences and to improve the indoor thermal environment for the occupants. Furthermore, a greater purpose of sustainable energy development will be achieved by the pre-design programming strategies discussed in the paper to maximize the energy acquisition and minimize minimizing the energy loss. This does not mean to throw away all the active mechanical equipment like air-conditioner, but to make full use of passive cooling manners so that the potential for reducing the presently awesome energy costs of mechanically cooling would have a considerable growth and the interior would be kept cool and dry, naturally. This study also shows how specific principles work truly as part of the integrated and iterative design process, and how to weigh the climatic elements through a bioclimatic chart to satisfy the swing of comfortable threshold.

1.5 Scope of Research

The research topic is conducted in two directions, mixing a cross-sectional study and a longitudinal promotion:

- Given the task of opening up the architectural minds, the “cross-sectional” study is going to provide an interdisciplinary vision to bridge the gap between widely different subjects and to ensure that the most rewarding results could be obtained. Based on the

historical scenario of science and architecture, the thesis may inspire the future readers by the archaeology of knowledge, discourse re-construction, and developing of tools, merging its ontology and instrumentality, and ultimately providing a new type of architectural form and paradigm. Existing for man, architecture encompasses double significant meanings ----- it is first a place or structure for material collection, then also includes manifold cultural aspects like the domestic activity of living or residing. As a result, it is far from enough if determine a scheme only with mechanical laws, actually, a successful design is often indebted to other scientific provinces which are directly concerned with man and his environment and society. Anthropology, climatology, aesthetics, and economics are in general of no less important than mechanical sciences to an architect. In addition, agriculture and aerodynamics are available to be drawn knowledge from. Intimately affected by the microclimate, agricultural scientists have long-time observations of the climate near the ground and in small localities, which can help to understand the phenomena of the microclimate and its complex relationship to the buildings. While in the application of aerodynamics, the methods of investigating airflow around the wings and bodies of aircraft are now being used to study airflow through, over, and around buildings. Scaled and full-size models can be tested in wind tunnels to determine the effect of the size, location, and arrangement of openings on the airflow through individual buildings, as well as the nature of wind patterns and forces between groups of buildings.

- The longitudinal research is undoubtedly going deep into thermal-related architectural factors. Design an experiment with proper variables under a hot-humid climate: selecting a certain program which has a predictable heat generation in its serving time, to

change its positions and test different indoor energy flow condition and calculate energy consumption.

1.6 Research Methodology

This study is going to utilize a comparative method between some existing architectural cases with ancient wisdom and some international frontier experiments in the same field. After an extensive reading on a variety of relevant literature resources, screen out the significant materials which closely tie to my research topic and start an intensive study on them. Then visit some successful projects and learn experience from talent designers during my foreign exchange period. Furthermore, improve personal ability in applying software to simulate diverse micro-environment to support the research results. Finally, make analysis diagrams to demonstrate my opinions and summarize different design means into a systematic methodology.

The intended instruments:

1. Background study: A deep exploration of the root cause of research problem, and the development trends & research status in the world's architectural realm in this area. Establish new research objectives based on the existing academic discoveries.

2. Interdisciplinary method & Systematic perspective: The view of systemic theory is universal to every discipline. In terms of architecture, the situation is the same. This research

will never view issues as static or isolated, but pay more attention to the macro or micro connections among those constituent systems. Also, in bridging different fields, this study will combine both creative and analytical approaches to develop a unifying architectural concept.

3. Computational simulation in Environmental Research & Design Lab in UH: Architectural performance analysis by software packages is part of my research contents, and the Lab in School of Architecture provides a platform of computational simulation to safeguard the reliability of the study results. Some comprehensive software systems such as Energy Plus and IESVE help a lot to embrace the architectural responsibility for good sustainable design practice, especially the latter which has a plug-in to be integrated into SKETCHUP or BIM, making the quantitative analysis technics more accessible for arch-students.

4. Literature review & Theory application: Investigate thermodynamic theories and suitable bioclimatic strategies before handling the case study, because these knowledge will act as a navigation to adjust the research direction and help gain new experience.

5. Cases analysis & Graphical comparison: Collect and analyze the relevant construction examples both from the books and some real sites, coupled with diagrams to visualize the abstract principles.

6. Site measurement: Measurements on humidity, wind velocity, and temperature will be undertaken on site with particular apparatus if needed, which, are prepared as data references for the simulation results.

7. Questionnaire survey: In such a people-oriented project, validating the energy efficiency only by software is not enough, feedbacks from the users are also of great importance to draw the correct conclusion.

1.7 Significance of Research

Building is, in most cases, described as a spatial artwork or a monument for technical progress and cultural prosperity, nevertheless, an essential value of which has been covered up by these extrinsic glories for a long time -----building is first a miniature environment providing more favorable microclimates for human beings to live by increasing the available thermal range. Numerous financial and material benefits will be brought to both individual and collective, from health to hedonistic pleasure, by building a concept of thermodynamic and using the principles of heat conduction, convection & radiation in architectural programming. Socially, it can enrich community life and the sensorial experience of citizens who discover relatively undetermined spaces ready for them to appropriate in creative ways.

This research is an introspection of the unrestrained use of machine to remedy the architectural weakness in respect of solving interior environmental problems. It also wants to trigger arguments on whether those “Green Certifications” are only business gimmicks,

and appeals to the authorities to open up significant opportunities for truly sustainable design. As for architects, who have a moral responsibility to consider whatever may affect the well-being of the housed people, the way they thought about the design should be changed to match environmental performance to creative performance. A greater understanding of the non-visual effect the building scheming early on starts to grow and over time a better ballpark appreciation of what design elements mean in terms of energy use develops.

Another value of the study is to provide a new review of the rule-of-thumb in traditional structures. Forms that combine comfort and beauty, social and physical functionality should be employed to substitute some of the contemporary building conventions that often emphasize the latest technique or ambitious design concept at the expense of social needs. But others validated to be less efficient may be rejected in future designs. The viable solutions concluded in this research will become a catalyst for launching feverish exploration of energy using in many other fields, to arouse those building-related engineers, homebuilders, researchers, and even the federal government, to devote themselves to the environment resource issues that constantly threaten human survival and cultural prosperity.

The academic world of architecture must emphasize the value of investigating and applying concepts scientifically.

1.8 Research Framework and Structure

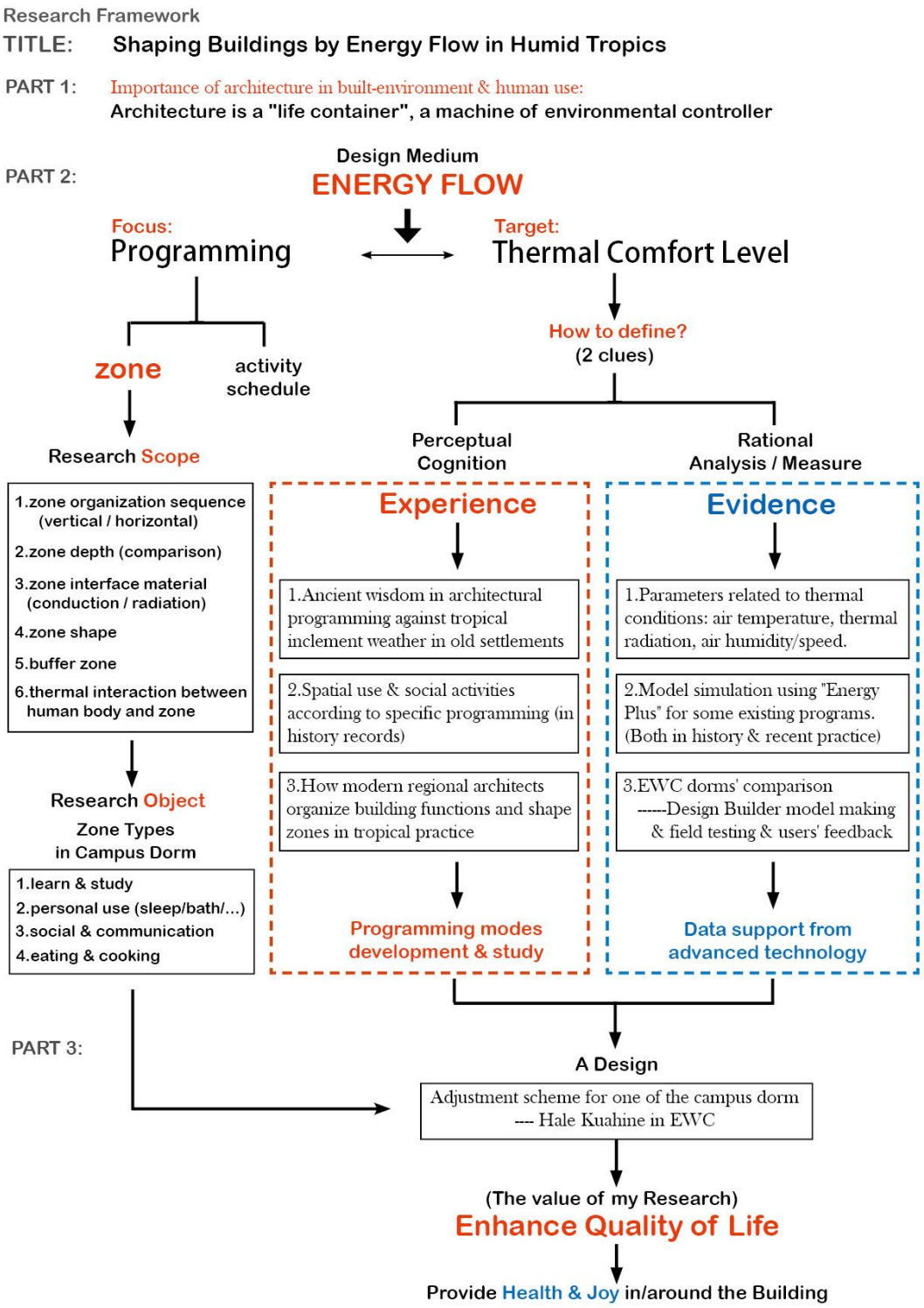


Figure 1-3， research framework (drawn by author)

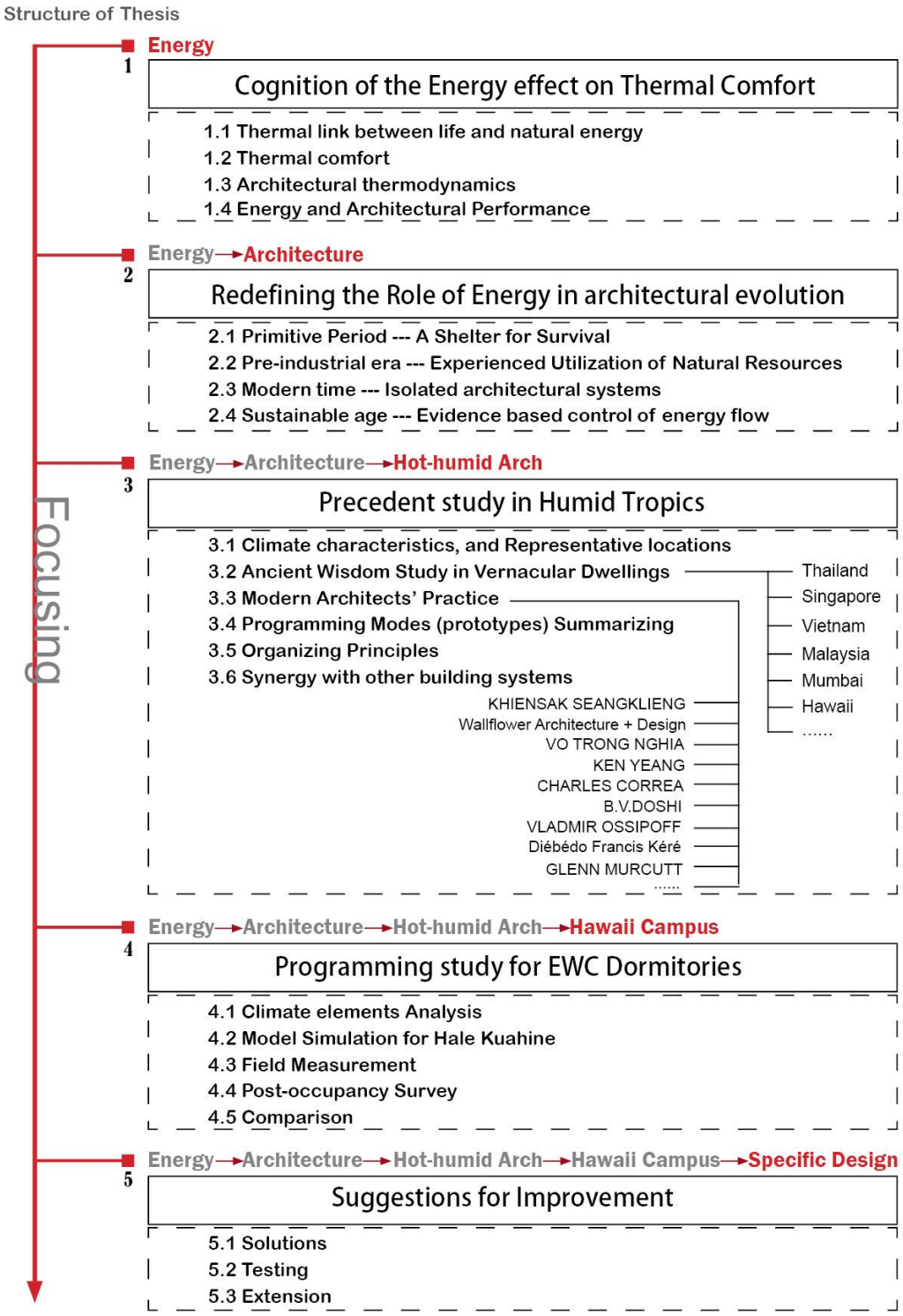


Figure 1-4, research structure (drawn by author)

2 COGNITION OF ENERGY EFFECT ON THERMAL COMFORT

2.1 Thermal link between life and natural energy

The central idea of biological evolution suggests that all of life is connected and can be traced back to one common ancestor; but during the process of successive generations, the genetic composition of a population varies into new species. This conclusion is drawn through observing the examination of fossils. In the mid-19th century, Charles Darwin formulated the scientific theory of macroevolution, which states that natural selection is the key mechanism of evolution because it encourages a population to develop the most suitable heritable traits to survive and reproduce in a certain habitat.

According to Lisa Heschong, changes in temperature is one of the most decisive factor that forces a species to evolve more suitable genetic traits and instincts to cope with its habitats. In her book, Thermal Delight in Architecture, she states that, "Life exist within a small range of temperatures…not only extremes but even subtle variations in temperature can be critical to an animal's survival." In other words, the ability to regulate and cope with the thermal change is a major heritability trait of a species needs to evolve in the process of successive generation. A disturbance in the surrounding climate can cause two adaptive changes that a species may adopt: it may develop a temporary physiological reflex or behavior adjustment

that remind itself to act or move around to avoid the changes; or it may develop a permanent mutation arise in the genome which may result in either visible reformations on their body parts or changes of the internal system that help to regulate the temperature within their bodies.

2.1.1 Climatic forming

Figure 2-1, plants differ in forms according to different living area

A representative genetic mutation that causes a change in the physical shape and appearance can be found among plants. The shape of a tree leaf is a manifestation of its long term ecological and evolutionary history. An ecosystem's limitation also encourages shape of a leaf to be modified in a specific way. Therefore, understanding of the mechanism behind the formation of a variety of leaf shape can help us in analyzing the particular functions a leaf is able to accomplish.

1. A leaf must "capture" sunlight for photosynthesis (and during this process, it is absorbing a great amount of heat)

2. A leaf must take in carbon dioxide, which is essential for photosynthesis, from the air using its stomata. When a leaf's stomata are opening to allow the diffusion of carbon dioxide,

transpiration also occurs in which water molecules are evaporating from the leaf's surface to cool the plant.

In order to perform the above-mentioned two functions, A plant's leaves on a tree can be arranged in two basic patterns—"mono-layer" or "multi-layer". A mono-layer arrangement ensures that no leaf is growing above the other to block the sunlight. This pattern is commonly found seen in low understory trees, such as the dogwood, which are easily covered by shadings of surrounding taller plants and objects. A multi-layer arrangement is more suitable for taller upper-story trees since they can maximize the amount of sunlight being received from various directions. The upper-layer leaves in this arrangement tend to be smaller in size and rounder in shape than the lower-layers so that they can facilitate faster heat loss and prevent self-shading.

Figure 2-2, nose difference

Another example of varied phenotypic trait among a species due to the different habitat climates, is found in ourselves. Through observation, we have learned that people living in colder place have relatively longer nose bridge but narrower nasal orifices whereas people living in hotter places have relatively shorter nose bridge but larger nostrils. The size of the nostrils decide the amount of gas that a person can inhale and the length of the nose bridge

determines the time to warm the inhaled air. In other words, they help the human body to adjust the external energy during inhalation to regulate our inner temperature. Therefore, varied shapes and length of our noses are the genetic mutations that are enforced in human beings to overcome the unfavorable climate of our habitats. In short, a species' physical component is born for a required function, but the reformation of the outer appearance of each component is to better regulate energy change in the surrounding environment.

2.1.2 Thermal Strategies of Organisms

During the process of biological evolution, many organisms left the stable thermal environment of ocean to live on the land. In order to survive, organisms had to develop thermal strategies to overcome the climatic extremes and wide daily fluctuations of the land. However, unlike the permanent mutations of a species' genome which results in a heritable traits in generations of that species, thermal strategies are mostly temporary reactions or behaviors that only act when there is a short-term change in the surrounding temperature.

2.1.2.1 Migration

Figure 2-3, animal migration

Migration is a typical temporary behavior that an animal species perform to avoid drastic weather changes. It requires relatively long-distance movement of individuals and is usually

on a seasonal basis. All major animal families, including birds, mammals, fish, reptiles, amphibians, insects, and crustaceans, consist of members that have the habit of migration.

2.1.2.2 Muscular Activity

Figure 2-4, muscular activity for generating heat

For other animals that cannot afford long-distance migration, they have to develop other behaviors to regulate the temperature. Some cold-blooded animals like butterflies and lizards, can maintain their body temperature through their muscular activity. A mammal has a more developed heat-generating technique which is to automatically vibrate the muscles to generate heat whenever it encounters coldness. Moreover, warm-blooded animals can generate heat through metabolism and even control how fast their heat is lost through their muscle movements—they can either rise their basal metabolic rate to acclimate to the coldness, or keep still in a shady place to cool down in hot days.

2.1.2.3 Blood Flow Controlling Mechanisms

Another capability that a warm-blooded animal equip to regulate the flow of heat is through the circulation of the blood. Mammals and birds can control how much blood is flowing to the surface of the skin, even to entire extremities. By flushing the skin with blood, the heat of the inner body is

Figure 2-5, blood-control animals

also pumped to the surface where it can readily escape. Conversely, by restricting the flow of blood to the surface, the heat is retained in the animal's inner core. Expansion mechanism of the vessel is another strong protector for the stability of the body temperature. When the body is too hot, the diameter of the vein become larger, allowing more blood to go through the skin's surface to quicken the cooling of the blood, thereby reducing both the internal and external temperature. These highly efficient and stable resilience abilities are interoperable with the thermodynamics.

2.1.2.4 Coating-regulating

In response to different climate, animals may also temporarily adjust their outer appearance to adapt the weather. Growing fur or feathers as insulation is the most common strategy that animals adopt. The quality, quantity or even color of the fur or feathers are usually changeable as the season changes. For example, rabbits experience seasonal molting which help them to shed hairs in summer and regrowing thicker fur during winter.

2.1.2.5 Nesting

Animal species also use nest building to regulate the microclimate, protect themselves from predators and organize their social structures within their community. Scientists have discovered that the construction of nest have displayed the extraordinary wisdom of animals in controlling energy flow. The complex structure of termite mound is a typical example: It consists of a mysterious inner system of temperature regulation and air circulation to support the demands of millions of termite populations.

Firstly, the shape of termite mound is designed for the purpose of solarization. It maximizes the surface of exposure to receive as much solar energy as possible in the daytime. At the same time, the orientation of a mound is designed to avoid the most over exposure of sunlight. For example, the Amitermes mounds are tall, thin and wedge-shaped, that is usually oriented north-south to minimize the heating area at noon while gathering weaker but uniform heating widely in the morning and afternoon. Throughout a day, every side of the mound is able to receive certain exposure to the sunlight.

The energy consumption of termites is very economical. They use partially digested excrements to build the nests and generate extra heat. An amazing feature of the termite community is their ability to cultivate a sustainable fungal farm that provide food for the whole mound. In order to maintain the fungal farm that requires precise temperature control, the architecture of the mound is designed to keep the temperature constant. The materials for a mound construction is usually a mixture of soil, termite saliva and excrements. The mound walls are filled with tiny holes that allow ventilation throughout the entire mound. On the top

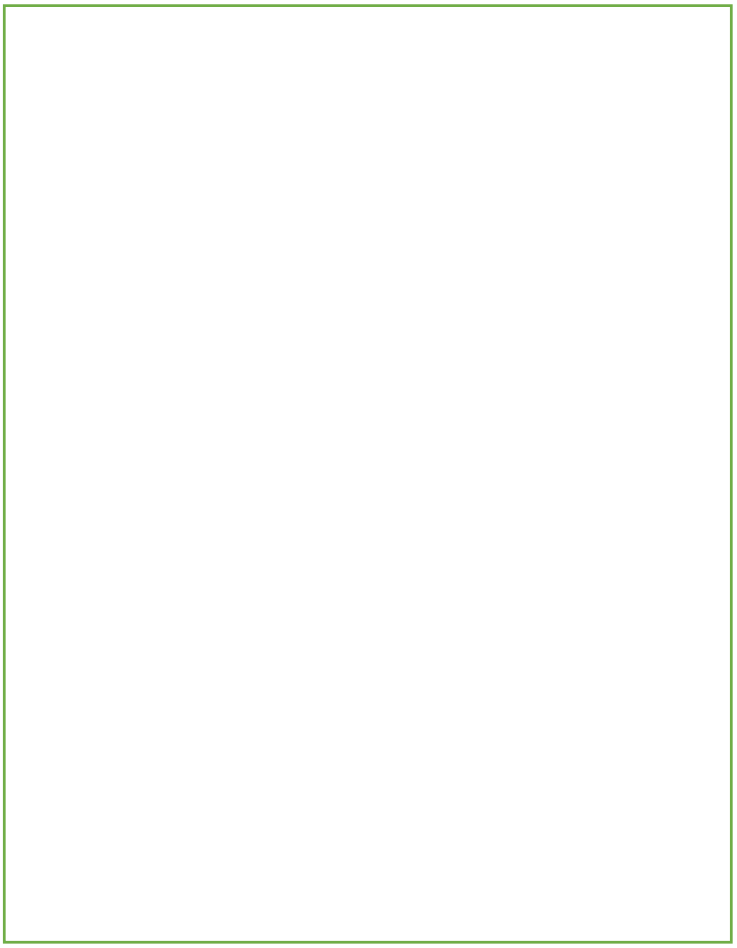


Figure 2-7， termites mound form & interior system

of the mound has an opening that is connected to the central cavity through a network of tunnels and passages. Air travels through the porous walls into these tunnels and brings the heat to the opening. When this warmer air mixes with the fresh cooler air, the cooler air sinks while the warmer air rises and escapes through the opening. In the daytime, this ventilation system constantly circulates the air without the help of natural wind. By night, the air movement is reversed due to the decrease in the outside temperature, and brings fresh air to the very deep of the mound that removes carbon dioxide and heat. Below the underground nest is a cellar, which is the coolest place in the entire mound. The series of thin plates that are built on the ceiling of this cellar can absorb moisture from the nest above and provide another cooling mechanism. Through close observations, scientists have found out that there are small rooms bestrewing the mound for the termites to hide during summer time. In cold weather, they move to the surface area to warm themselves up with the heat of sunlight. In this way, the clever usage of natural energy help to reduce the body energy consumption of termites to the lowest point.

Termites mound is no doubt a perfect thermodynamic model which highly integrates the material configuration with the control of energy flow. The utility of architectural structure to regulate the temperature of a mound is a great inspiration for human architectures which has more flexibility in choices of material and locations. Considering the fact that human only started constructional activities less than ten thousands of years, while animals like the termites have experience tens of millions of years in their evolution process to perfect their nest building; hence animal's architectural structure is a more advanced model for our architectures. Architects should always keep in mind that structures and organizations that can be found in the natural world are manifestations of more efficient energy saving systems that have been tested for over millions of years by generations of organism. Therefore, learning from the natural world is crucial in improving our human architectures.

2.2 Influential Factors in Thermal Comfort

2.2.1 Metabolic rate of human body

Our human body can maintain a constant temperature despite the fact that the external air temperature is always changing in a certain range. Like any other objects, human body can gain and lose heat by radiation through space, substances in contact or conduction between bodies. Passive objects like water or metal, can only be heated or cooled by external sources. However, for human beings, the metabolic processes can produce heat itself, and thus can work as an engine to support the energy needs for human bodies. According to the second law of thermodynamics, machines cannot generate work without producing heat, and in most cases, the unwanted heat will be dissipated into the environment. Human body's engine, the

metabolic processes, also obey to this law. Human body is working continuously to make sure that the gaining and losing of the heat are balanced. So the human body will dissipate the generated heat in the hot environment and vice versa. Human body can maintain a desired heat balance by adjusting its temperature through the amazing heat-regulating mechanism.

2.2.2 Clothing Insulation

The main role of the clothing is to protect the body from cold. Protective clothing can protect the body from hot. We can use two ways to protect the body from the cold based on the insulation mechanisms. The first is to stop the wind from penetrating and replace the layer of warm air close to the body. The second it to set up a layer of still air which serves as insulation. Factors that can affect the clothing insulation include posture and activity, and also the intrinsic properties of the clothing. We also need to consider the outdoor air temperature, indoor operative temperatures, relative humidity, etc. When all these factors are considered the necessary corrections were made, the clothing insulation effects can be correctly obtained.

2.2.3 Air Temperature

The air temperature is largely related to the comfort of human beings, and it is also the basis for the designing of insulating structures. Factors that can affect the air temperature include solar radiation, wind, landscape, etc. Among them, the solar radiation is the key factor. The air is almost transparent to the solar radiation, thus the solar radiation can only indirectly affect the air temperature. The temperature of the earth's surface rises after absorbing the solar radiation, and emit long-wave radiation. The air absorbs the long-wave radiation and thus its temperature also rises. The layer of the air that is in direct contact with the earth's

surface will be heated due to the conduction effects, and this heat can transfer to the higher layers of the air through convection effects.

The actual temperature of the air varies due to different locations, height and times. In Meteorology, the air temperature refers to temperature of the air that is 1.5 meters above the ground in the shady locations. Thus, the effect of the solar radiation must be eliminated when measuring the air temperature.

2.2.4 Radiant Temperature

The radiant temperature is the temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure. The thermal comfort we feel in a building is affected by the air temperature, as well as the temperature of the surfaces in that space. This surface temperature is what the radiant temperature cares about, and it is controlled by enclosure performances. A comfortable space should seek a balance between the operative temperature and the radiant temperature.

The radiant heat received or lost by the human body is the sum of all radiant fluxes exchanged by its exposed parts with the surrounding sources. So the radiant temperature can be get by measuring the temperature of the walls and surfaces and their relative positions with the person. So it is necessary to measure the temperatures and factors between the person and the surrounding surfaces.

2.2.5 Air Pressure & Speed

The gravity effect of the atmosphere around the earth result in the air pressure in the earth's surface. The air pressure changes when the altitude changes. The wind is formed due to the air pressure difference in different locations. The distribution and properties of the wind are determined by both global and local factors. These factors include the seasonal distribution of the air pressure due to the inhomogeneous of the solar radiation, the self-spinning of the earth, the temperature change of the ocean during day and night, and the landscape change. The wind systems can be categorized as the global wind systems and local wind systems. The global wind systems are usually referring to the atmospheric circulation that is caused by the temperature difference of the equator and the polar. The local winds are referring to wind systems that is caused by all kinds of factors in a local area. The properties of the wind will change during its motion process, and can carry the heat, result in precipitation, etc.

2.2.6 Humidity

Atmospheric humidity refers to the amount of water vapor or moisture in the air. The atmospheric vapor is mainly from the sea surface, the river surface and plants, it enters the air by vaporing and can be carried by the wind. Factors affecting the humidity of the air includes the properties of the earth's surface, the distribution of the water systems, the changing of the seasons and the condition of the weathers.

The atmospheric vapor amount is largely decided by the temperature. The vapor amount will increase when the temperature increases. The atmospheric vapor's distribution on the earth is non-homogeneous and the apex is in the equator, then gradually decrease toward the

poplars. In the vertical direction, the pressure of the vapor will decrease faster compared with the decrease of the air pressure, so the amount of the vapor will decrease when the altitude decreases.

2.3 Thermal Sensation and Comfort Evaluation

The indoor thermal condition provided by the architecture is the basis for the living of human beings, and enables human to obtain higher comfort. In the revolution of the human, the human bodies gained many mechanisms that can ensure the adapting with the complex temperature. In chilly temperature conditions, the human body will accelerate the circulation of the blood and the heat generating of the muscles to make up the loss of the heat. In hot environments, the human body can lose heat through thee vaporing of the sweat. Different parts of the human body also have apparent gradients, to protect the organs inside from the harm of the extreme temperatures. However, this kind of adapting is confined in a limited range, and the human bodies will lose comfort when the temperature goes beyond this range. In extreme cases, it will even jeopardize the life of the human beings.

Human being cannot adapt to the environment through physiological change like the growing of the fur, nor can they adapt to the environment through migration. As an advanced species, human beings construct buildings, to work as places for sheltering, keeping away from the effect of extreme environments. That is to say, the architectures should first create a thermal environment that can guarantee the living of the human beings and provide comfort.

Researches have proved that people will be more satisfied when they can feel subtle changes from the environment, which should be within the range acceptable within the social circumstances in specific society and climate. That means building designers should not only make the artificial environment predictable without sudden fluctuations of temperature, but provide thermal variety at appropriate time. Moreover, the built-environment should allow people to control or adjust according to their immediate sensation.

2.3.1 Relativity of thermal sensation

Thermal sense is bound up with the experience of the human body, which cannot be easily isolated from the visual, acoustic, olfactory, and tactile perceptions. Thermal comfort depend on external temperature, clothing, physical activities, etc. But thermal sensation sometimes depends on the previous experience. People may not be able to tell the exact temperature of cool or warm, but only can judge the relative feeling by comparing with the situations they were in before. That is why the indoor comfort standards are different in winter and summer.

2.3.2 Graphic & Analytical Comfort Zone

The comfort zone is defined as the range of climate conditions within which the majority of people would not feel thermal discomfort. The comfort zone is determined by a combination of factors including the air temperature, the radiant temperature, the humidity, the wind speed, the metabolic rate, etc.

The Figure2-8 is for 80% occupant acceptability. This is based on a 10% dissatisfaction criterion for general thermal comfort based on the PMV-PPD index (will interpret in 2.33), plus an additional 10 percent dissatisfaction that may occur on average from local thermal discomfort. The plot specifies the comfort zone for environments that meet the above criteria and where the air speeds are not greater than 0.20 m/s. Two zones are shown, one for 0.5 clo of clothing insulation and one for 1.0 clo of insulation. These insulation levels are typical of clothing worn when the outdoor environment is warm and cool, respectively[1].

[1] Ashrae, A. N. S. I. "Standard 55-2004, Thermal environmental conditions for human occupancy." American Society of Heating, Refrigerating and Air-Conditioning Engineering, Atlanta, GA (2004).

The figure 2-9 includes two sets of operative temperature limits—one for 80% acceptability and one for 90% acceptability. The 80% acceptability limits are for typical applications. It is acceptable to use the 90% acceptability limits when a higher standard of thermal comfort is desired. It is based on an adaptive model of thermal comfort that is derived from a global database of 21,000 measurements taken primarily in office buildings. The allowable operative temperature limits in Figure 3 may not be extrapolated to outdoor temperatures above and below the end points of the curves in this figure. If the prevailing mean outdoor temperature is less than 10 ℃ or greater than 33.5 ℃, this option may not be used, and no specific guidance for such conditions is included in this standard[2].

[2] Ashrae, A. N. S. I. "Standard 55-2004, Thermal environmental conditions for human occupancy." American Society of Heating, Refrigerating and Air-Conditioning Engineering, Atlanta, GA (2004).

2.3.3 Evaluation methods

2.3.3.1 Evaluation based on in-situ information

There are two ways to gather in-situ information, by survey and by physical measurements. Survey is mainly carried out among occupants and to record their satisfaction degrees. Then combine the results with the data from physical measurements to do analysis.

2.3.3.2 Predicting Approaches

PPD & PMV index is the comfort metric used in this paper.

The predicted Mean Vote (PMV) refers to a thermal scale that runs from cold to hot. It is originated and developed by Fanger and later was adopted by ISO standards. It can be used as an empirical fit to the human sensation of the thermal comfort. It predicts the average vote of a large group of people on the seven-point thermal sensation scale where:

- +3 = hot
- +2 = warm
- +1 = slightly warm
- 0 = neutral
- -1 = slightly cool
- -2 = cool
- -3 =cold

The math behind the calculation of the PMV is based on the deviation between heat loss and metabolic rate. The maths only apply under constant conditions and at constant metabolic

rates. However, it can give pretty nice results if the conditions within the built environment are within a small range.

Predicted Percentage of Dissatisfied (PPD) predicts the percentage of occupants that will be dissatisfied with the thermal conditions. It is a function of PMV, given that as PMV moves further from 0, or neutral, PPD increases. The maximum number of people dissatisfied with their comfort conditions is 100% and, as you can never please all of the people all of the time, the recommended acceptable PPD range for thermal comfort from ASHRAE 55 is less than 10% persons dissatisfied for an interior space.

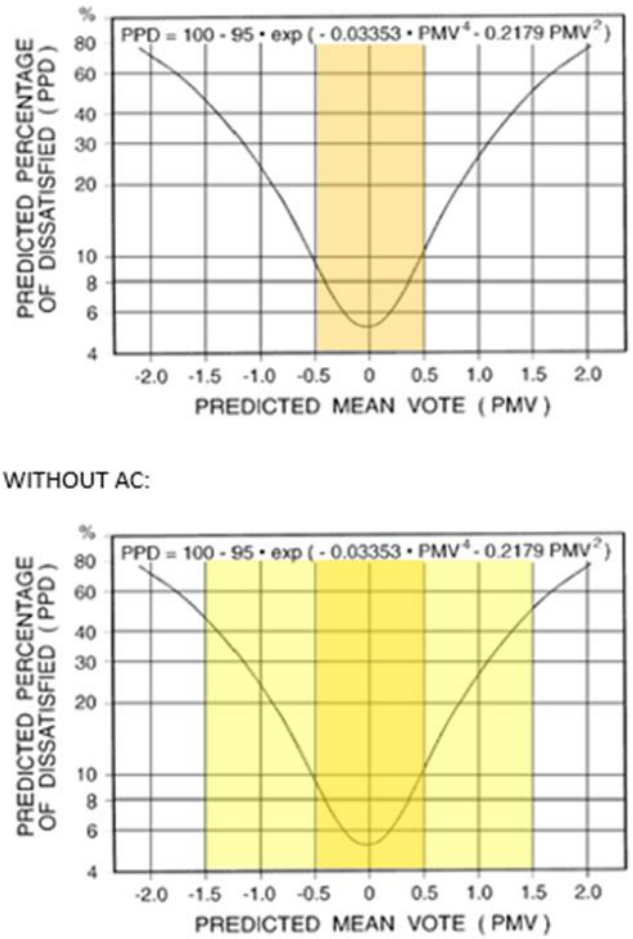


Figure 2-10, comfort interval difference according to AC

In a room with air-conditioning, the comfort interval is from -0.5 ~ 0.5, but if there is no AC system, according to the relativity of thermal sensation, the interval will be expanded to -1.5 ~1.5.

3 REDEFINING THE ROLE OF ENERGY IN ARCHITECTURAL EVOLUTION

When talking about evolution, the first representative comes to mind must be Charles Darwin and his theory of Natural Selection. However, those previous efforts and achievements were usually ignored by people, some of which had great significance for the development of evolutionary thought. One of the worthy predecessors is Jean-Baptiste Lamarck, a French naturalist, who took a great conceptual step and proposed a full-blown theory of evolution. Lamarck's theory is different from Darwin's: Lamarck insists that biological evolution is an adaptive process with directional variations caused by environmental factors, while Darwin thinks that indeterminate chance variations generate the possibilities for evolution --- as soon as any beneficial mutations arise, natural selection will favor its spread. So it can be concluded that Lamarck regards evolution as an active behavior, which, however, is believed to be a passive activity by Darwin. Years of biological research has demonstrated that the latter "passive selection" is much closer to the truth of species' survival and reproduction, but subsequently, Lamarck's conception of "active adaptation" become recognized as a useful tool by many scholars to explain cultural evolution, which has an extraordinary speed and breadth that is rare in biological evolution because active modification is always faster and more flexible than passively waiting for selecting. Under Lamarckian principle, the "genetic material" to transmit information in sociocultural channel has two types --- mental

artifices like theories or laws and material artefacts like buildings --- both of them are constantly updated by people on their own initiative based on the experience and lessons learned through mutual shaping and interaction between man and nature. Generations of human exploration finally lead to a correct and sustainable way for sociocultural progress. Acting as one part of sociocultural evolution, architectural evolution also has a certain direction for self-improvement, which is navigated by an invisible force --- energy flow --- deemed to be the essence of human society's existence.

Leslie A White, one of the presidents of the American Anthropological Association, was known for his advocacy of theories of cultural evolution which influenced a great number of later anthropologists. His famous discourse about "Energy and Civilization" clearly pointed out the primacy of energy in cultural evolution from a materialistic perspective, that is to say, the one that determines the level of cultural advancement is human ability to "harness and control energy"[3]. In order to state that the amount of captured energy is the measure to judge the relative degree of cultural development, White introduced a formula "P = ET"[4] where E is a measure of energy consumed per capita per year, T is the measure of efficiency in utilising energy harnessed, and P represents the degree of cultural evolution in terms of product produced. From this formula, we can deduce that human development can be differentiated into four stages according to two evaluation criteria --- 1. Human cognitive level and exploitation techniques on surrounding resources; 2. The efficiency of the instrumental means of putting the energy to work. So does the stage division of architectural

[3] Leslie A. White, "The Science of Culture: A study of man and civilization", Farrar, Straus and Giroux, 1949.
[4] https://en.wikipedia.org/wiki/Leslie_White#cite_note-LeslieWhite-2 , December 12, 2015

evolution: the first phase is Primitive Period when people use energy in very simple ways (they use the energy of their muscles, domesticated animals, or burning plants); the second phase called Pre-industrial era witnessed the perfection of skills and tools in the glorious agricultural civilization, which is a transition period from superficial understanding of energy usage to high-tech research on gigantic energy stored in atom; then comes the third stage --- the modern industrial age, with the breakthrough of technology, designers at that time focused more on the energy produced by machines rather than from nature; and the fourth phase starts with the goal of sustainability, during which people rethink the role of natural energy in building design and work out some effective methods to balance various energy parameters around a building. These four stages saw the paradigm shifts caused by the progress of energy idea.

3.1 Primitive Period
--- Energy and Construction as two independent survival options

It is generally believed that the discovery of fire drove the history of human society. Vitruvius described the origin of architecture in the second volume of his famous work *De architectura*:

> The men of old were born like the wild beasts, in woods, caves, and groves, and lived on savage fare. As time went on, the thickly crowded trees in a certain place, tossed by storms and winds, and rubbing their branches against one another, caught fire … After it subsided, they drew near, and observing that they were very comfortable standing before the warm fire, they put on logs and, while thus keeping it alive, brought up other people to it, showing them by signs how much comfort they got from it. In that gathering of men … they fixed upon articulate words just as these had happened to come; then, from indicating by name things in common use, the result was that in this chance way they began to talk …as they kept coming together in greater numbers into one place, … they began in that first assembly to construct shelters. Some made them of green boughs, others dug caves on mountain

> sides, and some, in imitation of the nests of swallows and the way they built, made places of refuge out of mud and twigs…[5]

The above description provides two basic architectural prototypes: one is a concentric circle extending outward from the central fire, the other is an inward space beginning from the building boundary. In Reyner Banham's book *The Architecture of the Well-tempered Environment*, there also has similar statements about the two archetypes. He introduces a parable about a savage tribe who arrives at an evening camp-site with fallen timber supplied. The tribe can exploit the environmental potential of those timber either to build a fire (a power-oriented solution generates an open concentric circle prototype) or to construct a shelter (a structure-oriented solution generates an enclosed prototype). In the view of capital expenditure, the power-oriented solution may represent a steady debilitation on resources while the structure-oriented solution usually involves a one-time investment, probably hurtful but has a permanent return. It is conceivable that people in ancient time did have difficulties in replenishing energy sources only by walking around and picking up branches. In fear of lacking resources, men will estimate the amount of available materials and how long to stay before deciding which solution to take. Therefore, primitive people separated structural system and energy system into two parts, and took steps to fulfil their environmental needs. Seen from many archaeological evidence, most of the world's civilized nations preferred to rely on the construction method as the first step to resist the harshness of natural climate --- building a shelter to improve their survival conditions. After constructing a living space with boundaries, the second step is to pile up the remaining combustible

[5] Marcus Vitruvius Pollio, "THE TEN BOOKS ON ARCHITECTURE", Book II, 38. HARVARD UNIVERSITY PRESS, 1914.

materials in the middle of space to be ignited for warm and create a center for family activities. This step of energy storage can be omitted when the resource is limited, in other words, energy construction at that time was a removable accessory of the whole building construction. Thus, the pristine building shape was irrelevant to the energy strategy, however, the interior layout showed the consideration for the distribution of energy: activities were arranged along concentric rings around a virtual center (supposing in the center there was always a camp-fire outputting heat and light), the distance from the center was determined by different programs' demands for thermal comfort and visual requirement, and no frequently-used functions were set on the downwind trail of fire smoke.

In this period, human ancestors knew little about nature, and they have not formed the idea of controlling surrounding energy flow, the only purpose of construction is to acquire an immediate escape from the adverse weather factors and other external threats. So the design approaches were immature: the building form is very simple, moreover, the shaping process

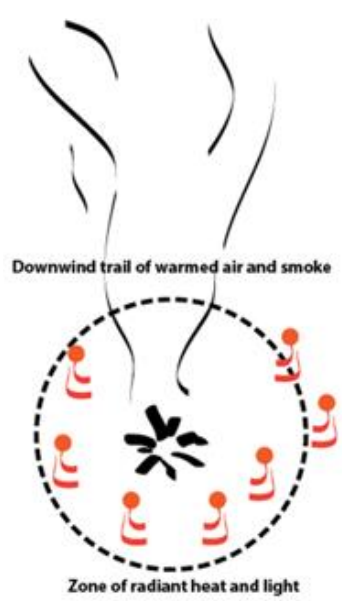


Figure 3-1, the prototype of primitive construction (left was drawn by author)

and layout design are out of sync, which means that people seldom thought about the functional arrangements at the beginning of erecting structures, and later threw some programs into the completed shelter. Although this time mankind did not integrate form, function, and energy together because of poor knowledge, we can still find the close association between energy use and public activities in daily life --- the communal center is also the power-operated center.

3.2 Pre-industrial era
--- Energy as a part of the Construction

This phase is a turning point in history when the human society ended the primitive backward environmental managing period and entered into a new civilized era. People were no longer satisfied with merely survive, but wanted to flourish.

During the past period, by sheer chance, mankind discovered that the soft structural property of clay will be hardened after being heated, which make it possible for people to create new productions such as household utensils and building bricks. Later with the similar principles, ancient people gradually developed more instruments and new materials. People realized that energy is the key factor to induce these amazing changes. This not only expanded human's imagination of design but also enhanced their technology of construction. Having benefited a lot from the new knowledge, people became more initiative in looking for new forms of energy medium and tried their best to reduce energy wastage. That is why in the building design, men converted their attitude and behaviour towards nature: once blinded by their fear

of unknown climatic phenomena, this time they saw the potential of natural resources & climate elements which can provide a large amount of energy. Consequently, several changes happened to architectural form and layout in order to make more use of natural force (sunlight, wind, rainwater) and maximize the circulation of residual energy. Energy channel became a necessary component inserted into construction system, acting as an iconic symbol which displays remarkably sophisticated thermal adaptation throughout the world's climate zones. For example, the "Malqaf" (a wind catcher) in hot arid zones represents the local consciousness of selecting favorable energy factors from natural environment and using them to improve interior comfort. Furthermore, there were also some particular architectural forms expressing the simple desire to save energy from physical resources (e.g. heat from fire), and these special structures later developed into one of the most important features of a house and formed the collective memory of regional culture, such as the tall chimney in the Western houses and the thick foundation where lying the "Ondol" system to heat the main rooms in northern Asia and Rome --- they were such wise creations that simultaneously satisfied daily comfort demands and the purpose of resources-saving. These new created energy constructions have a marked impact on the arrangement of building functions, and different energy targets established on diverse climates will lead to totally different layout results.

As approved by many anthropologists that human beings have biological attributes and cultural attributes at the same time, the former reflects in the adaptation while the latter stands for remolding. The Pre-industrial stage can be the most appropriate explanation for the above two properties: before this period, mankind were closer to "biological nature" since they usually mimicked animals' behavior and were afraid to transform their environment; but after this phase, people open the door of a new age and concentrate on doing renovations with technological supports, which tend to show more "cultural nature". The characteristics of living beings and the cultural ambitions were equally combined together only in this transitional era, so all the various cultural innovations in this stage reflected a deep respect for nature. The well-organized building design that we can see from the precious historical heritage was growing out of countless experiments and accidents. By taking lessons from primitive builders, people summed up a series of rigid rules for selecting orientation, choosing building method, and shaping materials. Though sometimes apparently arbitrary, the final forms can moderate prevailing climatic conditions very effectively.

Below will discuss some great experience about how ancient people applied their complicated energy strategies in different scales from an urban context to a piece of material. In fact, no matter which scale we are focusing on, the basic principles of controlling energy flow are the same.

3.2.1 Site Planning

With regard to the word "layout", the priority is usually given to site planning, because a reasonable relation between buildings can provide a better ambient condition where all the buildings in this site can get benefit.

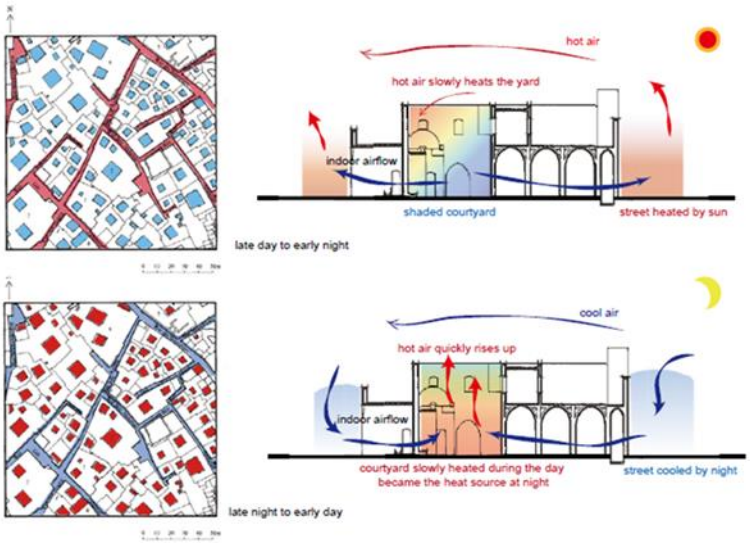


Figure 3-3, how site planning affects energy flow in hot-arid cities (drawn by author)

Under the similar climate scenario, a uniformity in urbanization may be found. The traditional towns in hot arid zones give a good example in this aspect, whose layout has two typical features: narrow streets and capacious courtyards. Both of the two patterns serve as reservoirs of cool, fresh air and heat sources in turn. From late night to the morning, courtyards are shaded by the surrounding walls and stayed cool while the outside streets are heated by the eastern sunshine. So the warm air in the street rises and is replaced by the cool air accumulating in the courtyard, which generates a cool wind movement seeping into the buildings from courtyard-side to the street-side. During the day as the sun goes higher, the shadow area in the courtyard gradually reduces, leaving more and more exposure to the sun so that the temperature there increases. At the same time, the streets are turning to shaded

place and gathering cool air. By virtue of the narrow meandering shape with closed vistas, the streets are able to retain cool air that may be swept out by the blast of wind occurring in other linear spaces like boulevards in a gridiron plan. As evening advances, air in the courtyard becomes much warmer than in the street, so the direction of convection reverses and a cool breeze blows from the street to the courtyard through indoor rooms.

In most contemporary cities, the gridiron plan pattern with wide straight streets is easy to cause a “greenhouse effect” that hot air laden with urban pollutions forms a “dome” above the dense city centre. The living quality beneath the dome suffers a lot from the stillness of heat and fumes. This situation can be improved by changing the plan pattern. So designers have to understand the principles about how solar energy affects air flow. By regulating the urban context and building height, people can control the solar heat gain on different types of ground cover to stimulate wind movement and eliminate the discomfort in micro-environment.

3.2.2 Building Programming

Building programming in this stage of history has obvious imprints of local climate, which, differ in the percentage of void, the relationship between heat-generating space and main living area, the perform mechanism of open spaces in controlling energy flow, and the schedule of occupation in different indoor positions, and so on. Here in the section will give the comparison among three representative architectural layouts in three climate zones: hot-arid, hot-humid, and cold region.

It has already been discussed above that courtyard is such a common and useful natural temperature regulator in hot arid places, however, in some traditional wealthy family's houses, only one courtyard is not enough. Normally, there will be two open courtyards: one is small, the other is large. The smaller yard is enclosed by the main building volume which casts shadows on the ground from different orientations throughout the

Figure 3-4, why airflow generates and passes through the loggia (drawn by author)

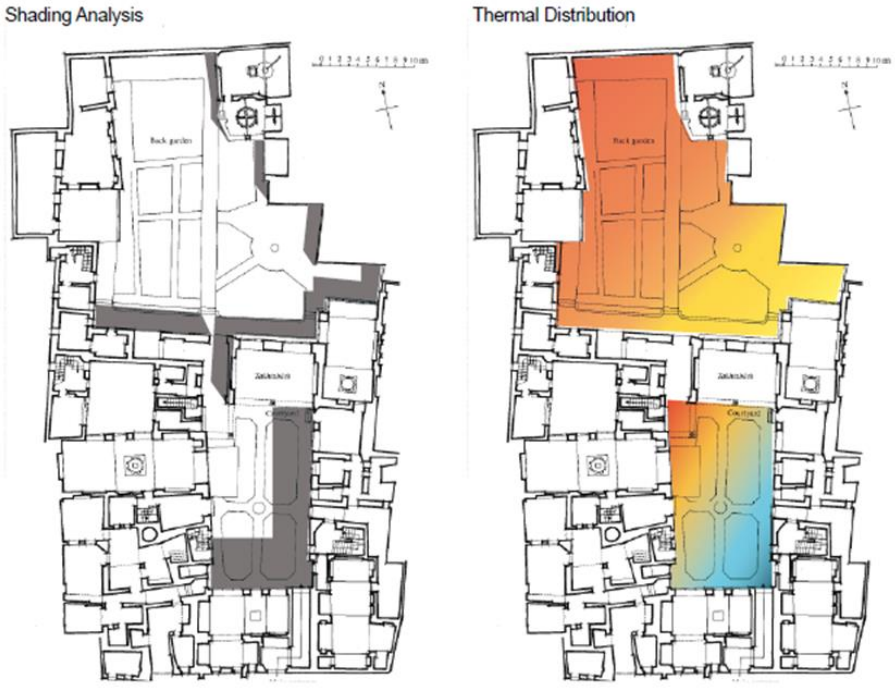


Figure 3-5, the two courtyards system in building layout in hot-arid areas (drawn by author)

daytime, while the larger yard (also called "the back garden") is less shaded and can be heated up by the sun more quickly. Between the two open spaces, there locating a loggia named the "takhtabūsh"[6] which is a covered outdoor sitting place at ground level. Since the warm air in the back garden will rise and draw a cool draft from the front yard, the loggia area turns into a comfortable meeting space for the occupants with constant air flow passing through.

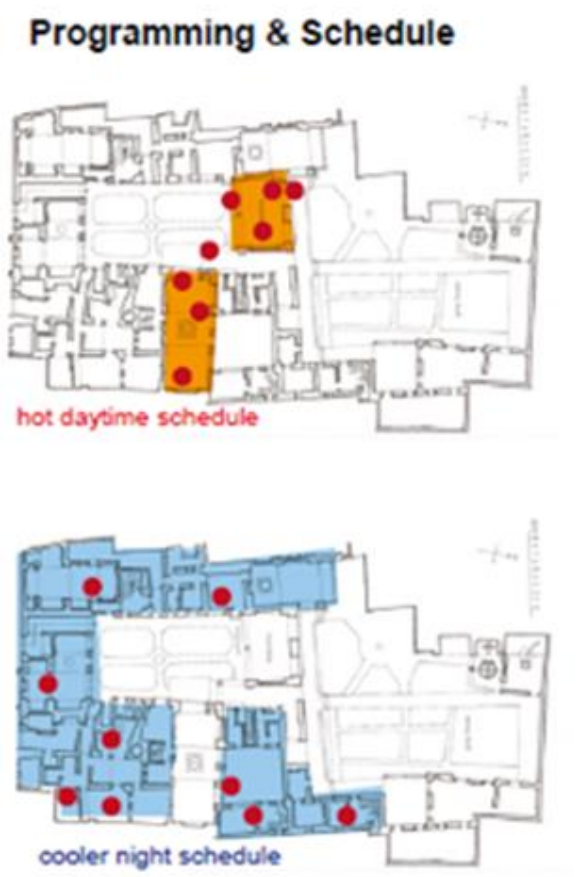


Figure 3-6, how people plan their daily schedule in layout (drawn by author)

As important as the outdoor sitting room, the indoor living room for receiving guests also has high expectation of the comfort level. Seen from the floor plan, the living room is sandwiched by other programs such as bedrooms and enclosed staircases, instead of directly touching the building boundary. It is very wise to site the night-use spaces and auxiliary functions adjacent to the edge as a buffer to block heat transfer, and thus the rooms that mainly occupied during the daytime won't be influenced too much by the outdoor heat wave. Moreover, the air temperature at night in arid areas drops

[6] Hassan Fathy, "Natural Energy and Vernacular Architecture", 63. Edit by Walter Shearer and Abe-el-rahman Ahmed Sultan. The University of Chicago Press, 1986

considerably, so the outer rooms will be cooled down very fast and provide an agreeable interior environment for people to relax at night.

Also rooted in the concern of energy flow, the prevalent vernacular house layouts in humid tropic regions and high latitudes display huge difference: the former is looser and the latter is tighter. People in these two climate zones use disparate rules to organise the relative positions of "heat source" programs like kitchen and frequently used living spaces. In hot-humid areas, the kitchen place is separated from the main living spaces and put aside with a buffer zone (corridor or courtyard) sandwiched in-between. However, in those cold regions, living rooms and kitchen are attached to each other and share the same wall, on which craftsmen open a small hole to draw the heat generated from cooking to the floor of living space, and then heat up the room via thermal conduction and radiation.

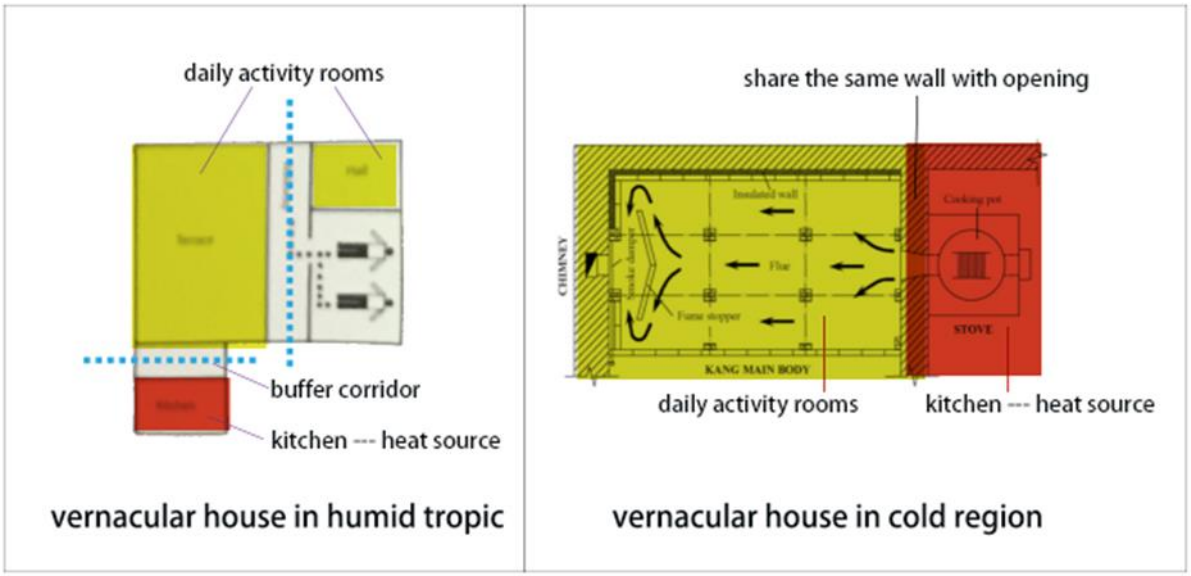


Figure 3-7, layout difference comparison (drawn by author)

Through the above analyses, the fundamental goal of each layout mode in the three extreme climate zones can be concluded: building design in hot-arid zone aims at prevent heat flow from entering the room; the porous layout pattern in hot-humid area is designed for quick removing the indoor heat and moisture by air movement; and the compact programming approach in cold region is for multi-level utilization of heat. Except the three special cases, other climate zones on the planet all have their own characteristics in building programming. The milder the climate is, the more flexibilities the layout will have.

3.2.3 Spatial Form

A good form of space contributes to making the building layout more efficient. This also proves that form and function are integrated by energy flow. This section is going to introduce three types of characteristic spaces belonging to the three climate zones mentioned before.

The building forms in cold areas can be abstracted as a simple geometry with smooth surface, whose shape coefficient is very small. Without external corners, the shadow on the building façade is reduced to a minimum, in other words, the solar heat gain on the envelope is maximized. Moreover, the roof curve is trying to avoid blocking wind flow so there won't be too much cold cross ventilation caused by air pressure differential.

Conversely, the architectural shape in hot areas is more irregular in order

to capture enough fresh air flow and create self-shadings. In arid countries, roof structure is the dominated part of the climatization system. The roof system consists of three parts: wind catcher as an air inlet, flat roof as an airflow heater, and a higher dome as a wind escape. When cooler upper air enters the room on the ground floor through the windward intake, interior wind movement will be faster if the air can be drawn out by suction device, and this process will perform even better if added an accelerator. In the case of hot-arid house, the flat roof which is completely exposed to the sun will heat the inside upper air, and increase the speed of convection --- air rises much faster escaping through the openings on the dome. Since the height of interior space is tall enough, the roof heating process will not disturb the thermal comfort below on the daily-activity level. Coincidentally, the roofs of many hot-humid vernacular dwellings also rise very high, shaping the whole building as a strong ventilating duct. The simplified section of these buildings are like an inverted trapezia, with wide overhang protecting the life below from the harsh sun. Supported by local structure designs in different regions, a variety of elegant spatial forms are created although based on the same goal of energy optimized control.

3.2.4 Natural Material and Component Design

In this experience-driving era, building materials are mostly selected from the natural resources, by considering in terms of their climatic suitability and thermal properties. For instance, thick walls made by earth with a good performance of heat re-radiation are popular in cold or arid regions, but are often undesirable in hot-humid areas, where the light material from plants (e.g. timber, thatch, reed, rattan, etc.) are more welcome. The botanic materials were so widely used not only because they are easy of access, but also for their perfect performance of regulating microenvironment which later discovered by scientists that they can absorb moisture when the surrounding humidity is too high, and then release it when needed, removing heat through evaporation.

Along with the culture developing, the construction methods devised upon these materials became more and more mature regarded from an energy perspective, which can be reflected in the architectural details. Some good examples of material design still retained today express a concept of “separation”, which means to divide a whole façade into several pieces

according to local conditions like sunlight intensity, wind pressure, and humidity, and finally unify these pieces with an integrated aesthetic system. A famous case is the wooden lattice screen called "mashrabiya" in Arabic architecture, which deals with several factors including light, air flow, temperature, humidity, and privacy at one time. The screen is divided into three vertical levels: the daily sitting level is the section where grids are arranged most intensively to ensure privacy and provide shadow for cool sensation; then the interstices become wider at the standing level, bringing in a clear view of outside scenery without producing uncomfortable glare and also blocking a portion of solar radiation; the upper part of the screen has the largest openings to strengthen the ventilation cooling, and simultaneously compensate the dimming effect caused by the small interstitial space below, allowing reflected light to brighten the room.

Similarly, a great number of world's classic architectural works pay high attention to the energy issue in treating local materials and determining component patterns. The diversity of material culture has been realized by combining the national cultural memory with the comprehensive energy regulating mechanism driven by multiple climatic factors and indoor demands in different positions of a building.

3.3 Modern time

--- Energy Quantification and Mechanically Isolated architectural system

The Industrial Revolution gave birth to a great era full of novel technologies and material inventions, which, has a profound influence on the development of architectural theory and practice. In 18th century, James Watt improved the Newcomen steam engine and laid the foundation of large-scale mechanization. The production of coal and steel has greatly enriched the form of construction and the structure of energy utilization. People realized that there contains enormous energy in the physical materials, and soon mastered a variety of methods to use them. On the basis of the popularity of electric energy in the 19th century, Willis Haviland Carrier invented modern air conditioning at the beginning of the 20th century, which made it possible for architects to create a sealed space with comfortable interior controlled only by machine rather than taking advantage of climatic energy. Although the initial purpose of the air-conditioning is to enhance the printing quality, people later found that working in such place will increase their efficiency and bring more economic benefits. That is why air conditioning is so widely spread and regarded as an indispensable part of modern architecture. The superiority of mechanism prompts ambitions to conquer nature, therefore, the link between building forms and natural energy disappears gradually. Most of the modern architectural designs are no longer restricted by external objective environment, replacing the complicated and valuable experience of building shaping and material construction born from the pre-industrial era with very simple volumes surrounded by glass curtain walls. Architecture become an isolated energy system occupied by fan coil units. Since the task of indoor thermal environment regulation has been taken over by engineers,

many theorists and designers found themselves deviated from their historical starting point and lost the foothold in the technological world.

With the globalization of this kind of “glass box”, regional architectural culture has been seriously threatened. Worse, the air-conditioned rooms not only generate high energy consumption, but also vent abundant heat when refrigerating, leaving the outdoor area as an abandoned land for waste heat, which destroys urban life severely. So the modern structure is described by some critics as “economically too expensive and environmentally incapable of delivering the performance for which society had hoped”.

Outside the main thread of modern architectural development, some pioneers are still active worldwide, whose achievements are different from the narrow victory of mechanism. Some regional architects kept working on the ancient experience and never ceased relevant innovations, while some high-tech proponents concentrated on improving the performance of active glass walls. The former formed a research system called “passive design” and the latter developed to “active design”. It was very late in the modern age that these two systems began to integrate into one project.

Besides, many energy theories appreciated in the next sustainable age were established by researchers at this time. So did the methodology. An important breakthrough is the quantitative calculation methods for energy, that is to say, natural climate elements can be quantified. Before this age, men only use qualitative approaches to solve the practical climatic problems. But in the new situation, data are collected from meteorological station and stored in a database for further use, to help optimize analysis diagrams and give a better

understanding of the available energy resource in specific living zones. Thanks to these advances in technology, human beings started to improve their traditional modes of energy conversion. Instead of burning fuels, they tried to capture natural energy (e.g. solar power, wind power…) for electricity generation. But this idea did not be added into the architectural system until the end of the "isolated" modern stage.

3.4 Sustainable age
--- Generalized Mechanization and Fine Control of Energy Flow

By introspecting the disadvantages of the modern time, a new age comes into being, to answer the question what was being increasingly mislaid in mainstream Modern architecture.

As Reyner Banham explained, the so-called "technological world" no longer referred to the world described by the modern architectural vocabulary of new building materials and structures in the conventional sense, but to a machine-occupied world that has a closer relation to the mechanical age. His definition about 'mechanical age' presented a gradual developing trend: at first, his recognition of machinery in architecture only included small household electrical appliances, however, he later shifted this thought and proposed a new idea that the core of mechanical age is to treat the whole building as an environmental regulating machine. This advanced concept has been greatly developed in the new sustainable age. And the word "environment" in Reyner Banham's statement has a particular meaning of architectural physical environment consisting of heat, light, and air and so on, rather than broadly including the topics of culture, society, psychology, or landscape.

By concluding the pros and cons of the previous periods, the sustainable age what we are currently facing offers a new direction of innovation for future architecture. The design procedure, instruments, logic, systemic theory and methodology have all been updated.

In the contemporary era, based on such a big background of data visualization, almost all the industries have been linked to computer parameters, architecture is no exception. Architects can seek help from the open access to local meteorological data, the micro environment simulation platform, and the wind tunnel testing system and so on, all of which are aiming at providing a more sophisticated data support to navigate the designs. Thus, today's designers are able to accurately control and adjust those complex environmental parameters on the micro scale. In order to make the data-based designing process more efficient, the necessity of prepositive simulation is stressed.

One of the greatest achievements in sustainable age is the new design philosophy named "thermodynamic architecture" put forward by GSD, which, emphasizes the significant role of the second law of thermodynamics in architectural discourse. Unlike the first law that defines the energy and matter in a closed system, the second law discusses the energy behavior in an open non-equilibrium system. Building system is also an open energy system as the second law said. So the modernistic isolation should be abandoned, instead, the missing interaction of interior and exterior should be rebuilt. This point is quite similar to the main idea of pre-industrial period, however, thermodynamic architecture is more than just passively adapting to nature or avoiding unnecessary wastes, and it also regards "energy capturing & channeling" as its own mission. Once the building edge & structure can only

defend the indoor space from the effects of adverse energy flow, but cannot produce energy for people to use. In the sustainable age, guided by the law of thermodynamics, the boundaries of building become an energy station to capture energy from outdoor environment, while the building structure can be used as a channel to transfer energy.

Connecting data and experience, this stage will see a thorough paradigm revolution upon the new energy conception, supported by synchronous innovation of building structure.

3.5 Chapter Conclusion

In the time before the emergence of computational simulation technology, people used to refer to individual experience on the regional climate, material, comfortable sensation, traditional custom and community lifestyle when involved with some environmental information related to architecture, or sometimes, they use some simple temperature measurement and thermal imaging to help complete the design. All of these methods have shown the designers' original initiative to climate energy. Although has been forgotten for a period of time, natural energy finally find its new role engaging in architectural system. As time goes on, more and more scientific analysis technologies help architects to regenerate interests and various ideas in the way they should be employed.

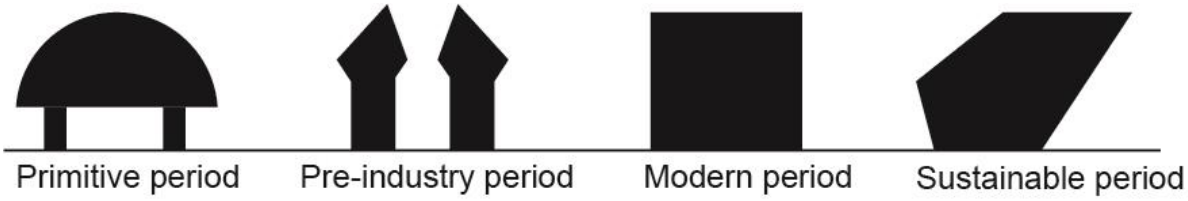


Figure 3-12, different prototypes/paradigms in the four historical periods （drawn by author）

Different building prototypes of the four historical phases implies the differences in comprehension level of energy utilization, which also presented in how people deal with the relation between building and environment. In the first phase, building is a tiny part of nature, and climate energy is thought to be an offensive element that needed block. In the second phase, people realized the advantage of natural energy and improved the design to use it more. In the third phase, the building is separated from the external energy system. In the fourth phase, the building system and environmental system are treated equally, and combined together through energy interaction.

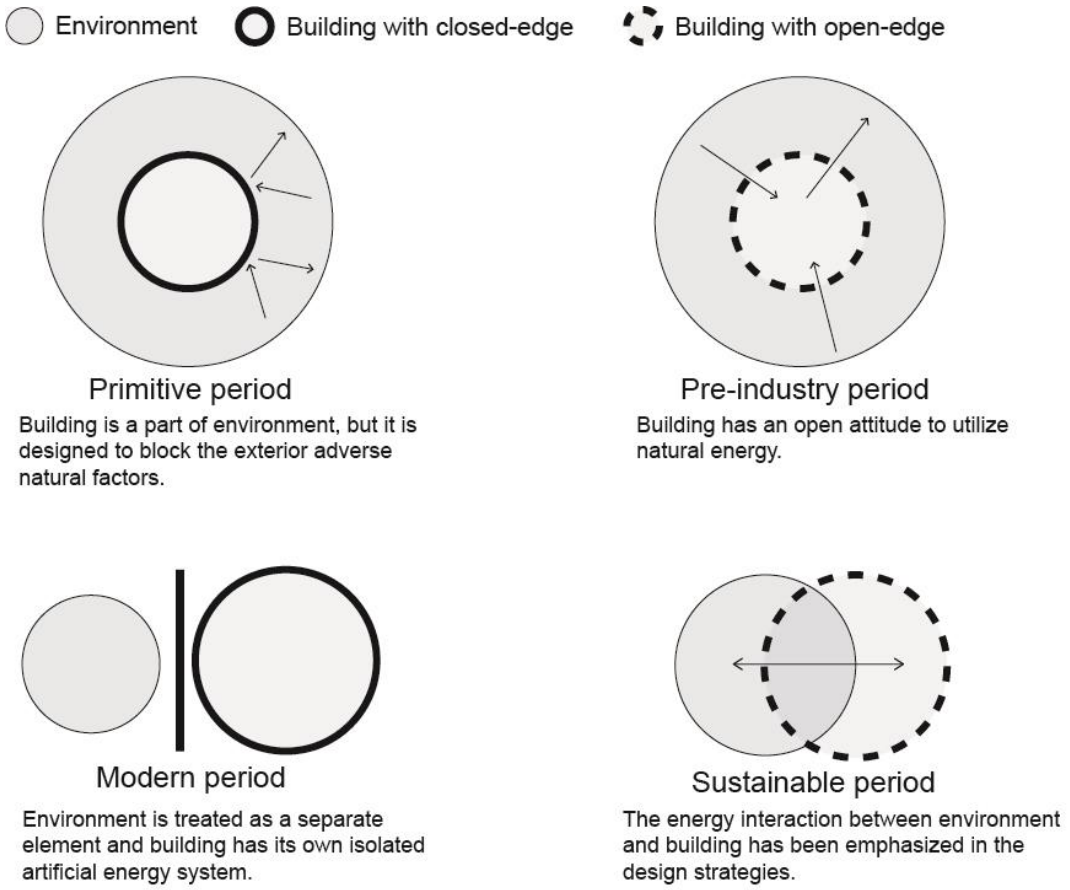


Figure 3-13, different relations between building and environment in four historical periods (drawn by author)

4 PRECEDENT STUDY IN HUMID TROPICS --- IMPACT OF ENERGY ON LAYOUT DESIGN EXPERIENCE

4.1 Climate characteristics, and Representative locations

Humid tropics have a hot-humid climate, with high temperature accompanied by very high humidity levels, which leads to immense discomfort. These places are usually close to sea or oceans where there is large amount of water vapour in the air. It is a common sense that land and water do not get heated at the same rate. Land gets heated faster than the water, so it will radiates energy to heat the air near the land. The heated air above the land becomes lighter and moves up, as a result, the cool air above the seas rushes to take its place and brings lots of water vapour to the land.

Under the effect of the sea breeze, the temperature in these hot-humid areas will not go up to that much high like some hot-arid deserts, but the humidity is always a big deal. From a molecular scale, gas steam is a bunch of H_2O molecules flying around at random, bashing into each other occasionally, while the molecules in liquid are much more tightly packed and are in contact with each other all the time. When heated up, the orderly arranged molecules can transfer heat directly to their neighbours but the random ones cannot be so efficient. So water is better at conducting heat than air, which means that at the same outdoor temperature,

moist air can conduct heat more easily and quickly to the indoor space, but this process will slow down in the dry air. This thermal conducting principle explains the huge differences in building layout and material selection of hot-humid area and hot-arid area though both of which are facing the same overheated condition. In arid zones, as dry air conducts heat inertly, a thick wall of rammed earth will be very helpful to block the heat flow, separating the cooler interior from the hotter exterior. However, this strategy is improper to humid zones because even using these walls as an enclosure, the inside moist air will still be heated very fast by thermal conduction, in this case, thick solid walls if used would result in an exactly opposite effect to what people wished and generate a muggy interior with less outlets for hot-humid air.

If dating back to the human architectural history of environmental management, one can conclude that doing “subtraction” is usually more difficult than doing “addition”, by which I mean that removing some existence is much harder than inserting something new. For example, the methods of cooling is more complicated than of heating. For heating, the only thing people should do is to shape a tight space enclosed by thermal mass with less openings; but for cooling, there are at least two necessary steps --- one is to create a sun-shading layer, and the other is to organize a proper route for invisible wind flow, and try to accelerate the air speed by calculating the sizes of inlets and outlets. Similar to this instance, humid issue is also regarded to be more pestiferous, subtle, and elusive of control than dryness. While the deficient humidity of an over-dried climate can be crudely made better by splashing water about, the removal of excess water from the atmosphere has always been a problem without solution in the pre-technological ages. So far, only mechanical means with power

consumption has been proven effective in sucking excess moisture. Helpless in water-separating, the effort of architecture can only be made in increasing evaporation, by wind or by heat.

Hence the hot-humid climate is not an easy object to deal with, and this chapter will be an intensive study on most humid tropical regions, looking for ancient experience and modern innovations in the building layout and other related factors. The target research locations will be Thailand, Singapore, Vietnam, and Malaysia and so on, where the temperature range is relatively high at around 26 - 35 ℃ and is fairly even during the day and throughout the year, winds are light or even non-existent for longer periods, but heavy precipitation and storms occur frequently.

4.2 Ancient Wisdom Study in Vernacular Dwellings

Vernacular wisdom is no doubt the compass for practice. It includes the inherited knowledge of climate, topography, seasonal variation, natural hazard, and suitability of site, and the

collective experience and norms accepted by the society concerned. That is why Paul Oliver said, “vernacular know-how”. Here will give some typical old dwelling examples in several tropical countries.

4.2.1 Houses in Thailand --- A unique icon in tropics

Traditional Thai Houses are well adapted to the tropical climate both in forms and layout. In order to protect from flooding, many houses are raised on stilts, and covered by a steeply slanting roof which helps to channel rainwater off the house. Natural materials are used to increase porosity both on macro-scale and on microstructure to improve the “breathing” ability of construction. There are two basic dwelling types: a nuclear family single house and a stem family clustered house. The differences in building layout does not related to what type/scale the house is, but to which part of Thailand the building belongs to. In Thailand, the northern part is much cooler than the central part, so the building layout in these two places are significantly different. The kitchen and living areas in the Northern Thailand are often

Fig
Th
ho

joined together, which makes good use of the available heat, while in hot central plains, the kitchen is always thrown to a corner to prevent heat transferring. A large, centrally situated veranda is the dominant feature of many traditional houses in central Thailand, and serves as an outside living area for much of the year, with scattered rooms clustering around. The veranda is sometimes partly covered to provide a shading edge running along the sides of the main structure. These "edge spaces" become more and more popular for family activities since people realized there is no direct sunlight but has unobstructed wind. This way of pursuing comfort is welcome by other building patterns, so we can see the River Houses in central Thailand, whose edge is expanded to a wide shopping place for trading and relaxing.

4.2.2 Other tropical vernacular houses

Unlike Ancient Thai Houses which had a distinct feature born from its independent civilization, other traditional tropical houses more or less have some similarities to one

another, especially the colonial regions in Southeast Asia like Singapore, Vietnam, and Malaysia.

The vernacular dwellings in these areas can be classified into two categories according to their functions. One type is from the remote kampong (in Figure 4-4) while the other refers to the ones aligned along the urban street. The former is quite simple in form with a steep roof covering a long but thin floor plan. The latter has a complex layout because of land-use limitation --- the house is sited in a very narrow bay. For the sake of getting more ventilation, a side corridor and an air well are set within the building. The corridor can be used as a wind tunnel straight connect two ends of the house. And the air well serves in the room-side as an air outlet contributing to stimulate cross ventilation. It is also very wise to separate bedrooms

and daytime-occupied rooms in two floors. During the day when the outside temperature is high and the roof is exposed to the direct sunlight, the upper space of the building will be undesirably hot. Then the bedrooms which are used at night can be a buffer to prevent heat from transferring downstairs, keeping the lower living space cool. Another ingenuity is the rear court where containing the service rooms like kitchen and toilet. Kitchen, as we know, is a heat producing center. So in this layout system, there are no main rooms sharing interface with the kitchen, no matter horizontally or vertically: the walls and windows of the kitchen mainly facing the rear court, and above its ceiling is an outdoor terrace. This arrangement minimized the influence of cooking heat on the adjacent important living spaces. From this traditional case, we can conclude that a mature and rational idea has been established and the generated prototype can be applied in the future architectural layout of humid tropics.

4.3 Modern Architects' Practice towards the hot-humid climate

4.3.1 Wind Vault House in Singapore

The overall form of the house needed to be pushed to the envelope limits. Naturally, there are also other considerations: the context and proximity of neighboring homes, the daily sun path and the prevailing winds. Conceptually, the house is a raised reinforced concrete tube whose open ends and oriented in a general north-south direction. On this site, the prevailing breezes also blow in from the south, from the direction of the nearby coast line. In practice, all rooms have walls that side either east or west, and front north and south. The tubular structure resists east west heat gain thanks to the solid mass of the reinforced concrete but encourages passive cooling through the open north south axis. The north and south facades

are treated with timber screens and their contribution is multifold. They are privacy filters for the bedrooms and are the first layer of glare and solar heat reduction to the spaces behind. The timber fins of the screen can also be angled so as to catch a breeze or to increases privacy as and when needed.

4.3.2 Parekh House in India

From the housing types developed for Cablenagar, came two pyramidal sections: One, termed the Summer Section (to be used in the daytime) protects the interior from the heat, the other, termed the Winter Section (to be used in the early mornings and the evenings) opens up the terraces to the sky.

Since this site faced east-west, this house consists of 3 bays: with the Summer Section sandwiched in between the Winter Section on one side and a Service Bay (for circulation,

kitchen and toilets) on the other. The bearing walls, made of brick, express directly the climatic concepts which underlie the design.

4.3.3 Liljestrand House in Honolulu

The Liljestrands presented Ossipoff with demanding requirements, while the topography and highly variable daily weather conditions—sun, wind, and rain—imposed further constraints. The house is on two terraces, with the carport, entrance, and main part of the long, narrow house on the uphill terrace, which produce really comfortable ventilation, and a lower story opening onto the downhill terrace. On a third, lower tier is a swimming pool. The upper side of the house is well sheltered from frequent mountain showers, while low-lying wooden louvers draw cooling breezes toward the larger openings on the side facing downhill. A long, open-sided recreation room extends beneath the bedrooms and faces onto a wide lawn. The large master bedroom at one end is angled to preserve an old stand of eucalyptus trees (natural shading), and a sharp, wraparound deck juts out from the living room end of the house,

overlooking the pool, the treetops, and a wide expanse of the city and the leeward side of the island stretching into the distance. Every room has a view.

4.3.4 Stacking Green in Vietnam

The house, designed for a couple in their thirties and their mother, is a typical tube house constructed on the plot 4m wide and 20m deep. Two microenvironment regulating strategies make the building become efficient and impressive ---one is “double-skin” system, and the other is ventilation system. In the building programming, 40% of the house is semi-exterior space, acting as a buffer to assist the other passive design methods.

- **Double-skin system:**

Unlike the Europe-style double skin façade constituted by glass-air-glass which may lead to local overheating in a hot climate, Nghia worked out a tropical-type double skin of “green-air-glass”. The out “green layer” is made of concrete planter groups which protect its inhabitants from direct sunlight, street noise and pollution, and even when heavy rains

coming, the green screen can allow the inner window open without getting wet. Rainwater is collected in the tank and pumped up for the automatic irrigation system installed inside the planters to water the plants.

- **Ventilation system:**

Cooled by the green filter, natural wind blows into the building and is accelerated by the vertical voids and the staircase tube, then takes the indoor heat out through skylights and opposite windows. A post-occupancy measurement of the indoor environment has proved the superiority of the design, so has the behavior of the inhabitants: they scarcely use the air conditioner even at a higher temperature, their electricity fees are just $25 per month thanks to the air flow.

4.4 Induction of Programming Characteristics

- Get rid of heat influence

1. Prevent heat from coming into the room --- orientation, shading (louver/ overhang/grid/exterior buffer space)

2. Minimize indoor heat sources --- natural daylight

3. Remove the indoor heat quickly --- lead cooler wind in, fan

4. Reduce the thermal impact from an adjacent room --- relationship between the relative positions of zones, partition, and indoor buffer.

4.4.1 Proportion of modules

Open & Semi-open for public activity

In the diagram analysis of typical tropical vernacular houses, it can be seen that the layout has “high porosity”. People insert some open spaces into their buildings as a tunnel for wind where may occur public activities. The proportion of these open public area to the enclosing private rooms are best at 1:1 or 2:1, which not only create self-shading on the outer building surface, but also increase the superficial area for heat dissipation.

4.4.2 Location of inner buffer

In many modern architectural practices, although the land-use is more compact than old ages, it still can be found that designers are trying their best to create porosity and add buffers between different thermal zones. ----- This is an inheritance from wisdom ancient layout strategies in hot-humid vernacular houses. Most of these buffers are no longer top-less

terraces, but become interior corridor or some auxiliary facilities like restroom or storage where people do not use quite often.

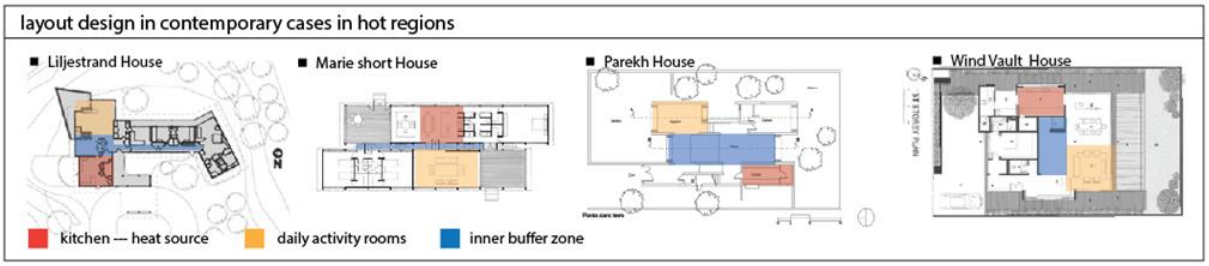


Figure 4-12， drawn by author

4.4.3 Form of outer buffer

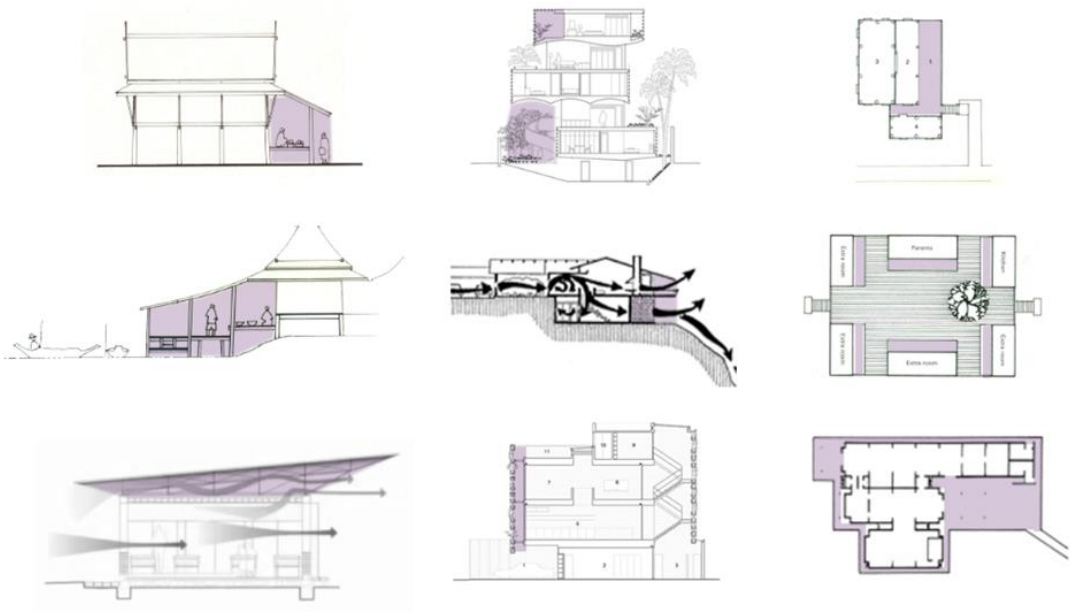


Figure 4-13, form of buffer zones in sections and floor plans (drawn by author)

Exterior buffer is necessary in the regions with intensive solar radiation. There are many different ways to design the exterior buffer zone in order to create more shadows. It may be a stretched roof, or an interlayer between double roof or wall screen, or generated by a cantilevered building part. It can be used as a corridor, a circulation core, a terrace, a multi-functional communication space, or even only a path for air movement. Instead of just

attaching some louvers to block the view, ingenious design of the buffer zone in architectural layout can benefit both comfort and pleasantness of living.

4.4.4 Interspersed dynamic zones

Higher wind speed contributes to bring in fresh air and remove the interior heat. The traditional layout mode to accelerate wind flow is to reduce the depth of building, and that is why ancient tropic houses had some linear parts scattering around a yard, with wind easily passing through the indoor spaces and escaping from the courtyard. But in recent times, the crowded city cannot provide that much land for building a capacious yard in every house, and people also find that a thicker layout which contains more programs in one place will make our life more efficient in dealing with multi-tasks. Thus, interior becomes more deep and hard for wind to travel through. In order to solve this problem, architects add some patios or vertical openings to break down the spatial thickness and stimulate wind flow.

5 THERMAL COMFORT PARAMETRIC SIMULATION --- KITCHEN AND LIVING AREA IN HALE KUAHINE

5.1 Site & Climate Data

Honolulu experiences a hot semi-arid climate (Köppen classification BSh), with a mostly dry summer season, due to a rain shadow effect. Temperatures vary little throughout the months, with average high temperatures of 80–90 °F (27–32 °C) and average lows of 65–75 °F (18–24 °C) throughout the year.

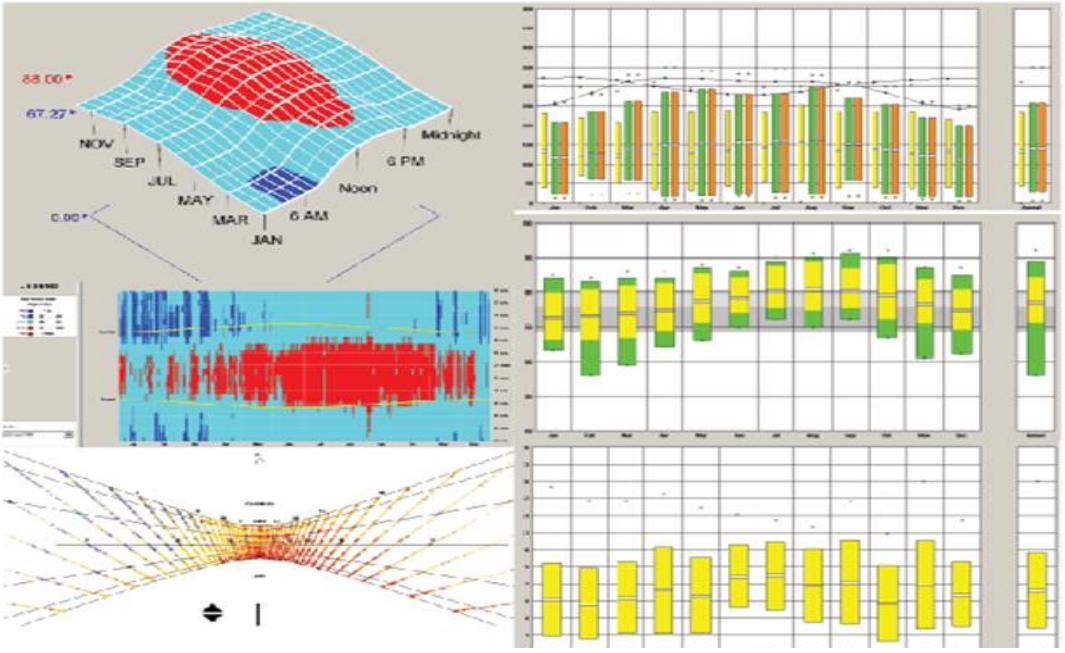


Figure 5-1, Honolulu climate data, from CLIMATE CONSULTANT

Figure 5-3, site map from EWC

Figure 5-2, photos of HK, shoot by author

5.2 Experiment Organization

- **Simulation object**

Why kitchen: Unlike the ordinary kitchen in a house (usually only housewife use it for a while) or in a canteen (kitchen is separated from the main dining area and cookers occupy the space from very early of the day until sunset), the kitchen area in the campus dormitory has its unique complexity (take HALE KUAHINE as an example):

The primary users of the kitchen are campus students who have very free schedule which is different from one another, so that the occupying period is long with a large amount of movement--- started from 6:00 in the morning and closed at 11:00 pm (see Figure 5-4 Figure 5-4, Usage Record of kitchen in HALE KUAHINE Dormitory, and the peak using time falls in the hottest hours of the day.

The kitchen is not only a place for cooking but also for communication. Students meet new friends and invite their guests to participate in making cuisine, which extend their staying time even longer. Moreover, as a connecting points of sitting room (indoor dining) and courtyard (outdoor dining), the kitchen becomes such a significant node in student's diverse daily life and can be treated as part of the living space in the dormitory. Sometimes, at the beginning of a celebration party, the density of occupants in the kitchen will see a dramatic rise --- more than 15 people huddle in the 400sf room at one time.

Installed with 16 stoves, 2 ovens, 2 refrigerators and one microwave oven, the kitchen is indeed a heat-producing place. Calculating along with the heat from human activities and

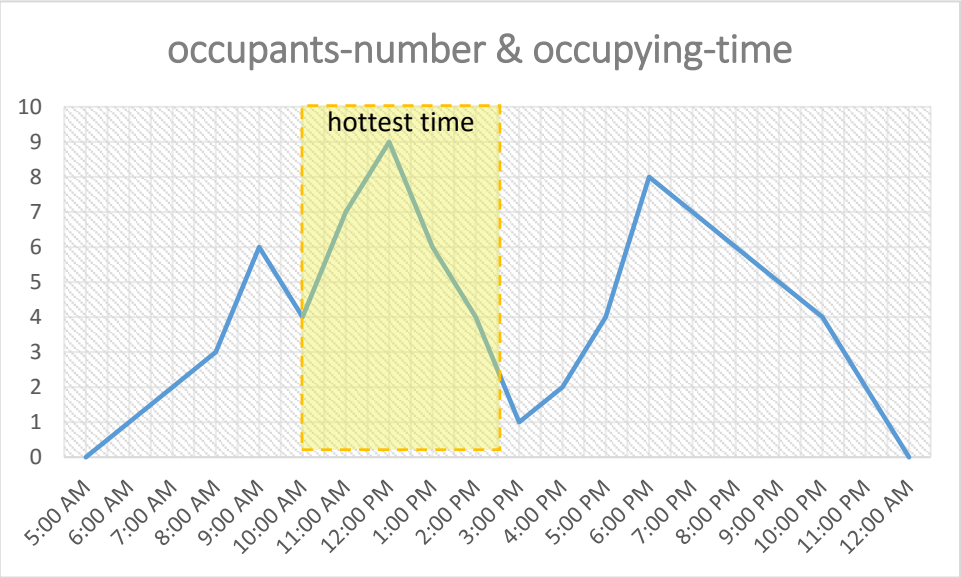


Figure 5-4, Usage Record of kitchen in HALE KUAHINE Dormitory

sunlight, the satisfaction of thermal comfort in the kitchen would be much harder to achieve. Besides, other living spaces nearby may also suffer in high temperature caused by heat transfer from kitchen.

Aside from afore-mentioned complicacy, another reason for selecting kitchen as a core of living space to be simulated in computer is because there was no kitchen space in the initial design of HALE KUAHINE Dormitory and it was the later administrators who add the furniture to a room then reform it to a kitchen. In that case, the results of simulation can just tell whether the current choice is a proper location to place a kitchen, and see if there would have other better positions.

- **Model building**

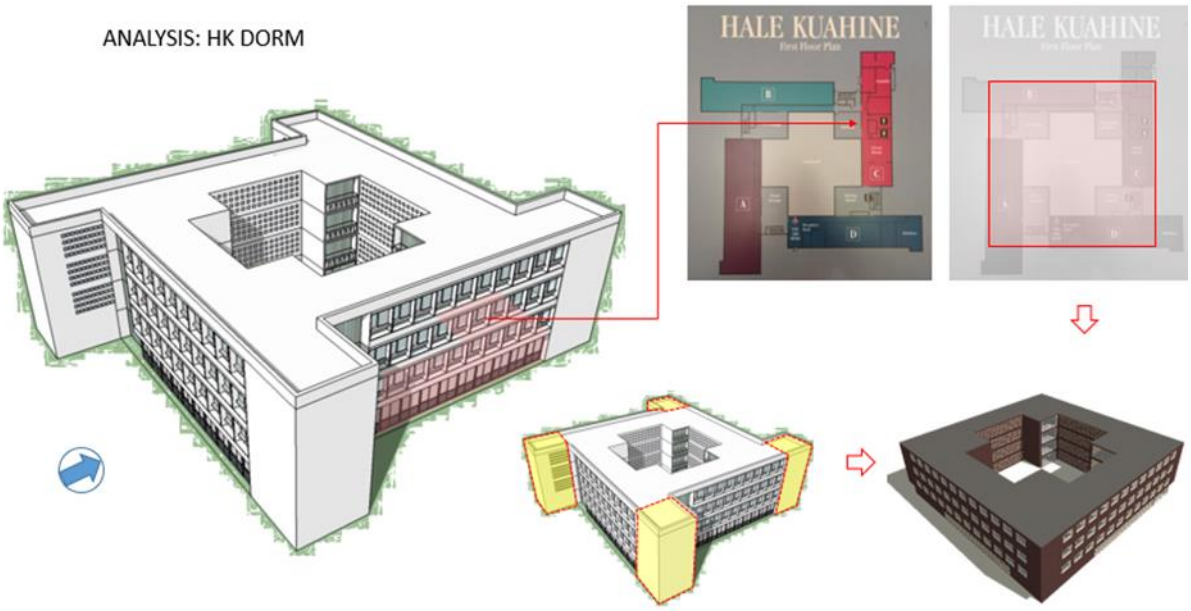


Figure 5-5, model built by author

The four circulation corners have nothing to do with the microclimate around living room, so they can be ignored in the simulation process.

- **Parameters**

TABLE 5.2.2.2A Clothing Insulation (I_{cl}) Values for Typical Ensembles

Clothing Description	Garments Included[a]	I_{cl} (clo)
Trousers	1) Trousers, short-sleeve shirt	0.57
	2) Trousers, long-sleeve shirt	0.61
	3) #2 plus suit jacket	0.96
	4) #2 plus suit jacket, vest, T-shirt	1.14
	5) #2 plus long-sleeve sweater, T-shirt	1.01
	6) #5 plus suit jacket, long underwear bottoms	1.30
Skirts/Dresses	7) Knee-length skirt, short-sleeve shirt (sandals)	0.54
	8) Knee-length skirt, long-sleeve shirt, full slip	0.67
	9) Knee-length skirt, long-sleeve shirt, half slip, long-sleeve sweater	1.10
	10) Knee-length skirt, long-sleeve shirt, half slip, suit jacket	1.04
	11) Ankle-length skirt, long-sleeve shirt, suit jacket	1.10
Shorts	12) Walking shorts, short-sleeve shirt	0.36
Overalls/Coveralls	13) Long-sleeve coveralls, T-shirt	0.72
	14) Overalls, long-sleeve shirt, T-shirt	0.89
	15) Insulated coveralls, long-sleeve thermal underwear tops and bottoms	1.37
Athletic	16) Sweat pants, long-sleeve sweatshirt	0.74
Sleepwear	17) Long-sleeve pajama tops, long pajama trousers, short 3/4 length robe (slippers, no socks)	0.96

Figure 5-7, clothing data in Energy Plus

TABLE 5.2.1.2 Metabolic Rates for Typical Tasks

Activity	Metabolic Rate		
	Met Units	W/m²	Btu/h·ft²
Resting			
Sleeping	0.7	40	13
Reclining	0.8	45	15
Seated, quiet	1.0	60	18
Standing, relaxed	1.2	70	22
Walking (on level surface)			
0.9 m/s, 3.2 km/h, 2.0 mph	2.0	115	37
1.2 m/s, 4.3 km/h, 2.7 mph	2.6	150	48
1.8 m/s, 6.8 km/h, 4.2 mph	3.8	220	70
Office Activities			
Reading, seated	1.0	55	18
Writing	1.0	60	18
Typing	1.1	65	20
Filing, seated	1.2	70	22
Filing, standing	1.4	80	26
Walking about	1.7	100	31
Lifting/packing	2.1	120	39
Miscellaneous Occupational Activities			
Cooking	1.6–2.0	95–115	29–37
House cleaning	2.0–3.4	115–200	37–63
Seated, heavy limb movement	2.2	130	41
Machine work			
sawing (table saw)	1.8	105	33
light (electrical industry)	2.0–2.4	115–140	37–44
heavy	4.0	235	74
Handling 50 kg (100 lb) bags	4.0	235	74
Pick and shovel work	4.0–4.8	235–280	74–88

Figure 5-6, activity data in Energy Plus

5.3 Simulating Target & Zone Creating

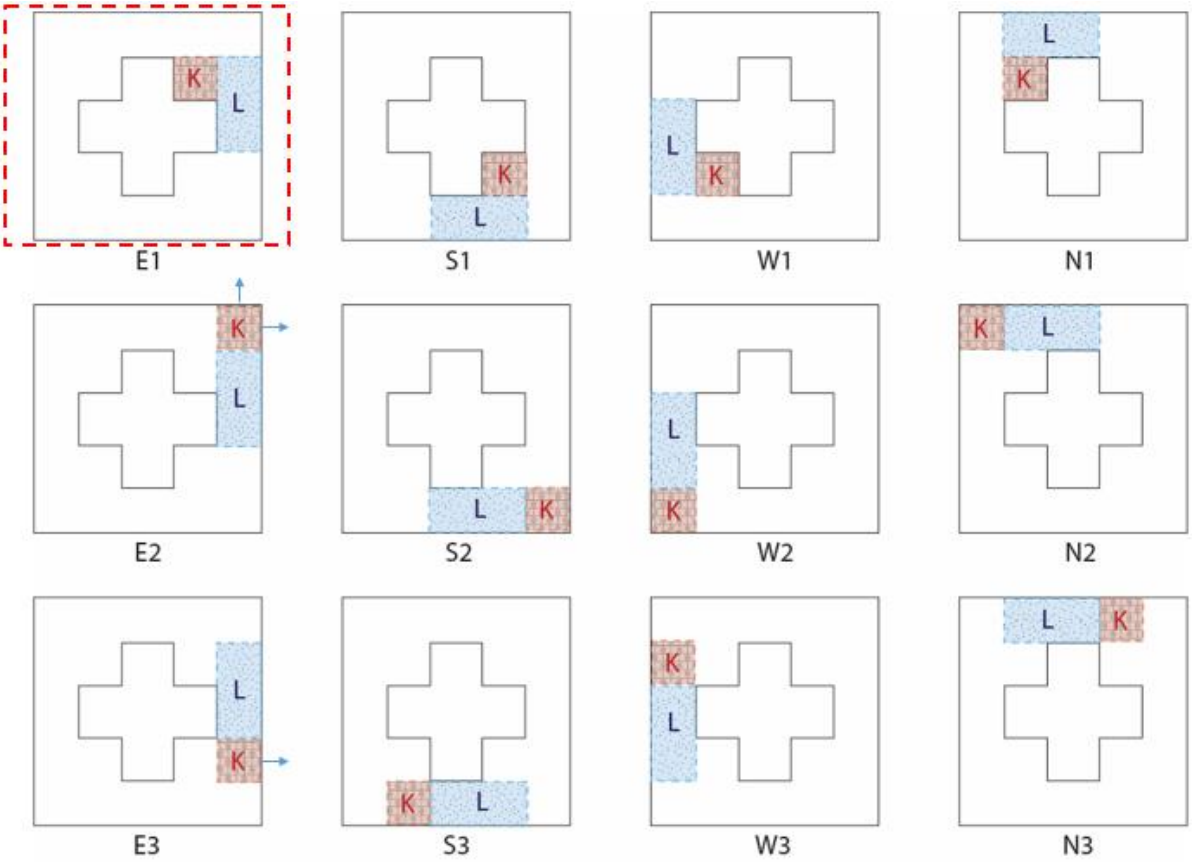
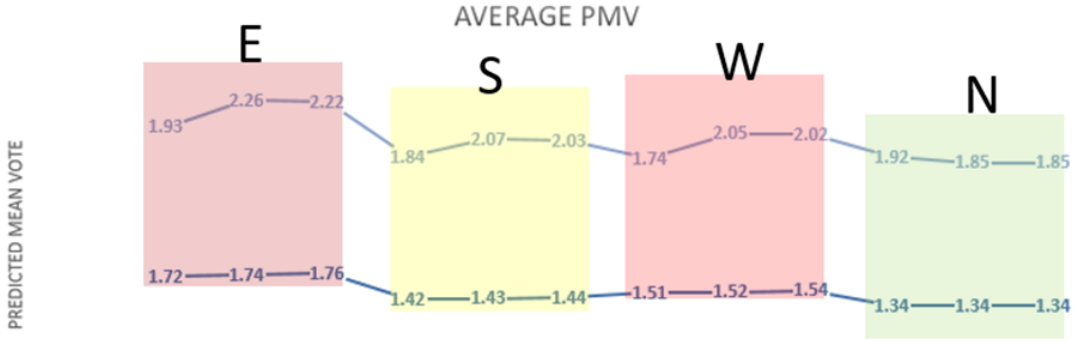


Figure 5-8, simulation groups according to different orientation (drawn by author)

5.3.1 Orientation influence



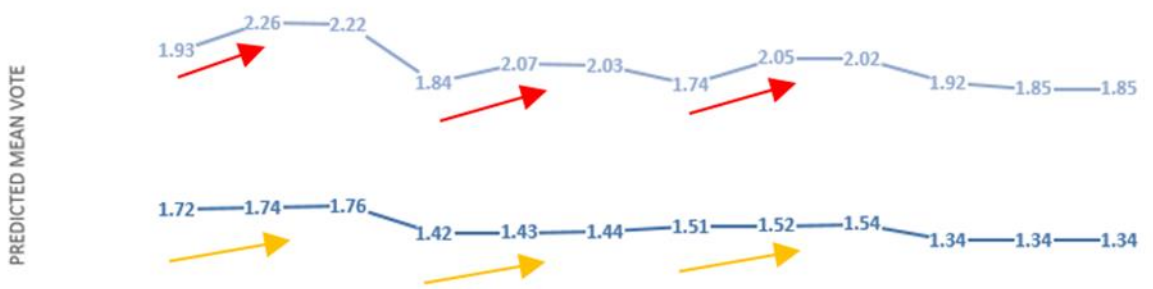
	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3
AVE(K)	1.93	2.26	2.22	1.84	2.07	2.03	1.74	2.05	2.02	1.92	1.85	1.85
AVE(L)	1.72	1.74	1.76	1.42	1.43	1.44	1.51	1.52	1.54	1.34	1.34	1.34

Figure 5-9， drawn by author

Average PMV data shows that kitchen area is always less comfort than living room because of heat generation from cooking appliance, even if the orientation of kitchen is much cooler than the living room direction.

In four direction groups, the northern group is the most comfortable one, then is the southern group, the eastern and western ones are the least comfortable.

5.3.2 Relative position influence



	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3
AVE(K)	1.93	2.26	2.22	1.84	2.07	2.03	1.74	2.05	2.02	1.92	1.85	1.85
AVE(L)	1.72	1.74	1.76	1.42	1.43	1.44	1.51	1.52	1.54	1.34	1.34	1.34

Figure 5-10, PMV relation between kitchen and living room (drawn by author)

The curve shows that on the premise of same orientation group and same activity schedule, if changing the position of the kitchen but still kept next to the living room which staying in the same place, then the comfort level of living room will drop when the kitchen gathers much more solar heat. This is because the kitchen will transfer some part of extra heat to the living room directly with no buffer zone between them.

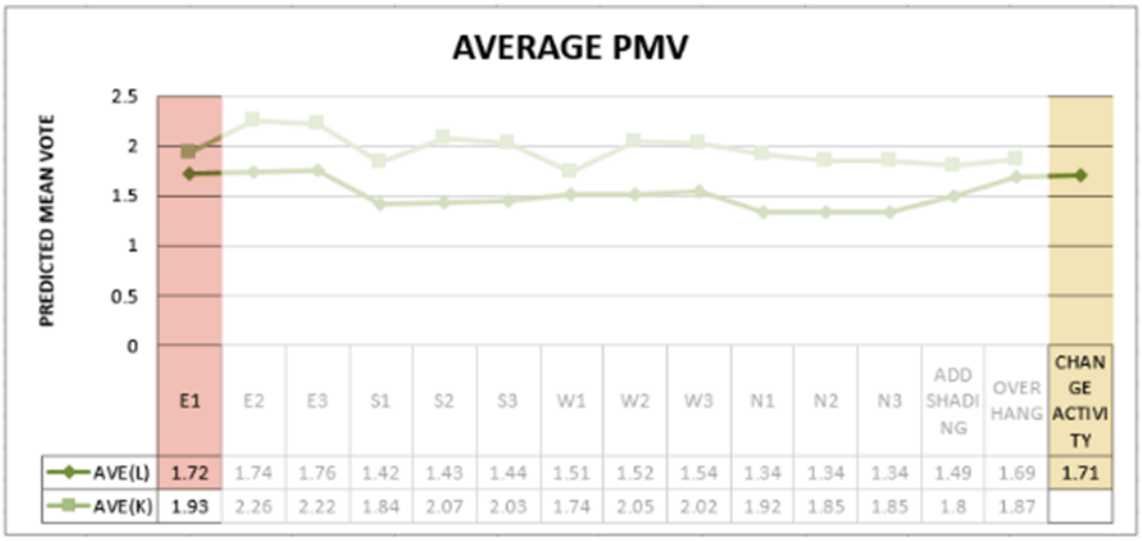
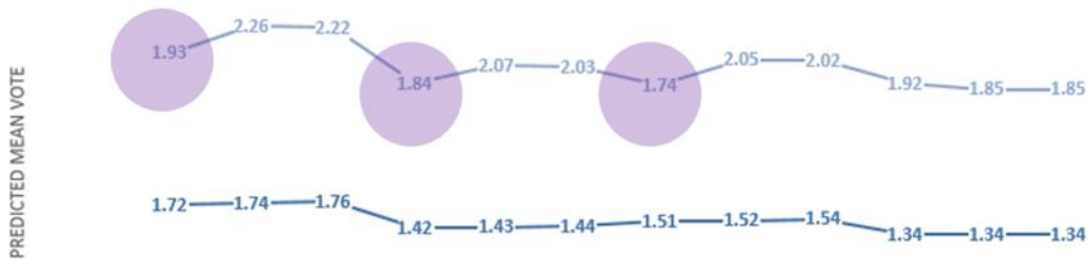


Figure 5-11, comparison between original location and change activity (drawn by author)

This is a testing that if the activity in the current kitchen place is replaced by any other programs with less heat generation, then the comfort level of living room will rise, which proved how important it is to choose a proper adjacent zone in improving the indoor living comfort.

5.3.3 Courtyard influence



	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3
AVE(K)	1.93	2.26	2.22	1.84	2.07	2.03	1.74	2.05	2.02	1.92	1.85	1.85
AVE(L)	1.72	1.74	1.76	1.42	1.43	1.44	1.51	1.52	1.54	1.34	1.34	1.34

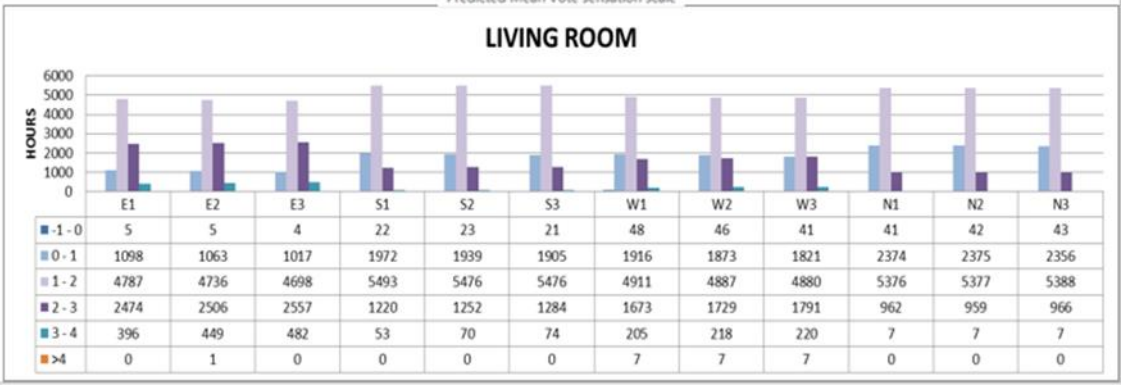
Figure 5-12, the lowest PMV occurring in courtyard side (drawn by author)

In each sunward direction group, it can be seen that the room facing courtyard is much more comfortable than the rooms facing outside. This is how hot-humid buildings can benefit from the courtyard area because of the shadow cast in the courtyard.

Value	Sensation
-3	Cold
-2	Cool
-1	Slightly cool
0	Neutral
1	Slightly warm
2	Warm
3	Hot

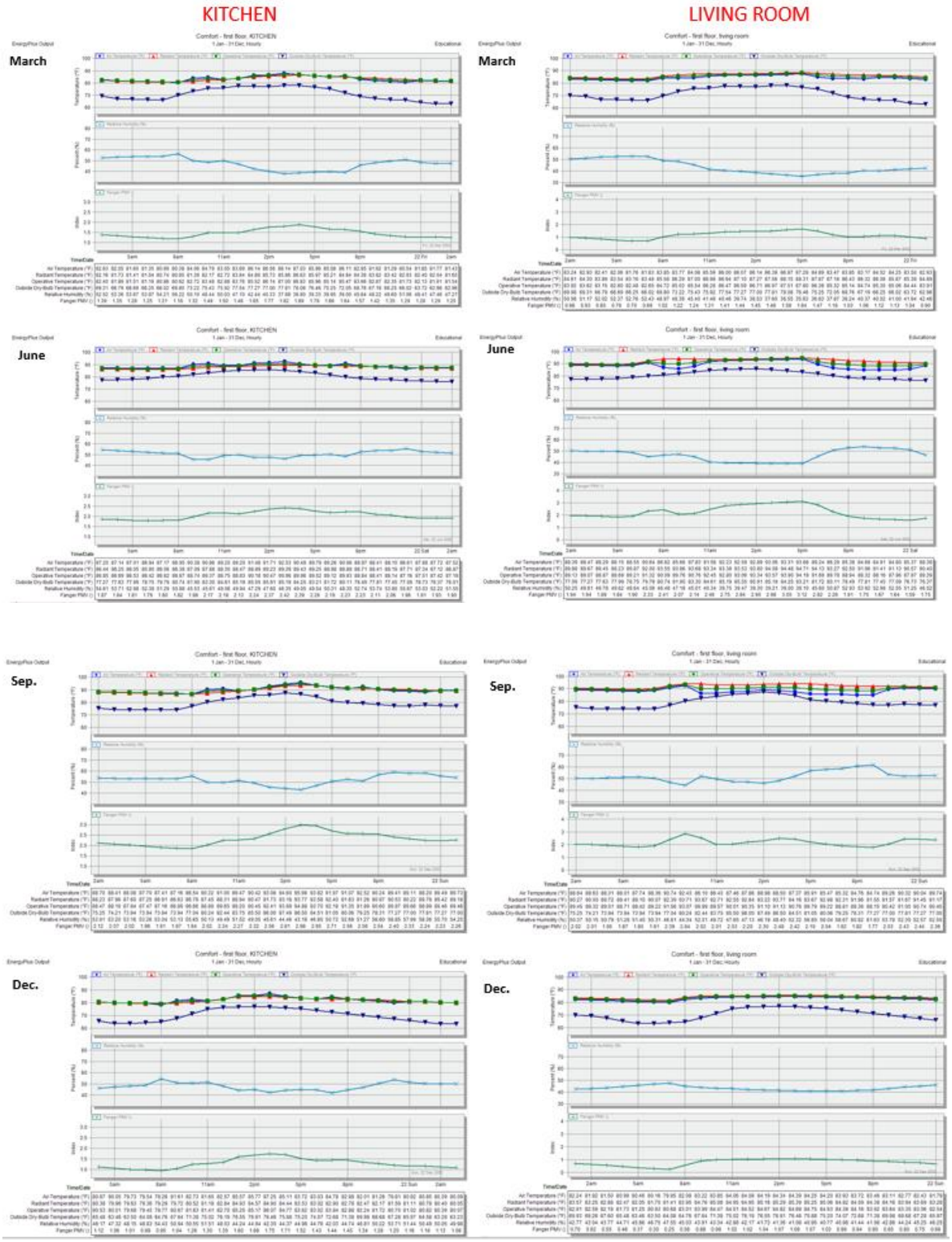
	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3
-1 - 0	0	0	0	0	0	0	0	0	0	0	0	0
0 - 1	70	25	32	187	52	76	304	87	103	123	215	229
1 - 2	4839	2940	3125	5312	3909	4118	5875	3998	4198	4796	5077	5147
2 - 3	3802	4762	4698	3207	4528	4334	2581	4276	4095	3818	3465	3381
3 - 4	49	1033	905	54	271	232	0	398	363	23	3	3
>4	0	0	0	0	0	0	0	1	1	0	0	0

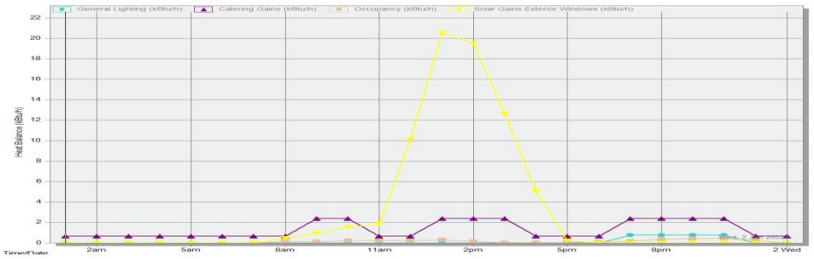
Predicted Mean Vote sensation scale

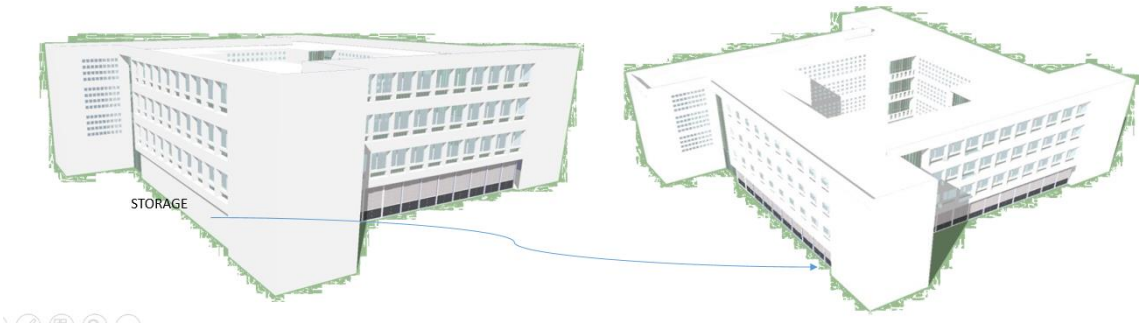


	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3
-1 - 0	5	5	4	22	23	21	48	46	41	41	42	43
0 - 1	1098	1063	1017	1972	1939	1905	1916	1873	1821	2374	2375	2356
1 - 2	4787	4736	4698	5493	5476	5476	4911	4887	4880	5376	5377	5388
2 - 3	2474	2506	2557	1220	1252	1284	1673	1729	1791	962	959	966
3 - 4	396	449	482	53	70	74	205	218	220	7	7	7
>4	0	1	0	0	0	0	7	7	7	0	0	0

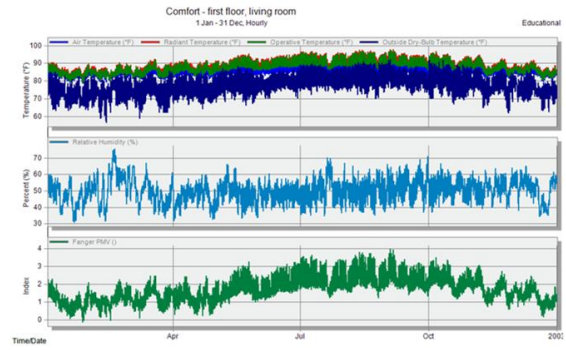
5.4 Analytical Diagrams of Testing Results





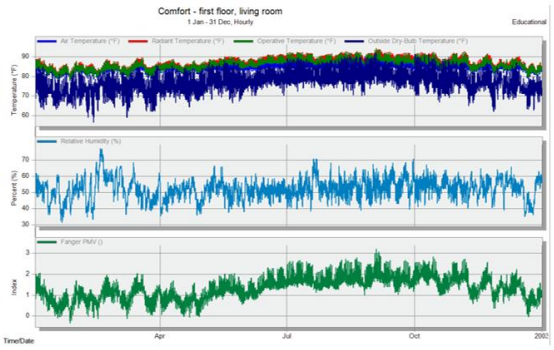


E1



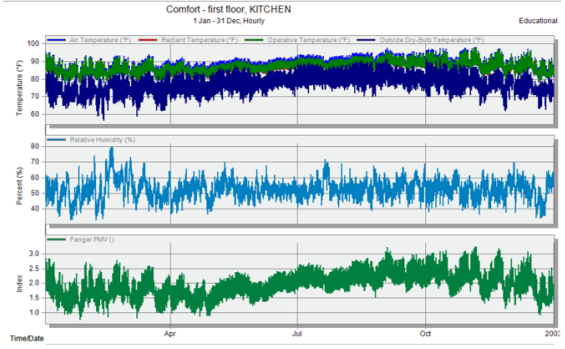
	Apr				Jul			Oct		2002
	83.46	81.18	89.36	90.90	84.91	85.66	90.28	85.41	88.00	86.20
	85.00	83.20	90.52	92.00	91.52	91.01	91.63	91.09	91.49	86.85
	84.23	82.19	89.94	91.45	88.21	88.33	90.95	88.25	89.75	86.53
	68.81	63.46	81.77	81.23	77.58	77.00	77.27	78.80	86.81	81.46
	49.87	41.15	40.67	45.59	52.10	48.41	46.50	63.14	48.35	47.76
	1.04	0.38	2.01	2.52	1.70	1.64	2.41	2.02	2.17	1.53

N2



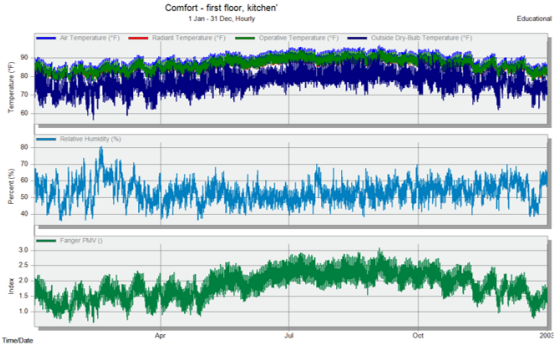
Time/Date	Apr				Jul			Oct		2002
Air Temperature (°F)	82.79	78.48	86.72	88.33	84.40	85.07	88.23	84.85	87.30	85.00
Radiant Temperature (°F)	84.28	80.00	87.74	89.24	89.37	89.27	89.58	88.75	88.91	85.46
Operative Temperature (°F)	83.53	79.24	87.23	88.78	86.88	87.17	88.90	86.80	88.11	85.23
Outside Dry-Bulb Temperature (°F)	68.81	63.46	81.77	81.23	77.58	77.00	77.27	78.80	86.81	81.46
Relative Humidity (%)	51.29	44.73	44.22	49.49	52.98	49.36	49.50	63.86	49.16	49.62
Fanger PMV ()	0.91	-0.12	1.33	1.87	1.35	1.37	1.90	1.60	1.82	1.28

E1



	Apr				Jul			Oct		2002
	84.88	77.64	87.24	88.56	88.41	88.16	88.91	87.85	90.65	88.95
	84.77	78.68	87.06	87.61	88.28	87.89	88.27	87.93	90.27	87.95
	84.83	78.16	87.15	88.09	88.35	88.02	88.59	87.89	90.46	88.45
	68.81	63.46	81.77	81.23	77.58	77.00	77.27	78.80	86.81	81.46
	49.24	48.93	50.87	55.31	52.00	50.05	49.93	59.20	49.26	50.73
	1.68	0.82	1.85	2.15	2.15	1.96	2.11	2.06	2.34	2.24

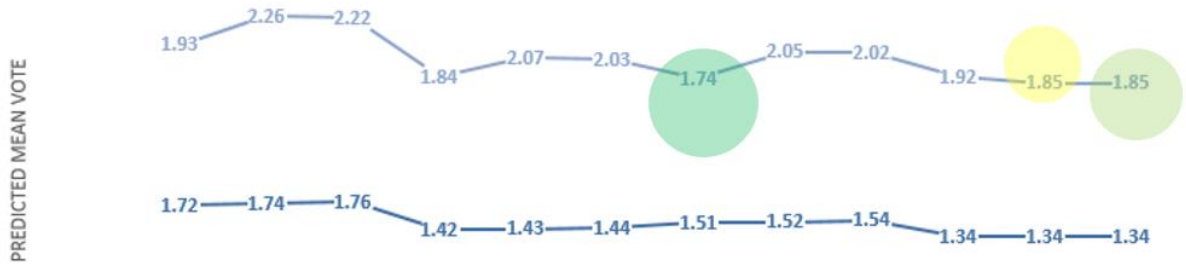
N2



Time/Date	Apr				Jul			Oct		2002
Air Temperature (°F)	81.98	76.99	87.54	90.26	89.08	88.97	88.74	87.23	88.83	85.73
Radiant Temperature (°F)	81.66	78.02	87.49	89.75	89.73	88.82	88.20	87.31	87.58	84.11
Operative Temperature (°F)	81.82	77.50	87.52	90.01	89.41	88.89	88.47	87.27	88.20	84.92
Outside Dry-Bulb Temperature (°F)	68.81	63.46	81.77	81.23	77.58	77.00	77.27	78.80	86.81	81.46
Relative Humidity (%)	53.97	49.81	50.47	52.67	51.26	48.70	50.18	60.33	51.67	55.78
Fanger PMV ()	1.33	0.74	1.91	2.42	2.32	2.07	2.09	1.96	2.10	1.82

5.5 Predesign Studies for Proposed Improvement

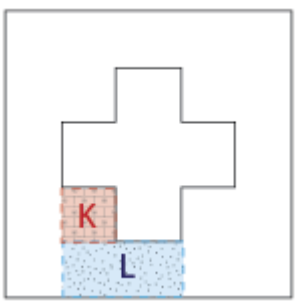
5.5.1 Change the current layout



	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3
AVE(K)	1.93	2.26	2.22	1.84	2.07	2.03	1.74	2.05	2.02	1.92	1.85	1.85
AVE(L)	1.72	1.74	1.76	1.42	1.43	1.44	1.51	1.52	1.54	1.34	1.34	1.34

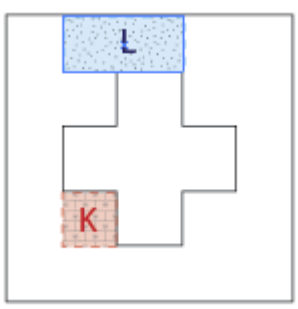
3 Most comfortable kitchen locations.

- **Move the kitchen & living room together**



If kitchen and living room are wanted to be adjacent to each other, then move the kitchen to the south-western corner of the courtyard and facing north while the living room facing south. In this way both view and comfort can be satisfied. If moved as the mode N2 or N3, which is the most comfortable one, the kitchen will loss the good view.

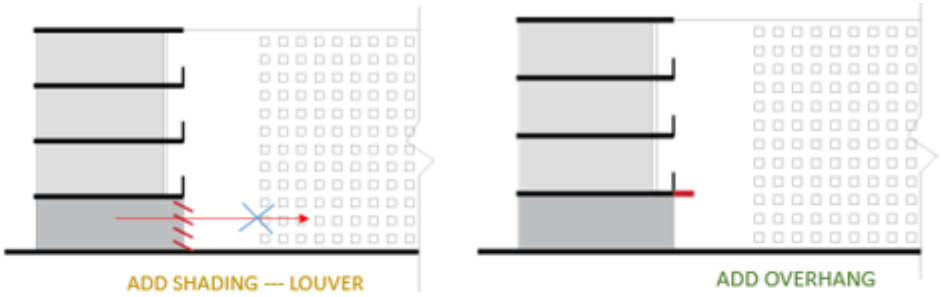
- **Separate kitchen & living room**

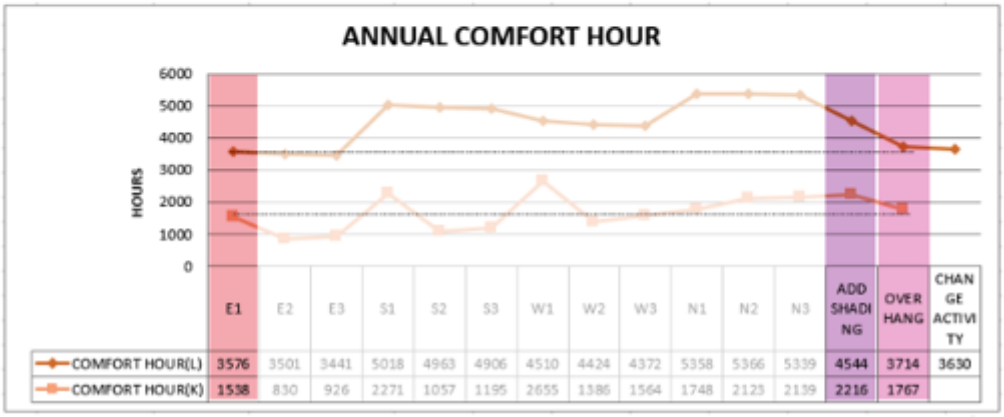


The best choice is to separate the kitchen and the living room, and put them into their most comfortable locations according to the "Energy plus" PMV data. This will reduce the thermal influence of

cooking activity on the living room area, and provide good view for both of them. In this case, the connection path can be a corridor along the west side of courtyard, or just walking through the courtyard.

5.5.2 Sunshade Components





	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3	ADD SHADING	OVER HANG	CHANGE ACTIVITY
COMFORT HOUR(L)	3576	3501	3441	5018	4963	4906	4510	4424	4372	5358	5366	5339	4544	3714	3630
COMFORT HOUR(K)	1538	830	926	2271	1057	1195	2655	1386	1564	1748	2123	2139	2216	1767	

Judging from the data above, if the current location cannot be changed, then adding shading will be a good choice for remedying the over-heating situation. Louvers work much better than overhang, however, louver will block the view from inside to outside when preventing the solar heat.

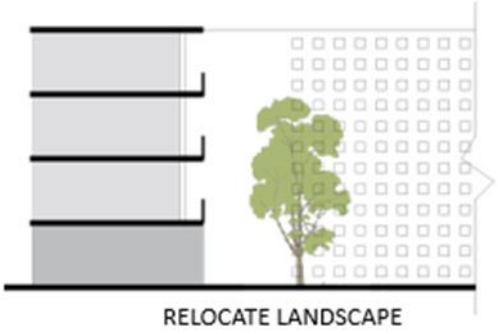
In order to create shadow and infiltrate scenery at the same time, a grid shading will be very helpful.

5.5.3 Wind Pathway: Increasing openings on windward side at the ground level

Change the solid envelope into rotatable partitions, which can be open as a wind entrance when needed and create a cool public space; and also can be closed at night for security or closed in some winter days to prevent adverse strong wind from blowing inside.

Figure 5-13，all made by author

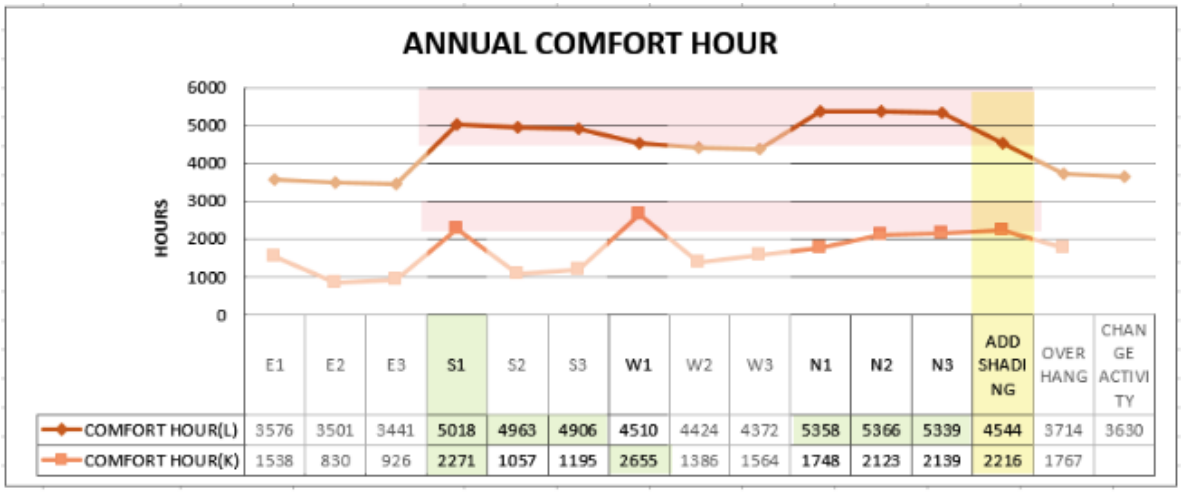
5.5.4 Landscape Assistance



Relocate the landscape (tree) as a natural shading.

5.6 Summary and Extension

The evidence of the computational simulation will become new experience.



	E1	E2	E3	S1	S2	S3	W1	W2	W3	N1	N2	N3	ADD SHADING	OVER HANG	CHANGE ACTIVITY
COMFORT HOUR(L)	3576	3501	3441	5018	4963	4906	4510	4424	4372	5358	5366	5339	4544	3714	3630
COMFORT HOUR(K)	1538	830	926	2271	1057	1195	2655	1386	1564	1748	2123	2139	2216	1767	

From this chart, it can be concluded that finding a proper location can bring more comfort hours than only adding louvers on the current position. That means we should keep the concept of “energy flow” in mind before starting layout design rather than attaching remedy after all the layout having been done. By doing this, it will make the design more reasonable in improving interior thermal condition.

6 RECOMMENDED LAYOUT DESIGN PROCEDURE UNDER ENERGY PERSPECTIVE

6.1 Grouping Zones

Parameter related to energy: equipment schedule; occupancy & activity

Table 6-1, How to group Energy Zones

INTENSITY OF USE	HIGH-FREQUENCY USE								LOW-FREQUENCY USE	
SERVICE TIME	DAYTIME USE				NIGHT USE				DOESN'T MATTER	
OCCUPANT DENSITY	HIGH		LOW		HIGH		LOW		DOESN'T MATTER	
HEAT PRODUCTION	high	low	high	low	high	low	high	low	high	low
ZONE TYPE	A	B	C	D	E	F	G	H	I	J
CRITERIA	STRICT →									FLEXIBLE

Tips for humid tropics

Before organizing building programs from an "energy flow" aspect, we should divide the zones into 10 different types according to "intensity of use", "service time", "occupant density" and "heat production" which are all related to thermal comfort. List them from A to J showing their design criteria from the strictest (with a lot of restricts and demands on neighbouring zones) to the most flexible (can be put anywhere). Not all the buildings will

have the whole 10 zone types, so just match what you have with the corresponding type numbers and design it obeying the guides below.

6.2 Locating Zones

Table 6-2, Tips for locating energy zones

ZONE TYPE	LAYOUT GUIDE
A	Set away from sunward facades, well ventilated, buffer zones around, cooling (fan, AC)
B	Well ventilated, add sun shade/buffer on the sunward side, cooling (fan, AC)
C	Set away from sunward facades, well ventilated, heat-insulating partition, cooling if needed
D	Well ventilated, add sun shade/buffer on the sunward side, cooling (fan) if needed
E	Sunward façade is OK (east better than west), well ventilated, buffer around, cooling (fan, AC)
F	Sunward façade is OK (east better than west), well ventilated, cooling (fan) if needed
G	Sunward façade is OK, well ventilated, buffer around, cooling if needed
H	Sunward façade is OK, well ventilated
I	Location can be flexible (better close to west façade as a heat barrier), heat-insulating partition
J	Flexible (set in the most unfavourable position), leave better microclimate to other zones

In view of the high ambient temperature in hot-humid areas, the principle of locating those exothermic groups in a building layout is minimizing extra heat gain from outside solar. If it also happens to be a main living area, one should not forget to add some buffer zones within the close connection to the adjacent activity spaces.

Layout guide for each zone should not only consider the comfort within the zone, but also pay attention to the thermal influence of this zone on the surrounding area.

Type A: if the zone is frequently used during the daytime, usually gathering a lot of people and generating heat by facilities or machines at the same time, that means this zone is not only a heat source but also a common destination for daily activity (such as workshop in a

factory, a lecture hall, or a communal kitchen & dining centre). For this kind of zone, the layout guide should be setting away from the sunshine, better to have virtual buffer in front of the sunward & windward direction in order to invite the wind flow and make the space well ventilated but prevent the sunlight from penetrating too much. Moreover, the zone should have a good heat-insulating partition and some enclosed buffer zones (like tool storage, restroom) around it to block the heat from conducting and radiating to other frequent-used zones. When sometimes the comfort level is hard to reach, then fans and air-conditioning can be turned on.

Type B: this type is quite similar to type A but does not have that much internal heat gain from equipment (such as classroom, office, reading room, or living room). In these cases, the boundaries of the zone do not need to be heat-insulated, because it won't have too much thermal influence on the surrounding. But as a place where usually crowded of people, it should attached with shading buffers and cross ventilation. Sometimes if the wind speed is low or outdoor air temperature is higher than indoor, then turn to fan and AC for cooling help.

Type C & D: these two type is quite similar to type A & B in most aspects, but the only difference is that the occupant density is low, which means the room is capacious and will reduce the feeling of thermal discomfort caused by the crowd. Thus, these two types of zones would not need cooling equipment so frequently, and their locations are not that much restricted to be included in energy supply areas like type A & B.

Type E, F, G, H are mostly used at night and that is why they can be set near the sunward façade. They can act as buffer zones for other important zones used during the daytime. If

the zone is a heat source, then heat-insulating partition should be added. Also, for the zones that has strict comfort demands like study room or dormitory, then eastern side is better than western side because the former will cool down during the afternoon and provide a better micro-climate for night use. Well-organised natural ventilation can fulfil the cooling needs in these zones during the night and spare extra energy consumption.

Type I & J are the zones used less by people, usually occupied by machine or sanitary ware. So we do not have to consider more about the comfort situation in these zones, and just use them as auxiliary media to help improve the whole building's thermal condition. For example, put them on the west side to block the afternoon solar heat, or scatter around the heat source to cut off indoor heat transferring.

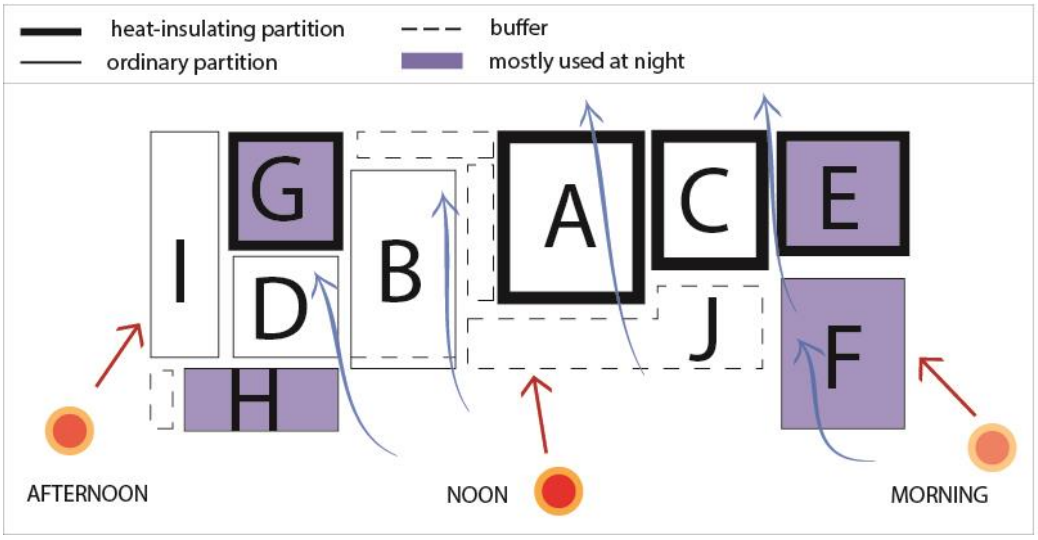


Figure 6-1, Conceptual graph of energy zone layout (drawn by author)

In some cases when the highly-used zones are set into adverse positions because of some unavoidable limitations, then buffer zones/components must be added on the edge where facing the undesired microclimate.

After grouping the different zone types, there are other principles of layout organization in humid-tropic also have to be emphasized, such as creating porosity for wind flow, taking use of temperature variation to stimulate air movement and so on.

6.3 Organizing Principles

Set against the trend of increasing emphasis on autonomy, building itself should be designed more and more like an efficient machine, taking advantage of its own structure and linkage mechanism to shape into the best form for "energy sailing". As shown below, seven programming principles are summed up from the remarkable precedents and scientific laws, and ought to be integrated as early in the design process as possible. All the guidelines stated here are generally independent from one another, but each has a particularly close connection and succession to the prior one at the same time. Following these approaches step by step, the whole building system will be well-tempered. Besides, it needs to be pointed out that unlike the rigid and homogeneous spaces inside those "box-like" constructions with supremeness of industrialization and convenience, the interior feelings produced by energy programming can be diverse and lively, especially under the aid of some emerging parametric shaping methods. Both the circulation patterns and the spatial forms will be marked with energy conserving features more or less, and lead towards a new innovative social-technical paradigm for contemporary architecture.

6.3.1 Grouping Zones by similar energy requirements

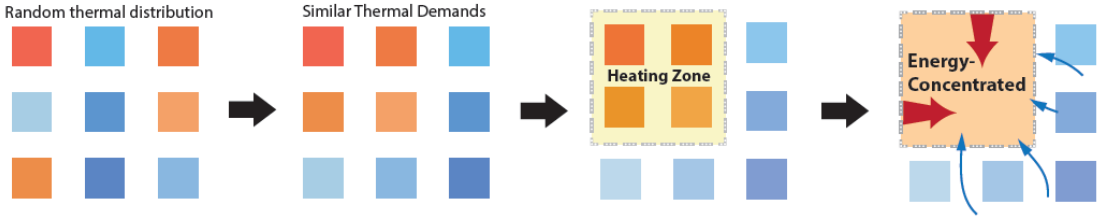


Figure 6-2, by author

A building system can be seen as a combination of a responsive envelope and an inner thermal storage which is a hybrid of small thermal units. Once, these units with individual demands of heating, cooling, lighting and ventilation, are presenting a random trend in organization. But now, the strategy stressed in this paragraph intends to moderately constrain the design freedom by some energy links. The basic procedure is to identify the degree to which different types of spaces require different comfort levels. In the light of different spatial functions, the criteria for temperature and humidity can be divided into four grades (outlined in the table). The stricter the criteria is, the harder it will be for passive strategies to always meet the comfort standard and some automated techniques will take part in the active adjusting. And for those uses less strict to thermal condition, they often allow the occupants to adjust their clothing and activity rates, to co-work with the only passive energy-saving system. Thus, spaces that have similar thermal needs can be zoned together to

share the same energy supply and zoning strategies in locating, orienting and arranging. Deliberate thought should be taken when determining the patterns (material, thickness, etc.) and positions of subdivision between different zones because energy flow is sensitive to the internal partitioning. Heat move from one room to another has direct influence on the control of the temperature swings, which, must be considered parallel to the interactions among exterior climate and cooling zones as the spatial prerequisite when projecting most mixed mode buildings in hot-humid areas. In this case, a shocking reduce may happen in total and peak energy use, first cost and operating costs and make it easier to achieve the so-called net-zero criteria.

6.3.2 Coordination: Thermal Zone—Schedule

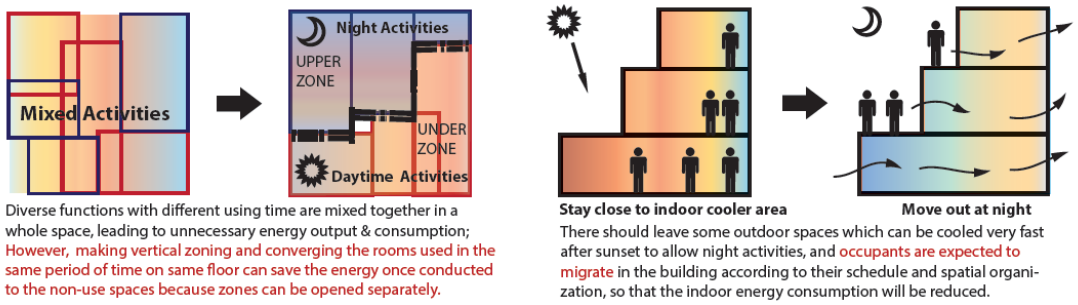


Figure 6-3, by author

The first chapter has mentioned that animals have an instinct of migration -----moving a long distance to find the best location to start a comfortable seasonal life. People in certain parts of the world keep some common traditions parallel to long animal migrations in coping with the surrounding thermal changes, exemplified by the British in India who packed up their utilities and public services and moved to cooler Himalayan areas during the hottest months. Likewise, many ancient emperors used to ask their ministers to seek out a place away from

sweltering hot weather where can be built a summer palace to deal with political affairs, some of which are still famous today as a summer tourist resort, such as “Montaza Garden” in Egypt, “Summer Palace of Peter the Great” in Russia, and “Garden of Clear Ripples” in China. This habit continues in rich families. A number of cottages along the seacoast or somewhere in the country are waiting for their owners’ coming when the nearby cities are suffering adverse climates. However, multiple trips are obviously too expensive causing wasted time, energy, and money, and may not be applicable for the ordinary households. Being neither nomad nor wealthy, most of us settle down in one position without relocation for years. As construction activities are carried out all around the world covering diverse climate zones, a permanent structure must be designed to tolerate climatic variation, which is, to some extent, analogous to the situation that plants are facing. It is well known that plants cannot shift their locations arbitrarily, but they are capable of mobilizing internal mechanism with micro cell deformations to catch more opportunities of basking in the temperate sunlight and to hold sufficient moisture and organics for growth. Similarly, in terms of architecture, builders should also turn to the inner space for solutions. That means, if long-distance travelling is unfeasible for the majority of dwellers, then one can consider another way of “indoor migration”, which can efficiently acquire comfortable feelings with less resource consumption.

Migration within a building has a close connection with the daily schedule of occupants, which, can be regarded as a bidirectional coordination between architectural programming and lifestyle inside. In other words, spaces are static while users are movable, thus, architects should combine users’ behavior patterns to their designs and make buildings serve better to

induce positive movements. Below are two methods to realize this goal ----- one is about time-related function regrouping and the other is going to raise the spatial richness from a thermal view.

Shown in the left two diagrams beneath the subheading, the first approach is to group the required programs in a schedule-oriented design logic and install a clear partition (a floor or a thick wall) between the new zones that are used in the different times of a day. This approach is especially useful for the buildings with living functions (e.g. house, dormitory), because people engage in these spaces with various activities throughout the course of a day, unlike the office towers or hospitals which only have a single mode of occupancy. Before starting a project, designers are demanded to get familiar with the living habits of the target users. If there would have diverse users with their own time preference, one should select a time table which is proper for the majority, judging by a survey or past experience. The next step is to divide the multifarious functions into several groups according to different spatial service time, for instance, they can be simply put into two parts ----- “daytime part” from breakfast to dinner & “night part” after dinner till early morning. Imagine if all the programs are mingled together, the air-conditioning coverage will contain too many unnecessary places at one time. Shared energy by the vacant bedrooms during the daytime, the living room where people frequently use in that period will not get cool that much easily, resulting in a slow process to reach the comfort level and extra energy loss. Whereas, if setting the living room and the bedroom in two separated energy-use units enclosed by thermal insulating partitions will lead to better energy use. Occupants are able to close one unit when using another one, which will reduce the area of energy provision and make it much faster to achieve the desired

temperature. Employed in alternation, the two thermal zones meet different needs in different times effectively and economically. Moreover, several attentions should also be noted: on one hand, it would be better if small elastic spaces are added into each unit, to increase the possibilities of accommodating more activities. For example, suppose there is a multi-functional room near the kitchen, or even just a settee standing somewhere, then a housewife can nap or read in the place without going to the bedroom or study in the next thermal zone when finishing housework, the longer she stays in the same area, the more energy waste can be avoided. This idea also applies to campus dormitories with the same purpose of minimizing students' frequency to shuttle among different thermal units within a short period of time. On the other hand, it must be admitted that the daily habits of human beings are changing over time, and vary among ages and races. So designers have to update their knowledge base regularly and reserve adjustability for future transformation in building functions.

The second way outlined on the right two images is inherited from some conventional instruments in North African dwellings where people migrate within their buildings both daily and seasonally. The core of this means is to create spaces with different thermal properties via architectural techniques. Building is a

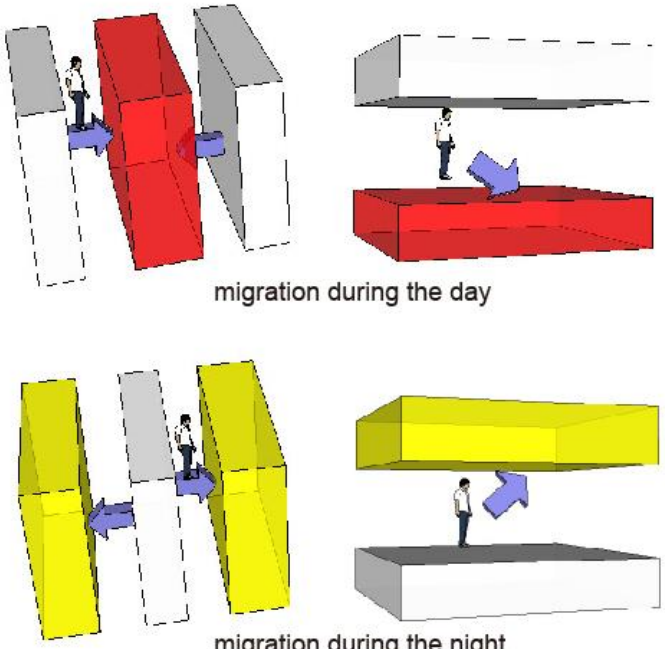


Figure 6-4, by author

complex system integrated by multiple microclimates, which are generated because of different locations and surrounds. Even a single "box" will create at least six new microclimates as soon as built on site: the south wall is warmed by the sun and the north wall keeps a relatively low temperature in shade; the east side bathes in the morning sun while the west side gets broiling in the afternoon; the roof is exposed to inclement weather but the indoor ground is sheltered. All these thermal patterns can be taken advantage of when people are selecting the comfort zones most suited to their needs at specific times. So as to offer more comfortable choices for the users, buildings are required to have diversified spatial organizations rather than a simple stacking of similar volumes. Colonnades and terraces, for instance, are no longer only the architectural lines that strengthen alternating rhythm on the façade, but should also be treated as "microclimate generators" ----- the former can create a shadow to protect the sidings from the sun's heat; the latter which is fully exposed to wind and sun with a dramatic fluctuation in temperature from day to night, can provide a cooler space after sunset in summer. Therefore, a tropical house armed with the above elements, will inspire the family residing therein to have a short migration from deep inside to the open roof or the upper loggia when the sky turning dark and outdoor air cooling down. Although it is only a small action, that will help decrease the need of air-conditioning during the whole night.

In a word, the wisest way to unify building programs and user's behavior is molding diverse spatial shapes to encourage thermal discrepancy and organizing these zones in a certain order which obeys the rules of thermodynamics. People then will have more options to work out

their own reasonable life patterns with an effective utilization of thermal energy, and lead a healthy longevity.

6.3.3 Heat source as a Dynamic Factor

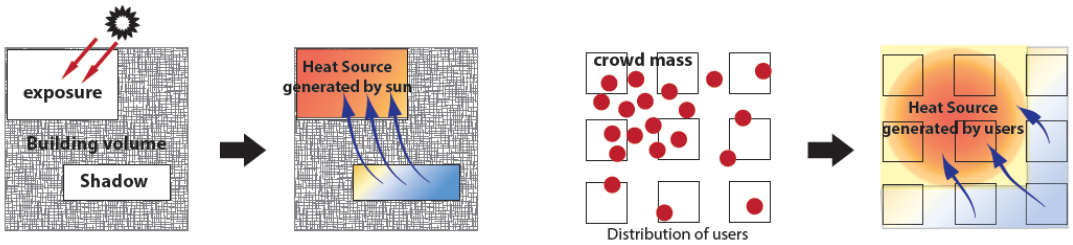


Figure 6-5, by author

Natural ventilation is always desirable in hot-humid regions but, special climate phenomena and chaotic urban layout sometimes cause a windless situation. Facing this unstable factor, a building can induce its own ventilation by proper design strategies like duplicating the forming conditions of wind itself. It is common that warm air rises while cool air sinks, and the rising air automatically seeks its way upward out of an enclosed space and draws cooler replacement from below[7] in the meantime. One of architectural applications of this natural law is "thermal chimney", known as using a solar-exposed structure taller than the roofs around with a higher thermal mass to capture and retain heat as a power for exhausting useless air and maximizing the indoor cooling speed. This method produces a typical section of passive cooling, however, in fact, the principle of creating a continuous heat source in a building as a driving force for maintaining air movement, can be harnessed not only in vertical dimension but also on the floor plans. In order to heat an isolated pocket of air to greater than ambient temperatures and to accelerate the influx of cooler wind, both natural

[7] Passive Cooling---Designing natural solutions to summer cooling loads, RESEARCH & DESIGN, The Quarterly of the AIA Research Corporation, Volume II, Number 3, Fall 1979, P8

and artificial factors can help, including direct solar radiation, heat release by mechanical equipment, and thermal energy production of human activities, etc. Yet, only these elements are not enough, it takes more architectural programming approaches to optimize the "passive heating—thermosiphon systems". An ingenious way to implement this system is taking use of courtyards, which would better appear in pairs but have different features. One can be largely opened without any cover to gather heat from the sun as much as possible while the other should be a planted, shaded area to act as a storage of cooler air. The greater the temperature difference exists, the faster the heat convection will be, thus leading to a strong breeze through the interjacent rooms. Another example is associated with physical movements of people. Some spaces in a building where containing a dense crowd like auditorium, or where those activities of high metabolic rate are taking place such as gymnasium, will become a center of heat generation, and can be designed with a taller story height than the near parts, and upper openings directly towards the outside should be attached to the enclosure together with lower air entrances facing other interior areas, which may be the coolest location in that building ----- a semi-opened pilotis space away from sunlight or an air pipe or storage chamber underground. In this way, the wind can be pulled from the bottom up under the effect of certain indoor public events and the thermal condition will also be adjusted to the best at the same time.

Although the idea introduced here by inserting a heat-collecting space may seem to go somewhat against the ultimate aim of architecture in humid tropics at keeping unwanted heat out in summer, the aforementioned instances have proved the validity of this thermodynamic

system, and that buildings are able to hold the initiative to control energy flow within it even lacking of exterior environmental assistance.

6.3.4 Buffer & Filter

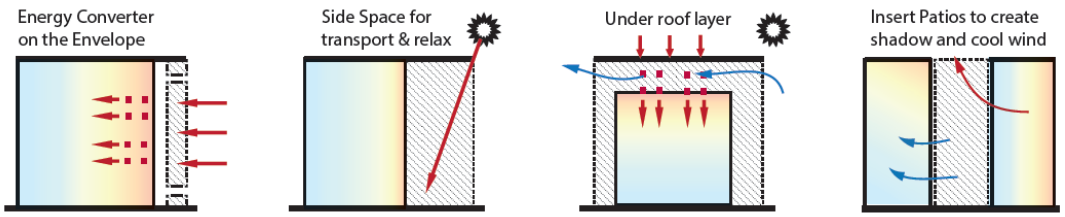


Figure 6-6, by author

Buffer is not a strange word to architects who are interested in sustainable design, which is explained in Wikipedia as a medium for "separating" or a "cushioning"[8] against external force. In architecture, we use "buffer zones" to underline the significance of those rooms located between undesired climate and spaces with rigid temperature requirements. Buildings with buffer zones will have better tolerance of temperature swings.

The forms of architectural buffers are very flexible.

First, they can be designed as a layer coupled to the envelope to compose a "thick wall" like the Trombe system or a membrane filled with water by making use of the thermal absorption, reduction, and lag characteristics of the material. The delay and attenuation of the heat transmission caused by the layer do benefit the whole building system very much when bearing hot weather. At this point, it will be of great help for strengthening the time lag effect of the wall if manually installing a curtain or other obstructions on the outdoor side. For

[8] https://en.wikipedia.org/wiki/Buffer, 18/11/2015

example, in hot-humid areas, some desiccant devices can be added into the buffer layer to deal with the moist problem along with the hot one. A rotatable plate having desiccant salt (or activated charcoal) on two sides may be a proper choice: one side faces the living space absorbing interior moisture, and will be turned out after saturated, evaporating in the sunlight for reuse. Two sides take turns to work, keeping the continuous of the desiccant process.

The second form is a boundary space, commonly including but not limited to a porch or a balcony. Those spaces with intermittent occupancy period are considered suitable to be arranged in buffer area because of their wider range of acceptable temperature determined by the nature of use. But there are still some subtle differences in fitting these functions to specific locations, say, auxiliary rooms like storage, bathroom, or circulation are going to play the biggest role when siting in the west end of a building to filter out large amounts of western heat gain; while spaces like bedrooms with stringent comfortable standard only at certain times of a day can be set along the east side where embraces sunshine in the morning and turns to sun shading after noon, proving a cooler indoor condition for the night sleep accompanied by prevailing wind sometimes. Compared to the above two directions, the buffer zones on the south (sunward) side should be more permeable in case of blocking natural air flow. A latticework envelope may be a wisdom solution, creating a semi-enclosed cool air space around the inner house to welcome leisure activities like a coffee-break or a private conversation along the building edge. The façade of the southern buffer also can be shaped irregularly and cast flexible shadows by itself to produce multiple thermal modes for diverse use in transition space: the warmest corners that are uncomfortable for staying might

be chosen as greenery planters and the relatively cooler ones just serve people. Such an uncommon interface must be more attractive than a totally flat buffer.

The third type is to connect the buffer zones between double roofs and around exterior walls together to form a kind of building hood. Under the protection of this coverage, there will arise multilevel decks on the top of the inside building boxes to provide better microclimate for outdoor programs when filtering needless thermal radiation.

Inbuilt buffer zone is the fourth design pattern by inserting airbags within thicker architectural plans to stimulate air circulation. Usually set in the surrounding shade, the bottom of that buffer is much cooler than nearby areas, so the hypothermal air there can pour into the building if with effective guidance. To give consideration to both light demands and great air convection, the depth-height ratio of these buffers are worth calculating.

6.3.5 Interstitial space as wind pathway

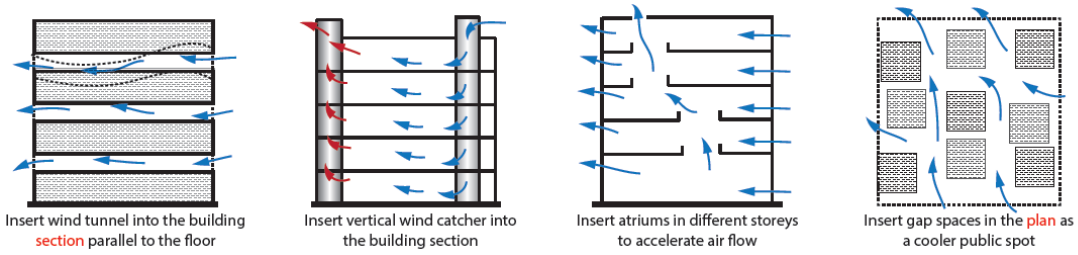


Figure 6-7, by author

This rule of design is dedicated to enhance the air convection within the muggy room, whose core concept is to spatialize the conventional ventilating device. When air flows around a building, it causes higher pressure on the windward side and lower pressure on the lee side.

A common but effective manner is to place the inlets in the higher pressure zones and the outlets in the lower pressure area ----- usually seen as windows on the opposite walls. However, this simple icon on the façade is so familiar to everybody that make it harder to

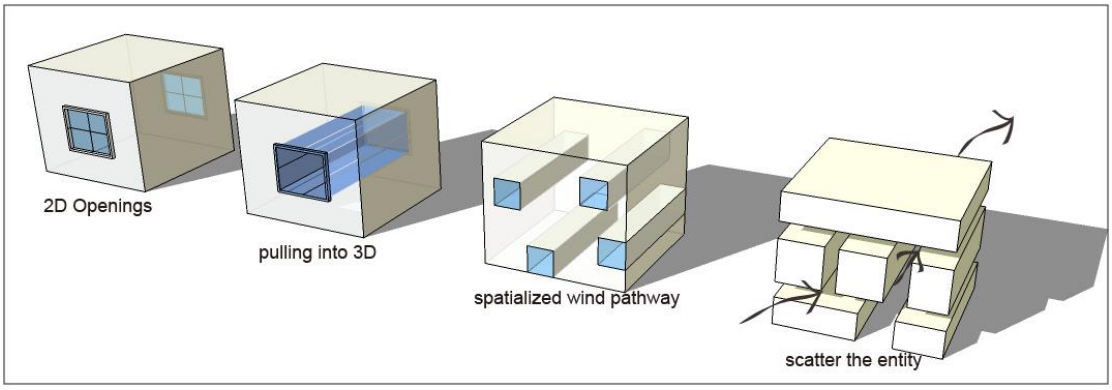


Figure 6-8, by author

draw public's attention to the climate-oriented design. A marvelous way, which may give people a strong feeling of the positive meaning that unobstructed energy pass brings to the interior comfort, is to amplify or intensify those "energy directors". In other words, one can extend the two-dimensioned openings into three-dimensioned voids, and use them to scatter the originally dense entity. Both in the building plan and section, the space in-between can be programmed flexibly as a 'play zone' with various activities and main circulation. This scene is much like the cool lanes in some old rural town in southern China, where villagers gathered for leisure conversations and watching pedestrians passing by. So the interstice in the site plan successfully became a medium of general communication. The uninterrupted

cross-ventilation in this area removes the heat and reminds people of the explicit design intention in response to natural energy. Other applications, for instance, a cross-layer atrium, a gap between the roof and wall, or a wind catcher projecting from the housetop, are all striking symbolic vocabularies of energy structuring, and well suited to most public recreational spaces. But in case that the outside temperature is higher than the inside, or other harsh conditions like air pollution take place, the situation would maintain good if employing the wind corridors and the aforesaid buffer zones in combination, no matter be split into two pieces or integrated in one component. Sometimes when designers add an active "power station" on the edge of those architectural cavity, air can not only be filtered clean but adjusted to a pleasant temperature before accelerating in the building. Surrounded by buffer zone as a switch of energy flux regulation, the penetrable spaces expected in this principle will prepare a better environmental quality with high speed & low temperature natural wind for their users' social life in hot summer.

6.3.6 Auxiliary Landscape

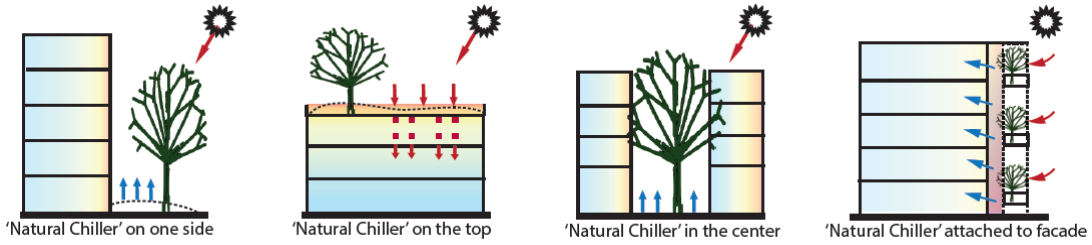


Figure 6-9, by author

Landscape, here referring to some natural items (earth, vegetation, water, etc.) should be exploited more than an urban ornamental in the current built context, but be part of the

architectural grammar considered in the physical design of a site. Warm in winter and cool in summer, massed earth is what mankind first sought for shelter, and has enormous capability to attenuate extreme air temperatures. And vegetation is an asset of greater value. Tree leaves reflect infrared, heat-bearing energy and filter cool, green light to the ground. When the passing through wind accelerates the plant transpiration, the ambient heat can be absorbed by the free moisture in the leaf cell to evaporate into the air. Waterscape, in the same way, has a cooling influence because of its high specific heat capacity.

In order to take use of their tremendous impacts on reducing energy loads and improving natural comfort inside a building, architects have to treat these natural objects as a necessary component to be assembled onto a building like a window or door, or as an indispensable "green zone" added to the existing programs. The illustrations present that flexible positions can be elected to fit the "green components" in different forms: to channel the wind flow when being set windward; to insulate the solar radiation when covering the building top; to stimulate air circulation when growing in a yard; and to shade an external wall when attached to a façade.

Not only can these landscaping be harnessed directly as a passive energy controlling means, but they also provide opportunities for running some active techniques such as embedding subterranean cool pipes in the body of earth or water to pre-condition air before sent into the building.

6.3.7 Thermal Delight as a Spatial Identification

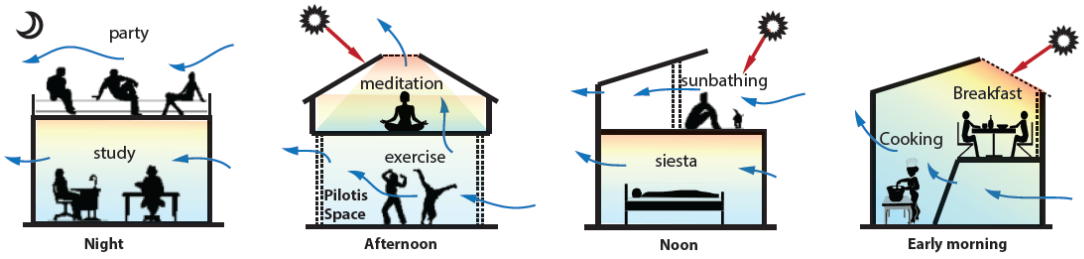


Figure 6-10， by author

To begin with the seventh methodology, an interesting architectural work deserves to be mentioned as an annotation for better understanding this instrument. It is a private house

named “Light Valley” done by Future Studio in Japan is a perfect, which defines the current active space by time: the period people occupying a zone is precisely when the sunlight from the slits in the ceiling casts into that area. The gently curved linear volume acts somewhat like a sundial while the light line is the pointer that indicates something is happening at a certain moment. Created based on the purpose of governing daily routine to follow the light movement, the floor plan was parted into three zones: the morning zone that allows for plenty of morning sun placed a main bedroom and a dining room, the afternoon zone was set for living room, and the evening zone for children’s room used after school. Programming in this way, the harmony between the life pace and pleasant luminous environment would be fulfilled continuously while playing with the natural elements.

In this case, light seems to be a switch of the space availability, and also a signal and guarantee of entering into particular activities with satisfaction. Nonetheless, this indicative function is not the patent of light, thermal sensation has the similar potential, which proved

by a novel architectural experiment ----- 'Digestible Gulf Stream' -----conducted by Philippe Rahm Architects on Venice Biennale 2008. Two horizontal metal planes at different heights formed the prototype for architecture. Operating on both the neurologic and atmospheric scales, this structure generates a landscape of heat dynamic rather than a homogeneous feeling, by heating the lower plane to 28 ℃ while cooling the upper one to 12 ℃. So there was a continual air convection born between the two sheets: rising hot air cools on contact with the upper cool panel then, falling, and is reheated when touching the hot one below. The participants were invited to move around in the construction of meteorology to experience this invisible landscape, and to freely choose a comfortable microclimate according to his or her activity, clothing, dietary, or even social wishes. Judging from the gestures and expressions of the users, people are so pleased to find a position with suitable temperature and air velocity to do what they want. Thus, thermal conditions will bring different degrees of joviality, videlicet, this kind of thermal delight can be utilized as a behavioral prompt or a spatial identity in the design of specific programs. When making decisions on locating functional zones, thermal-associated psychological satisfaction should be given the same consideration as physiological standards. For instance, a breakfast room is not usually strict with the position, but inhabitants would be happy if the place has mild sun stream in each morning. These wills include not only the everyday sorts, but also somewhere we go only for special occasions, like a shady pavilion for summer picnics or a sunny beach for body stretching. On the premise of meeting the six above-mentioned principles, the design will be guided to an even better place if not only catering to the existing needs, but creating demands for human beings. Just looking at how smart phones change our lifestyles, buildings also

have this capability to start new living patterns within limited space and to bring different excitements to the cerebral cortex by the corresponding well-handled “thermal signals”.

6.4 Simulation & Adjustment

In a real project, the environment must be more complicated than the ideal model, that’s why simulation technology is an important tool for designers to adjust their layout based on the ideal guidelines, and also help to integrate the building circulation system and other non-energy factors together in the energy programming prototype.

6.5 Supplement Strategy

Layout guided by Energy flow sometimes has to compromise on some practical reasons, at this time, supplement strategies are needed, so the next step of energy layout should be design of shading types, material forms and landscapes.

7 EPILOGUE

- **Potential Impact of research**

The first three chapters mainly studied the energy issue and influence from an extensive cognition of natural life to an intensive exploration in architecture cases, especially in hot-humid areas. With efforts in diagram analyses and specific data calculation, the paper has concluded seven strategies on energy programming, which take not only the building forms but also the occupants' activities into consideration. The core concept is not to differentiate between the passive design and the active one, but to re-establish a set of design procedure. Instead of obeying the primal faith "form follows function" in Modern Architecture, the energy-oriented design is first going to set up a thermodynamic structure by regarding the whole building as a system, and then insert programs which are grouped as modules according to different comfort requirements into the interior. Thus, it can be stated in a principle as "Form follows Energy, and evokes Function", which is also a continuation of the construction methods used in the remote history which may be forgotten by the high-consumption age.

- **Limitation & Weakness**

Implemented in humid tropic, the fundamental aim of architectural design is to keep the heat out, i.e., to minimize the indoor heat gain. However, some of the approaches summarized before which rely on some natural assistances are still uncontrollable and need to be tested on their economic efficiency. So that in the further experiments and designs of the EWC dormitories, a measuring metric (e.g. PPD, PMV) should be selected and a thorough experimental plan should be created, to ensure the project goes on wheels with scientific and academic rigor.

- **Second Phase Conclusion (Comparison with Research results)**

•To find out layout strategies that can satisfy the thermal comfort demands in hot humid areas by considering the above energy flow issue.

•To give HALE KUAHINE dorm some improvement measures based on comfort simulation related to layout changes.

8 GRAPH INDEX

8.1 Source of Images

1) Figure 0-1， http://www.philipperahm.com/, Dec 16, 2015.
2) Figure 2-1,Figure 2-2,Figure 2-3,Figure 2-4,Figure 2-5,Figure 2-6, collected from google image
3) Figure 2-7, http://www.pbs.org/wnet/nature/the-animal-house-the-incredible-termite-mound/7222/, latest edit October 28, 2011.
4) Figure 2-8, Figure 2-9, Ashrae, A. N. S. I. "Standard 55-2004, Thermal environmental conditions for human occupancy." American Society of Heating, Refrigerating and Air-Conditioning Engineering, Atlanta, GA. 2004.
5) Figure 2-10, originally from ASHRAE, re-drawn by author, Jan 10, 2016.
6) Figure 3-2， https://mandyhyj.wordpress.com/2011/12/07/moe-interactive-surfaces/, latest edit December 7, 2011.
7) Figure 3-8, Figure 3-11, Hassan Fathy, “Natural Energy and Vernacular Architecture”, 63. Edit by Walter Shearer and Abe-el-rahman Ahmed Sultan. The University of Chicago Press, 1986.
8) Figure 3-9, http://pon99.net/viewtopic.php?f=44&t=57476, Apr 4, 2011.
9) Figure 4-3, “The Thai House, History and Evolution.”
10) Figure 4-4, from Professor Willian Chapman’s lecture
11) Figure 4-5, https://www.pinterest.com/pin/47147127320086673/, Mar 1, 2016.
12) Figure 4-9, Figure 4-10, http://votrongnghia.com/projects/, Sep 10, 2015.

8.2 Tables

1) Table 6-1: How to group Energy Zones, Drawn by RUYUN XU, 2016/01/27
2) Table 6-2: Tips for locating energy zones, Drawn by RUYUN XU, 2016/01/27

9 BIBLIOGRAPHY

Joo-Hwa Bay and Boon Lay Ong. “Tropical sustainable architecture: social and environmental dimensions.” Routledge. September 26, 2006.

Paul Oliver. “Shelter in Africa.” Barrie & Jenkins. October 28, 1971

Nithi Sthapitanonda. “Houses by Thai architects: Eastern reflection.” LI-ZENN PUBLISHING LIMITED.2011.

Ong-Ard Satrabhandhu. “Tradition of serenity: the tropical houses of Ong-Ard Satrabhandhu.” RIZZOLI. April 2015.

James Steele. “Hassan Fathy.” Academy Ed. 1988.

Paul Oliver. “Dwellings: the vernacular house worldwide.” Phaidon Press. May 1, 2007.

Paul Oliver. “Built to meet needs: cultural issues in vernacular architecture.” Routledge. October 17, 2006.

Paul Oliver. “Dwellings: The House Across the World.” Univ of Texas Pr. August 1987.

Mats Egelius. “Ralph Erskine, Architect.” Coronet Books. June 10, 1990.

Jean-Louis Bourgeois. “Spectacular Vernacular: The Adobe Tradition.” Aperture Foundation Inc. June 1996.

Richard Hyde. “Climate Responsive Design: A Study of Buildings in Moderate and Hot Humid Climates.” Taylor & Francis. September 10, 2000.

Robin Guenther and Gail Vittori. “Sustainable Healthcare Architecture.” John Wiley & Sons Inc. July 22, 2013.

Ali Sayigh. “Sustainability, Energy and Architecture: Case Studies in Realizing Green Buildings.” Academic Press Inc. October 10, 2013.

Nyuk Hien Wong and Yu Chen. “Tropical Urban Heat Islands: Climate, Buildings and Greenery.” Routledge. October 13, 2008.

Edward J. Kormondy. “Concepts of Ecology.” Prentice-Hall International, Inc. (London).1969.

Ken Yeang. “Designing With Nature: The Ecological Basis for Architectural Design.” McGraw-Hill, Inc. (New York). April 5, 1995.

Philip Jodidio. “Architecture: Nature.” Prestel Publishing. October 1, 2006.

Hagan Susannah. “Taking Shape：A new contract between architecture and nature.” Architectural Press. April 17, 2001.

lnaki ABALOS. “Interior ---- Sources and Sinks.” Time + Architecture, 17-21. Tongji University. Vol.2. 2015.

Salmaan CRAIG. “Fit Form to Flow.” Time + Architecture, 38-41. Tongji University. Vol.2. 2015.

G.Z.Brown and Mark DeKay. “Sun, Wind & Light: architectural design strategies.” (3rd edition), WILEY. 2014.

Christian Honger, Roman Brunner, Urs-Peter Menti and Christoph Wieser. “Climate as a Design Factor.” Quart Publishers. 2014.

Kiel Moe. “Insulating Modernism.” Birkhäuser. August 22, 2014.

Kiel Moe. “Thermally Active Surfaces in Architecture.” Princeton Architectural Press. 2010.

Lisa Heschong. “Thermal Delight in Architecture.” The MIT Press. 1979.

Reyner Banham. “Architecture of the Well-Tempered Environment.” University Of Chicago Press. 1984.

Michael Hensel. “Performance-Oriented Architecture: Rethinking Architectural Design and the Built Environment.” WILEY. 2013.

SEA.http://www.sustainableenvironmentassociation.net/index.php?option=com_content&view=article&id=52&Itemid=59

OCEAN Design Research Association. http://www.ocean-designresearch.net/

EBD blog. http://ebdjournal.com/about#sthash.y6YchsyM.dpuf

E. Prianto, F. Bonneaud, P. Depecker and J-P. Peneau. "TROPICAL-HUMID ARCHITECTURE IN NATURAL VENTILATION EFFICIENT POINT OF VIEW----A Reference of Traditional Architecture in Indonesia." International Journal on Architectural Science, 80-95. Vol.1. 2000.

William W. Braham. "Architecture and Systems Ecology: Thermodynamic Principles of Environmental Building Design." Routledge. September 9, 2015.

M. Sala, C. Gallo and A. A. M. Sayigh. "Architecture - Comfort and Energy." Pergamon. 1999.

José A. RabiI, Robson L. SilvaII and Celso E. L. OliveiraIII. "Human thermal comfort: an irreversibility-based approach emulating empirical clothed-body correlations and the conceptual energy balance equation." 2012. http://www.scielo.br/scielo.php?pid=S1678-58782012000400005&script=sci_arttext.

Kiel Moe. "Convergence: An Architectural Agenda for Energy-----Energy Hierarchy and Architecture." Routledge. August 31, 2013.

Nikos A. Salingaros. "Life and Complexity in Architecture from a Thermodynamic Analogy------ Detail and Temperature in Architectural Design." 2013. http://archive.is/qwJdi.

Masanori Shukuya. "Exergy: Theory and Applications in the Built Environment." Springer. 2012.

Architectural Thermodynamics and Human Comfort in Hot Climates.

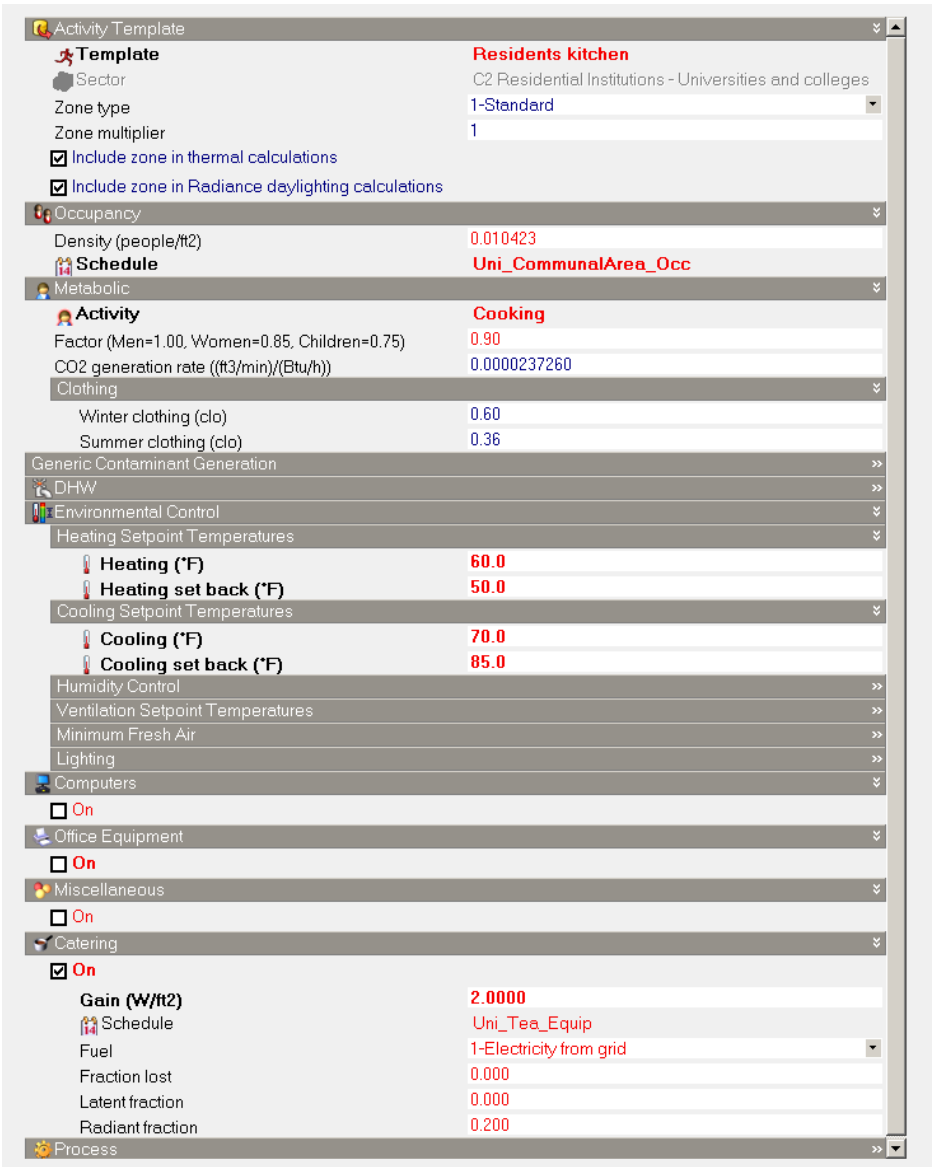
http://archive.unu.edu/unupress/unupbooks/80a01e/80A01E04.htm.

ASHRAE Standard 55. "Thermal Environmental Conditions for Human Occupancy." 2013.

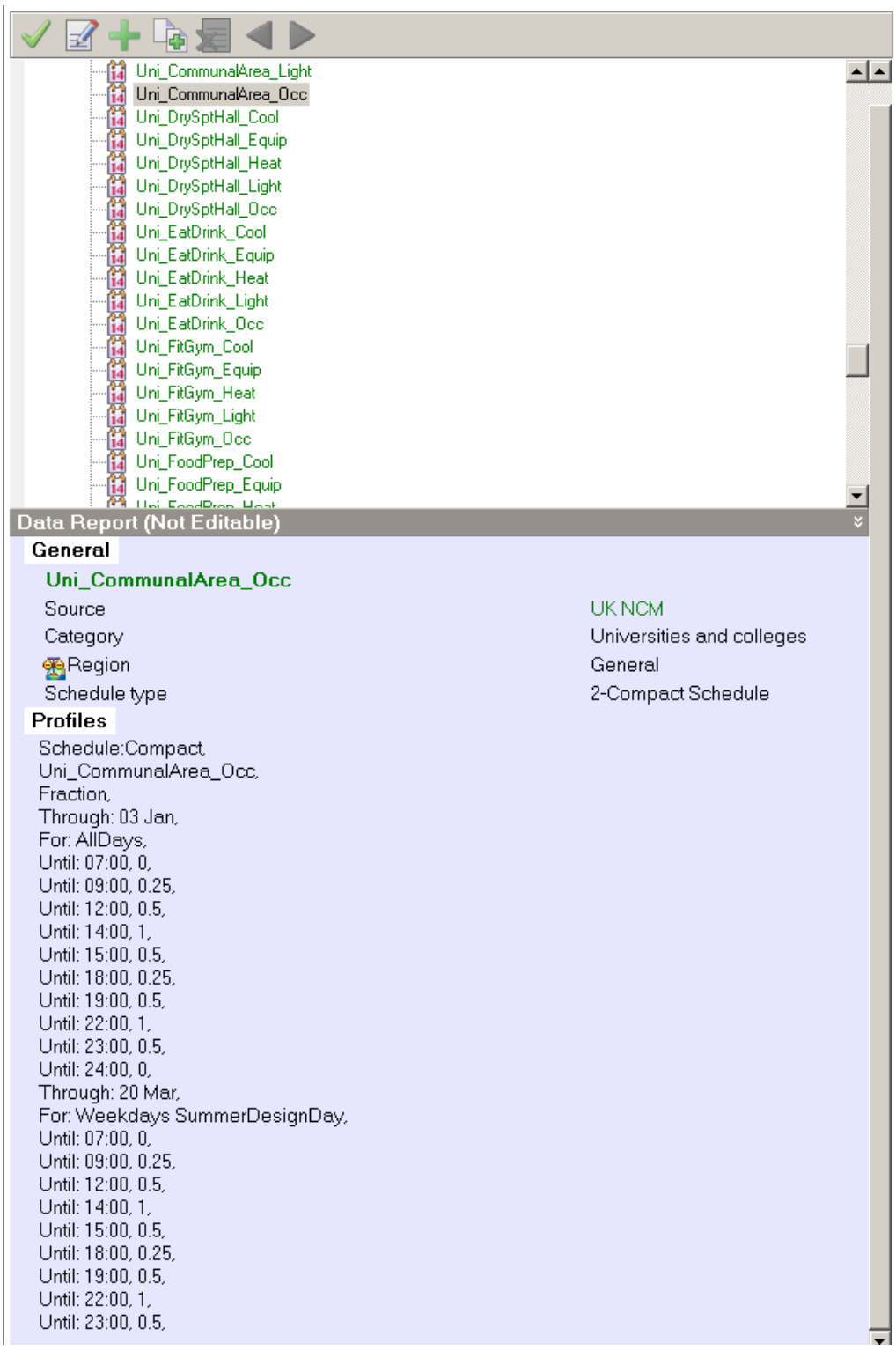
10 APPENDIX

10.1Data setting during the experiment process

Kitchen parameter:



Activity Template	
Template	**Residents kitchen**
Sector	C2 Residential Institutions - Universities and colleges
Zone type	1-Standard
Zone multiplier	1
☑ Include zone in thermal calculations	
☑ Include zone in Radiance daylighting calculations	
Occupancy	
Density (people/ft2)	0.010423
Schedule	**Uni_CommunalArea_Occ**
Metabolic	
Activity	**Cooking**
Factor (Men=1.00, Women=0.85, Children=0.75)	0.90
CO2 generation rate ((ft3/min)/(Btu/h))	0.0000237260
Clothing	
Winter clothing (clo)	0.60
Summer clothing (clo)	0.36
Generic Contaminant Generation	
DHW	
Environmental Control	
Heating Setpoint Temperatures	
Heating (°F)	**60.0**
Heating set back (°F)	**50.0**
Cooling Setpoint Temperatures	
Cooling (°F)	**70.0**
Cooling set back (°F)	**85.0**
Humidity Control	
Ventilation Setpoint Temperatures	
Minimum Fresh Air	
Lighting	
Computers	
☐ On	
Office Equipment	
☐ **On**	
Miscellaneous	
☐ On	
Catering	
☑ **On**	
Gain (W/ft2)	**2.0000**
Schedule	Uni_Tea_Equip
Fuel	1-Electricity from grid
Fraction lost	0.000
Latent fraction	0.000
Radiant fraction	0.200
Process	


Uni_CommunalArea_Light
Uni_CommunalArea_Occ
Uni_DrySptHall_Cool
Uni_DrySptHall_Equip
Uni_DrySptHall_Heat
Uni_DrySptHall_Light
Uni_DrySptHall_Occ
Uni_EatDrink_Cool
Uni_EatDrink_Equip
Uni_EatDrink_Heat
Uni_EatDrink_Light
Uni_EatDrink_Occ
Uni_FitGym_Cool
Uni_FitGym_Equip
Uni_FitGym_Heat
Uni_FitGym_Light
Uni_FitGym_Occ
Uni_FoodPrep_Cool
Uni_FoodPrep_Equip
Data Report (Not Editable)
General
Uni_CommunalArea_Occ
Source
UK NCM
Category
Universities and colleges
Region
General
Schedule type
2-Compact Schedule
Profiles
Schedule:Compact,
Uni_CommunalArea_Occ,
Fraction,
Through: 03 Jan,
For: AllDays,
Until: 07:00, 0,
Until: 09:00, 0.25,
Until: 12:00, 0.5,
Until: 14:00, 1,
Until: 15:00, 0.5,
Until: 18:00, 0.25,
Until: 19:00, 0.5,
Until: 22:00, 1,
Until: 23:00, 0.5,
Until: 24:00, 0,
Through: 20 Mar,
For: Weekdays SummerDesignDay,
Until: 07:00, 0,
Until: 09:00, 0.25,
Until: 12:00, 0.5,
Until: 14:00, 1,
Until: 15:00, 0.5,
Until: 18:00, 0.25,
Until: 19:00, 0.5,
Until: 22:00, 1,
Until: 23:00, 0.5,

Living room parameter:

Activity Template	
Template	**Domestic Lounge-Dormitory**
Sector	Residential spaces
Zone type	1-Standard
Zone multiplier	1
☑ Include zone in thermal calculations	
☑ Include zone in Radiance daylighting calculations	
Occupancy	
Density (people/ft2)	0.001742
Schedule	Dwell_DomLounge_Occ
Metabolic	
Activity	Eating/drinking
Factor (Men=1.00, Women=0.85, Children=0.75)	0.90
CO2 generation rate ((ft3/min)/(Btu/h))	0.0000237260
Clothing	
Winter clothing (clo)	0.60
Summer clothing (clo)	0.36
Generic Contaminant Generation	
DHW	
Environmental Control	
Heating Setpoint Temperatures	
Heating (°F)	**60.0**
Heating set back (°F)	**50.0**
Cooling Setpoint Temperatures	
Cooling (°F)	**70.0**
Cooling set back (°F)	**85.0**
Humidity Control	
Ventilation Setpoint Temperatures	
Minimum Fresh Air	
Lighting	
Computers	
☐ On	
Office Equipment	
☐ On	
Miscellaneous	
☐ On	
Catering	
☐ On	
Process	

Schedules

- Dwell_DomCommonAreas_Equip
- Dwell_DomCommonAreas_Heat
- Dwell_DomCommonAreas_Light
- Dwell_DomCommonAreas_Occ
- Dwell_DomDining_Cool
- Dwell_DomDining_Equip
- Dwell_DomDining_Heat
- Dwell_DomDining_Light
- Dwell_DomDining_Occ
- Dwell_DomKitchen_Cool
- Dwell_DomKitchen_Equip
- Dwell_DomKitchen_Heat
- Dwell_DomKitchen_Light
- Dwell_DomKitchen_Occ
- Dwell_DomLounge_Cool
- Dwell_DomLounge_Equip
- Dwell_DomLounge_Heat
- Dwell_DomLounge_Light
- Dwell_DomLounge_Occ

Data Report (Not Editable)

General

Dwell_DomLounge_Occ

Source	UK NCM
Category	Residential space
Region	General
Schedule type	2-Compact Sched

Profiles

```
Schedule:Compact,
Dwell_DomLounge_Occ,
Fraction,
Through: 31 Dec,
For: Weekdays SummerDesignDay,
Until: 16:00, 0,
Until: 18:00, 0.5,
Until: 22:00, 1,
Until: 23:00, 0.67,
Until: 24:00, 0,
For: Weekends,
Until: 16:00, 0,
Until: 18:00, 0.5,
Until: 22:00, 1,
Until: 23:00, 0.67,
Until: 24:00, 0,
For: Holidays,
Until: 16:00, 0,
Until: 18:00, 0.5,
Until: 22:00, 1,
Until: 23:00, 0.67,
Until: 24:00, 0,
For: WinterDesignDay AllOtherDays,
Until: 24:00, 0;
```

10.2 Other case study in humid tropics done by author

VO TRONG NGHIA ---Vietnam

Nghia said that as a Vietnamese, he wished to devote himself to Vietnam and make Vietnamese architectural works well-known to the world. He is full of social responsibility and focuses on seeking a cheap but eco-friendly approach in facing the stress on both natural land and poor house-holds caused by the contradiction between uncontrolled urbanization and huge population base. Four features can be summarized from many of his works: 1. Aerodynamics and thermal comfort are treated as the design "formula" of space shaping in achieving the aim of "energy saving". 2. Equal attentions are paid to advanced computational environment-simulation system and low-tech assemblies which can be easier for the farmers to master and build. 3. Indigenous materials are the eternal theme in his creations, and bamboo is now the most frequent choice in those tropical countries with no winters. 4. Green insertions are always their top priority for returning vegetation to the earth and bringing fresh breeze to the city of "concrete jungles".

Every innovation by VO Trong Nghia was driven by the four aforementioned design principles, but appeared to be different from each other. Nghia compared himself as a gamer: "Whenever I reach a level, I want to reach a higher, more difficult level."[9] Continuous breakthroughs made by these years have proved its worth for his simple but ingenious way

[9] http://english.vietnamnet.vn/fms/special-reports/26351/architect-vo-trong-nghia-and-his-journey-to--seek-failure-.html, 2015/10/17

of developing the potential in the natural resources, as he pursued the economic and practical value without sacrificing the architectural aesthetics.

Enthusiasm for Bamboo ----Major Buildings

Regarded as the "green steel of the 21st century", bamboo was elected to be a major element of Nghia's buildings not because of his personal preference. However, the reasons for choosing are multiple. Unlike Japan and New Zealand, timber is a luxury in Vietnam, yet bamboo grows easily and mature rapidly in such climate. Availability is usually the base of low cost ---one bamboo stalk only cost $1.oo, and it can become as durable as timber just by using proper insect-resistant and anticorrosive treatment --- soaking in mud and smoke-drying. Moreover, bamboo has incredible tensile strength, meaning that it can withstand significant amounts of stress and is comparable to steel's tensile property. Thus, bendable bamboo construction is suitable to create open spaces or semi-outdoor spaces surrounded by nature. Located in a hot-humid area, Vietnam suffered a lot from the seasonal floods, whereas bamboo system can survive in the water disaster and is convenient to be rebuilt.

Proficient in traditional "bamboo skills" with the firsthand knowledge from his childhood making bamboo baskets, tableware and furniture, Nghia succeeded in finding an inexpensive way to deal with structural junctions by harnessing ropes, bamboo wedges and nails, rather than those metal components which may cause additional local loads and dramatic increase in price after mass production. As his bamboo works spreading out of Vietnam, he devised some more construction modes with respect to distinct bamboo characteristics in different locations. For example, when doing the project of Jardines de Mexico, the Mexican bamboo named Guadua is much harder than the bamboos in Vietnam. According to this property, the architect reduced the bending curve of bamboo, and generated a charming feeling of "pointed arch" below the roof like a gothic cathedral.

Inevitably, there will exist some difficulties when using bamboo in the building process: one issue is to control the accuracy of the structure because bamboo is an uneven material; while the other is lacking of contractors with experience of bamboo construction. So, in order to realize the space as envisioned, it is essential for them to apply unit-frame prefabrication and educate workers by themselves.

Wind and Water Bar

Located in the center of an artificial lake in Binh Duong Province, wNw Bar is Nghia's first construction totally depend on bamboo. Frequent outdoor wind together with cool water create a "natural air conditioner", which can achieve its maximum performance under the effect of a 1.5m- diameter skylight on the top of the roof, by exhausting the hot air inside the bar outside. The main part of the architecture is a thatched dome --- 10m high and spanning 15m across, framed by 48 prefabricated units, each of which is made of several bamboo elements bound together and bent into arches. The system is so well-modulated that it can be finished by local workers only in 3 months with less money but give a luxurious feeling. Originated from nature, the building is now merging in harmony with nature, and with time it will return to nature ---such special lifecycle has laid its important status in the world's eco-architecture. Although the function is a bar, the project has its own uniqueness and has become a focus of urban landscape.

Bamboo Wing

Bamboo Wing is an experimental architecture with a pure bamboo cantilever structure flying over the sky as bird's wings. The amazing 12-meters-wide structure balances itself on one leg and enables to realize the spacious free space without any columns on its edge, meeting the function of the culture center to hold fashion shows, music lives, as well as conferences. Seen from a distance, the shape of the roof may be tempting to be thought of old seaside reed-thatched houses, however, the cambered surface has been calculated precisely to channel the cool wind into the main space from the surrounding pond. Sitting under such a structure encircled by water and shadow cast by the eaves and trees, people will be given a comfortable thermal feeling without using air conditioners.

Kontum Indochine Café

Kontum Indochine Café is designed as a part of a hotel complex along Dakbla River in Kontum City, Middle Vietnam. Adjacent to Dakbla

Bridge, a gateway to Kontum City, the cafeteria serves as a breakfast, dinner and tea venue for hotel guests. It also functions as a semi-outdoor banquet hall for wedding ceremonies. Located on a corner plot, the Café is composed of two major elements: a main building with a big horizontal roof made of bamboo structure and an annex kitchen made of concrete frames and stones.[10] Bridges cross the water to provide access to the café from three sides.

Nghia designed the Café in a rectangular plan with all elevations opened to the air, inviting uninterrupted views across the surrounding shallow pools of water, and beyond that towards the neighboring river and distant mountains. Supported by 15 inverse-cone-shaped bamboo columns ---referencing the typical Vietnamese fishing baskets, the roof of the structure is clad with bamboo but also contains layers of thatch and fiber-reinforced plastic. In some places on the ceiling, the translucent synthetic panels are exposed, allowing natural light to permeate the canopy. There's no air conditioning, but the architects explain that the large-area lake and the shade of the overhanging roof help to keep the space cool, even in the hottest seasons. Meanwhile, the form of the construction maximizes the wind flow into the building during the summer, while resisting harsh storms during the windy weather. Apart from the value of energy-saving, the bamboo configuration also produces a distinctive inner lining that gives visitors a spatial impression of being in a bamboo forest.

[10] http://votrongnghia.com/projects/kontum-indochine-cafe/, 2015/10/20

House for Trees

Built under a tight budget of 155,000 USD, “House for Tree” is Nghia’s first step of “green revolution”. Hidden from the street, five individual bamboo-textured concrete boxes with different functions and heights are designed as “pots” to plant trees on their tops. The tree chosen in this project is known as “Ficus Benjamina”, a tropical species that has aerial roots to catch ground and is easy to maintain with little water. With thick soil layer, these “pots” also function as storm-water basins for detention and retention, therefore contribute to reduce the risk of flooding in the city when the idea is multiplied to a large number of houses in the future. The inside rooms are cool enough with no need of any mechanical devices to modulate temperature, on account of having a natural protection consisting of tree-shading , earth insulation, plant transpiration and cross ventilation. Standing as a rare urban oasis among aggregated city, this green-roof house is an obvious spot from the top-down view.

FPT University

Located in Hightech Park Hoa Lac, Thach That, 34 km far away from Hanoi, the project “Administrative building of FPT University” is a modern 7 floor building with green façade and green roof. The erection is famous for its checkerboard-like elevation, which can be regarded as a continuity of the idea in “House for Trees”--- using concrete surface to enwrap

cubes and stacking them into a stagger grids. To install "green" into the vertical blocks, big one floor trees are planted alternately in the "checkerboard grids", providing the staffs numerous small parks rather than only opening balconies. Each block is designed to get lighting and natural air go through in this project to save energy consumption and to adopt to "black out" situation happening frequently in Hanoi. Roof of the building is covered by green, big plants to create exercise place for users and to protect sunlight for whole building. Terrace and void make the special architectural volume feel more complicated, however the real supporting framework is ordinary and simple to fabricate. It is believed that the current situation of not having any environmental education/self-sufficient buildings but being surrounded by air-conditioning decorated facades can be changed after the project completion, which will also establish a bridge between public and landscape.

Farming Kindergarten

Designed for the children of shoe-factory workers, the "Farming Kindergarten" aimed at offering food and agriculture experience to Vietnamese children, as well as safe outdoor playground, by connecting green roof with continuous slopes. Three different courtyards are enclosed by the ribbon-shaped building with corridor running through it. Diverse functions corresponding to different age-groups are well-organized under the roof vegetable garden. In order to reach a low budget of construction and management, the building has employed several energy-

saving strategies. For instance, the form has been tested many times in the simulating software to ensure every classroom a well-ventilated condition, and to eliminate the need of AC. Also, pilotis spaces and small openings are created as wind pathways. Other visible details ---such as deep eaves, leave-twined louvers, operable windows, recycled water irrigation & flushing system, LED lights and solar heater system ---are incorporated thoroughly in the architecture as well , and have economized 25% of energy and 40% fresh water for the kindergarten within 10 months since put into use.

CHARLES CORREA

HOUSE AT KORAMANGALA

The traditional courtyard houses of South India represent a typology much older, and really quite different, from that of the bungalows built by the British- which is usually a long shed (with the Living and Dining rooms down the center and the bedrooms on either side), wrapped around with continuous verandahs The result: rooms which are large and generous, but sadly lacking in light and cross-ventilation. In contrast, the traditional old Hindu houses in Tamil Nadu and Goa are usually organized around a small central courtyard, with a tree or tuisi plant in the middle.

The front door, intentionally placed off-center on the main façade, leads one along a shifting axis to arrive at the courtyard – which acts as the central focus, and brings wonderful bounce-light and ventilation to the rooms that surround it.

RAMKRISHNA HOUSE

This large residence, built for one of Ahmedabad's mill owners, is based on the spatial and climatic concepts developed in the Tube House and the Hindustan Lever Pavilion. The plan sets up a series of parallel bearing walls, punctuated by interior courts and "canon", climaxing in the living room which opens out onto the main garden to the south. The house is placed at

the northern end of the site so as to maximize the size of this garden and to enhance the spatial sequence of getting there.

ACKNOWLEDGEMENT

I would first like to thank my thesis advisor Professor Joyce M Noe of School of Architecture at University of Hawaii. The door to Prof. Noe office was always open whenever I ran into a trouble spot or had a question about my research or writing. Sometimes late in the midnight, she was still working to help improve my thesis drafts and presentations. She also found some useful resources where I can turn to when encountering some problems. She consistently allowed this paper to be my own work, but steered me in the right direction whenever she thought I needed it.

I would also like to thank the experts in my D-ARCH committee: Professor William Chapman of American Study Department at University of Hawaii, and Scott Inatsuka who is the Principal of Inatsuka Engineering LLC. Professor Chapman gave me a lot of reading materials that relate to my research realm (on history part) and always encouraged me on further work. Scott has many valuable comments on my simulation work which was quite unfamiliar to me before this research, and provided a rational engineer perspective different from my perceptual architecture knowledge.

Moreover, I want to acknowledge Professor Wendy Meguro and Mike Poscablo in Environmental Research & Design Lab of UHM, and I am gratefully indebted to their

suggestions on the content of my experiment via software. Without them the simulation process of my research could not have been successfully conducted.

Finally, I must express my very profound gratitude to my parents and friends for providing me with unfailing support throughout my years of study. This accomplishment would not have been possible without them. Thank you!