ARCHITECTURAL RESEARCH, Vol. 7, NO. 2 (2005), pp. 13-21

A Study on Architectural Design Factors for Tall Office Buildings with Regional Climates based on Sustainability

Jong Soo Cho
Assistant Professor, Graduate School of Architecture, Konkuk University, Seoul, Korea

Abstract

Throughout history, buildings have been interrelated with certain indigenous characteristics such as regional climate, culture and religions. In particular, the control of regional climate has been primarily a concern for compatibility with nature. In our modern age, technologies to control climate have been successfully developed in architecture but the consumption of large quantities of natural resources can also produce environmental problems. This study is based on the proposition that this negative trend can be minimized with architectural design that is motivated to coexist with a regional climate.

This study develops these design strategies for tall office buildings by analyzing various combinations of building design configurations based on regional climates. The objective is to determine the optimum architecture of tall office buildings during the initial design process that will reduce energy consumption for regional climatic conditions. The eQUEST energy simulating program based on DOE-2.2 was used for this comparative analysis study of the energy use in tall office buildings based on architectural design variables and different regional climates. The results are statistically analyzed and presented in functional architectural design decision-making tables and charts.

As a result of the comparison of architectural design consideration for tall office buildings in relation to regional climates, buildings physically need less energy consumption when the architecture is concerned with the regional climate and it produces a more reasonable design methodology. In reality, imbalanced planning which is architectural design's lack of regional characteristics requires additional natural resources to maintain desired comfortable indoor conditions. Therefore, the application of integrated architectural design with regional nature should be the first architectural design stage and this research produces the rational. This architectural design language approach must be a starting point to sustaining long-term planning.

Keywords: Architectural Design, Tall Office Building, Regional Climate

1. INTRODUCTION

(1) Prelude

The tall building and the twenties century can be synonymous since the tall building style is one of the landmarks in our age. This is a dramatic phenomenon and a powerful expression of architecture in the modern civilization.

The height of building is evident on certain structures and forms from ancient times in the various civilizations. Higher towers have been built in almost all cultures from time immemorial. Conceptually, the significant evolution of tall buildings from ancient towers is a "change of function" from some religious symbols to a commercial concept that has aesthetically become acceptable with the changing of modern society and culture driven by a technological development.

Generally, tall buildings greatly impact the scale and context of the urban environment due to their proportional mass and height, and tall buildings are a natural response to the scarcity and high cost of land and concentrated population growth. Physically, tall buildings have a concentration of built space placed on a small site area. Functionally, they enable usable floor spaces to be stacked high. In addition, growth in population and economic resources along with limited building sites and infrastructure in major business districts have motivated the rise of the construction of high-rise building to maximize the use of urban space in the big cities around the world.

The architecture of tall building style has been developed with mutual contributions of architectural aesthetic form and advanced technologies. In particular, the technologies to control climate in architecture has been primarily a concern for compatibility with nature but it can also produce environmental problem by use of large quantities of natural resources. That is, the evolution of the mechanical system for heating, cooling and air handling systems provides for demanded comfort in a tall office building which causes higher energy demand. Thus, this situation has allowed architectural design to be free from adapting to a regional nature system.

Consequently, the great paradox is that modernized nations have succeeded in uncoupling humankind from nature though modern technology and the exploitation and depletion of fossil fuels. Yet civilizations still strongly depend on nature; not only for energy and materials but also for the vital life process. Therefore, if human life is to be sustained in the future, it must depend on knowledge and intelligent action to preserve and enhance the natural condition by means of a harmonious rather than disruptive technology.

Architects can be forced to develop design strategies for optimized design considerations based not only on low energy and low cost, but also on minimizing the environmental crisis for sustaining long-term human life. That is, architectural design should be concerned not only with interrelationship of space, but also with external factors such as climate.

(2) Definition of Tall Buildings

The concept of tall buildings can be defined as a relative concept of our time and contextual conditions. The tall building cannot be defined by its height or the number of stories of the building since the outward appearance of tallness is a relative matter, but it does depend on the effect and quality of the tallness of building.

> The multi-story building is not generally defined by its overall-height or number of stories, but only by the necessity of additional operation and technical measures due to the actual height of the building. (Beedle, 1971)

The significant criterion is that the design is influenced by some aspects of "tallness". That is, the height of a building differently impacts on architectural, structural, and mechanical designs, as well as construction and building use when compared with "common" buildings of a certain region and period.

(3) Office Buildings in Architectural Design

Office buildings should generally be designed by considering the inter-relationship between a user's functional need and regional characters such as microclimatic system since illumination and thermal comfort must coexists during most of the day throughout the year. It will have physically and mentally effect on human comfort. The 1950's, the architectural design strategy was to physically use as much natural lighting and ventilation as possible. Although the engineering for air-conditioning systems to control temperature and humidity were developed during 1920's and the fluorescent bulb became commercially available in the late 1930's, the limited abilities of these initial mechanical systems kept the office building floors very narrow. However, since the 1950's the high land cost in major cities along with increased equipment reliability and low energy costs have produced the concept of large open spaces with office landscaping and sealed buildings.

Developed equipment reliability has to take care of the direct influence of climate on the internal space and provide all of the required comfort conditions at the expense of non-renewable energy sources. That is, before the energy crisis of the early 1970's, the annual energy consumption for an office building was a minor concern in relation to other design considerations, because of the technological development in equipment capacity and relatively inexpensive energy supply, it was not considered necessary for building design to respond to local climate characteristics and solar effect.

This method of designing office buildings that were dependant on mechanical system technology resulted in unnecessary large energy consumption to achieve human comfort. Consequently, these situations led to architectural design becoming dependant on mechanical systems.

(4) Statement of General Approach to the Problem

The population growth and non ecological technology development have generally brought the rapidly required energy consumption, and the simultaneous destruction of CO_2 diminishing forest regions of the earth. From IPCC (Intergovermental Panel of Climate Change), 1992, the global mean temperature will surpass the 1990 average by approx. 1.8-4.2K by the end of the 21st century which is based on the assumption that the atmospheric CO_2 content, 360ppm in 1992 will rise to double the pre-industrial rate, i.e. to 560ppm.(Daniels, 1997) For the situation, one of the essential variables was the emission of carbon dioxide as a parameter. In fact, the combustion of fossil fuels since the industrial revolution has led to an excessive build-up in CO_2 and these CO_2 levels will continue to increase with the demand of energy consumption. As result of these air-polluting elements, there may be climate changes which will show various kinds of the greenhouse effect and have a negative influence on the ecosystem. (Daniels, 1998) From IPCC, 1995, global warming would impact temperature change, rise in sea levels, extreme weather, human health, forests, coasts, snow and glacier formation.

Therefore, the destroying the balance nature clearly means having concerns for not only human life but also all other living organisms. In other words, the crisis of a natural system is not one of human comfort, but a question of survival.

(5) Statement of General Impact Factors in Architecture

General impact factors relating architectural design with sustainable issues can be categorized by "policies and social responsibility with globalization", "lack of commitment" and "large population growth" in the Study.

The energy policies and social responsibility are generally related to environmental protection and renewal. As a result of the oil crisis in 1973, many countries have adopted some kind of policies to actively improve the production and application of renewable energy systems based on an economical purpose. This effort to actively promote the energy efficient systems may first come from governments that initiate taxation incentives, introduce energy regulations and codes of practice and promote renewable energy. Secondary, it may also come from communities and industries that are motivated to take advantage of energy polices. And, it may be generated by the individual who becomes aware of his of her social responsibility in environmental protection and renewal. (Lim, 1999) Globalization can also generally provide for energy and environmental protection with a positive political point of view. In fact, the world is being changed with presenting ethnic, religious, or culture in almost all societies. Globalization is being spread and absorbed in different religious and culture by the growing interdependence of the world's nation economies, and the integration of the financial and telecommunications markets. "Globalization is also driven by the universal drive to respect human rights and to preserve the environment". (Serageldin, 1997) Therefore, the polices or rules from governments may be a desirable way to control and promote energy consumption patterns. Economic viability and social acceptance are also equally significant opportunities to achieve a low energy/ sustaining world in the future.

Despite a common agreement on the benefits of energy efficient/ecological design regarding the protection of the environment, reduced energy bills and increased comfort, architects do not appear to incorporate its features to a notable extent in their works. “One major reason for this disregard may be architect’s lack of commitment towards energy efficient/ecological architecture”.(Wittmann, 1998) Generally, architects and other designers did not consider the climate as a defining inevitable design factor in the modern age after the industrial era. This contrasted with the pre-industrial architecture with a unique society and culture without high technology and an architectural design that responded to the regional climate conditions. Conceptually, this traditional design was based on a local culture which expressed the local constraints such as location, topography, climate, culture, heritage, building materials, and available technology. After the rapid evolution of technology, architects tended to depend on available technology to solve the local constraints problem. This attitude generally accepted an architecture that did not consider the local natural system (weaken local characteristics), but designed the building to maintain human comfort by technology which, in turn, created an environmental problem because of the higher energy consumption to support the mechanical systems in a building.

Large population growth may accelerate the depletion of energy resources because of the demanded increased energy consumption and then it will have a negative impact on the global environmental systems and human ecosystem. In developing countries, if the population of these countries double as expected, their required commercial energy would increase 7.5 times from 1980 to 2020, and the increment in energy consumption would be 1.3 times the world’s total energy usage in 1980.(Shea, 1999)

(6) Necessity of Designing with Climate

The climatic condition of each building site depends on the influence of the regional climate and the microclimate modified by the surroundings of the building. Regional climate is defined by geographic location - latitude, longitude, and altitude. Local deviation on the regional climate is caused by site topography, vegetation, water bodies, land slope, neighboring man-made structure, etc. This study focuses on the impact of the regional climate because it makes possible the comparison between diverse regional environments and their effects on architectural principles and building elements.

Throughout history, local builders have used ingenuity in working within the exigencies and constraints of nature and a regional climate. This has been true ever since humans first constructed shelters to create a comfortable space and developed their traditional buildings to preserve heat in a cold outdoor climate or as protection from in a hot outdoor climate. Even protection from precipitation was done by designing with a maxim adaptability to nature. Then, with the rapid growth of science from the Industrial Revolution, modern man began to believe that these shelter problems could be solved by technology and that it was no longer necessary for human life to be in harmony with nature. These trends are in conflict with the local natural system and have produced negative unbalanced environmental problems.

For the future of architecture, it is desirable to use an integrated design to achieve an optimal combination of regional characteristics and a fundamental understanding of nature and technology. This research is based on the proposition that design information from a regional climate is significant for energy-conscious architectural building design to minimize the negative environmental impact, more efficiently distribute the daylight to the interior space and to absorb the winter solar gain or keep out summer sun. Therefore, the building designer must optimize the early solutions by understanding the relationships of individual energy characteristics.

(7) Research Framework

This study generally will develop fundamental concepts and applications by incorporating different regional climate conditions. Through a hypothetical construction of a tall office building model positioned within regional climates, architectural design considerations will be examined. Based on the examined design data, a set of quantitative analysis is pursued with two design considerations – building sizes and lease span depth[1] as major internal design factor – for the development of tall office building design methodology.

The results demonstrate general integrated design information for the initial design determinations of tall office buildings in different regional climate conditions, not as a forecast or exact value but rather as a quantitative comparison with available alternatives. These quantitative analyses contribute to the first stage of the design process with a climate condition to measure whether the alternatives are becoming more or less energy efficient within regional climates. Building energy use is influenced considerably by early design decisions such as building scale and internal design variations within a specific climate which can rarely be reconsidered close to or at the end of the design process. Efforts toward optimization of their energy impact should be undertaken as early as possible.

To perform such analysis, computer-aided energy modeling helps the building designer by providing information on the relationship between potential design solutions and their performances.

2. ARCHITECTURAL DESIGN ETHIC WITH NATURE

Designing with adaptability to nature strongly depend on providing human comfort from the regional climate and the microclimate modified by the surroundings of the buildings in architecture. Based on the concept, providing

[1]Lease span depth means the length from exterior wall to interior structural wall such as the core in the study.

human comfort can be found from the traditional town structure, building material, building form, building façade, orientation, room depth, and etc. since there are strongly interrelated with local climate condition.

With the development of an industrial society, the new forms of industrial production and capital organization were demanded. The new society also affected architectural building design and constriction based on new technologies to control regional climate.

Architecturally, a comfortable human life in a building space can be achieved by the use of local environmental characteristics, by applying artificial technology, or by combining both of them, as shown in Figure 1.

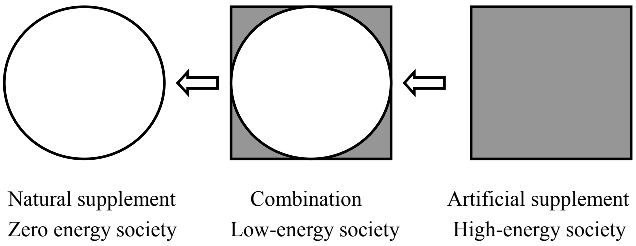


Figure 1. Society and energy use pattern

Low-energy societies have traditionally needed low energy consumption to maintain comfort in a space by their use of local environmental system. High-energy societies have demanded a higher energy supplement of fossil fuel to provide comfort in a space. That is, these high-energy societies after industrial revolution with their developed technologies to control climates, have brought convenience to human comfort by depending on high-energy requirement from nature. This has resulted in unexpected impacts on global nature.

Thus, the necessity of physical designing with nature for sustaining long-term human life on the earth can start with a conceptual basis of ecology[2] in architecture. Ecological design conceptually means a partnership with nature for the long-term survival of all species on the earth, and it must clearly address the design with nature in architecture.

3. APPROCH OF A CONCEPT FOR THE MODEL

The energy design of an architectural environment to achieve an optimum human comfort can conceptually be divided into a relationship between an architecture designed with nature and one with engineering control (designing with artificial technology). The end result generally provides an occupant's comfort in a space that is sensitive to the global environmental and the issue of artificial energy generation and consumption. Figure 2 shows the relationship of architectural design and nature.

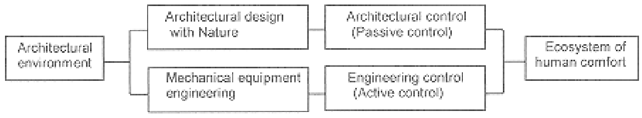


Figure 2. The composition of architectural environment

Conceptually, there should be an increasing portion of architectural designing with nature (passive) and a decreasing portion of engineering (active) to maintain the desired human comfort in a tall office building. The relationship between both factors is ideally an inverse proportion. Therefore, a performance of maximizing passive control for human comfort in a space can achieve not only minimizing active control, but also minimizing the environmental consumption as a positive result for sustaining long-term human life. Figure 3 indicates the relationship between passive control and active control in architecture.

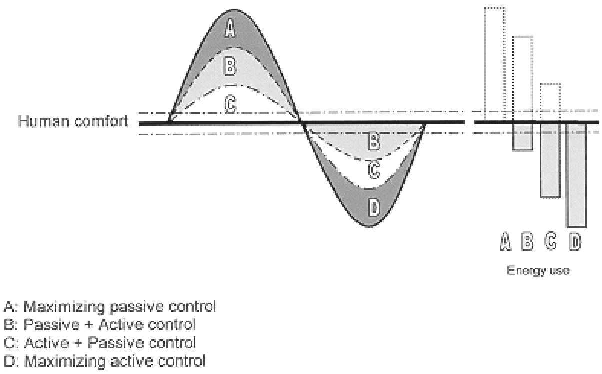


Figure 3. The relationship between passive control and active control

4. CONSTRUCTION OF HYPOTHETICAL MODEL

The hypothetical model of the tall office building for the experimental study has been constructed based on architectural and engineering assumptions in the study.

(1) Architectural Considerations

To establish a pragmatic study model of a tall office building, this study made use of the quantitative design analysis of the existing tall office buildings. It is to analyze commonly used design pattern and method for constructing adaptable model. From the quantitative design analysis, commonly used design factors piloted to set the criterion of the constructing the hypothetic tall office buildings which have the same total area, the same volume, the same typical floor area, the same rentable space ratio, the same core ratio, and the same interior conditions in the space. This objective was to have the same comparison in the study for architectural design and planning considerations. From these considerations and analysis, the architectural

[2]The meaning of the word, ecology is derived from the Greek "oikos" which means household, and "logos" which means study. Thus, the study of the environmental house includes all the organisms in it and all of the functional processes that make the house habitable. (Odum, 1983)

factors are constructed as shown in Table 1 based on Figure 4 in the study.

Table 1. Construction of architectural factors

	Characteristics	Conditions
General Description of Modeled Tall Office Building	Building function	Office with open plan
	Building Gross area	2,166,000 sqft
	Building Typical floor	36,100 sqft
	Number of floors	60
	Percent of occupied area	70% of total building area with open office plan
	Percent of core and others	30% of total building area with utility core
	Modeled building forms	Square
Zone 0 (Outdoor)	Cool climate	Chicago, Illinois
	Temperate climate	New York, New York
	Hot-Arid climate	Phoenix, Arizona
	Hot-Humid climate	Miami, Florida
Zone 1 (Façade)	External walls	Aluminum (uncolored) exterior finish + 1in. polyurethane, and for roof, 2in. polyurethane + medium exterior color
	Windows	Double insulating 1/4in, 1/2in; see window library – double paned windows 2004 in eQUEST with curtainwall frame type Frame type: Aluminum without brick
	Modeled window areas	100%
Zone 2 (Indoor)	Lease span depth	Based on 45 ft, variation span depth: 30 ft, 35 ft, 40 ft, 50 ft, 55 ft, 60 ft, 65 ft, 70 ft
	Perimeter depth	20 ft
	Floor-to-Floor height	13 ft
	Ceiling height	9ft
	Floor structural material	Metal deck + concrete slab (Composite)
	Typical floor finish	Carpet (no pad)
	Ceiling material	Suspended ceiling system with recessed fluorescent luminaries/ Lay-In Acoustic title (no ceiling insulation)
Zone 3 (Core)	Core type	Central utility core system
	Core material	Concrete composite

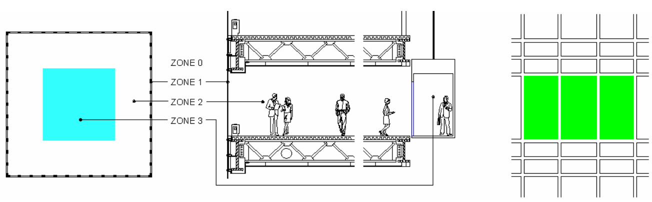


Figure 4. Organization of Tall Office Buildings in the Study

(2) Engineering Considerations

The engineering decisions for the model construction are based on general programmatic requirements and design criteria or common engineering practices which are assumed and applied to the hypothetical models with the same conditions as the systems in the study.

External thermal and solar loads are assumed as transmission through exterior walls and windows. Internal thermal loads are assumed as heat gain from occupants, lighting fixtures, and commonly used office equipment. Mechanical and electrical systems are hypothesized to provide the services required to constantly maintain temperatures and required lighting levels. A variable air-volume system is modeled for the HVAC system. And engineering assumptions for mechanical and electrical systems are constructed in relation to typical office building requirement as shown in Table 2.

Table 2. Assumption of engineering factors

Factors	Assumptions
HVAC system	Standard variable air volume system with electric zone reheat, return air path by duct Electric resistance for heating equipment Chilled water coils for cooling equipment, open tower Chiller type: electric centrifugal hermetic
Occupancy schedule	9:00am to 6:00pm, Monday through Friday
Space requirement	150 sqft per person 52.5 sqft for restroom
Indoor thermal	72 °F for heating set point (occupied) 75 °F for cooling set point (occupied) 50% relative humidity for cooling
Indoor lighting	50fc for ambient perimeter zone lighting level (lighting level) 3.0w/sqft for artificial light design 1.5 W/sqft for equipment density 0.4 W/sqft for task light Lighting controller type: Continuous, Maximum glare: 20
Indoor ventilation	20 cfm per person for outdoor air requirement in typical space 15 cfm per person for ventilation in corridor 7.35 cfm per person for restrooms 45 cfm per person for mechanical room

(3) Others

This study selects region to perform the research as the United States. Because that country has various climate conditions according to different region, has lots of tall office buildings in cities and has exact weather data from government. From the selection, climate zones selected based on four different climatic conditions in the United States; cool, temperate, hot-arid, and hot-humid.

Considered regions selected by four major cities in the United States according to climate zones; Chicago - Illinois, New York - New York, Phoenix - Arizona, and Miami – Florida as shown in Table 1.

For comparative analysis in the study, results of total annual energy consumption of modeled buildings used for the quantitative analysis. And output data for energy use in modeled buildings indicated as kWh.

The study is based on using photo-sensors in the occupied zone to evaluate daylighting from outside through the windows into a space. The height of installed photo-sensors are above 2.5 feet from floor, continuous lighting type controller, maximum glare is 20 and the design light level is set as 50 fc.

5. ANALYZING STRATEGY OF THE MODEL

(1) The Tool for the Achievement of Experimental Study

The objective of this research is to develop the design methodology for tall office buildings with regional climate adaptability. To measure regional climate adaptability, the criterion of the comparative analysis for evaluation of considered architectural design factors in each of the regional climate is total annual building energy consumption.

For the analysis, the simulation of energy consumption is a useful design tool for designers who want to evaluate the impact of building design on energy performance. The complexity of energy analysis and the high level of interaction between many variables require a computer to link design and analysis. With computer aids, energy simulation has become increasingly powerful, quickly providing information on design solutions and their performance characteristics for decision-making.

The process makes an experimental study by means of computer simulating as the tool for experiments to achieve comparative analysis between model to be considered and regional climates in the study. This computational parametric analysis can assure accuracy to achieve its objectives. This study uses the eQUEST program based on DOE 2.2 and it will be utilized to obtain expected data between design considerations and energy performance to measure annual energy consumptions in relation to regional climate conditions.

(2) Analysis of Sequence and Structure

As a result of the previous discussion, this study has developed an integrated method of building design and planning, incorporating heating, cooling and lighting that use a unique combination and sequence of computer simulations and regional data related to different climate conditions. The study then produces energy consumption according to building sizes and interior design(lease span) considerations. Therefore, this method is characterized by the following:

- Analysis problems
- Selecting design considerations for tall office buildings
- Model definition based on empirical research database
- Computer simulation (analytic engine)
- Analysis of collected data
- Development of integrated design information

6. ANALYSIS OF DESIGN CHARACTER

(1) Design Analysis of Tall Building Size with Climate

The purpose of this experiment is to analyze the energy use pattern and differences according to different tall office building sizes with regional climates.

To achieve the information of energy use patterns and differences in tall office buildings according to climates, three tall office buildings having different sizes are modeled as shown in Table 3. The selected buildings are constructed to have the same architectural and mechanical conditions to make the equal comparative analysis that is analyzed by kWh per square foot/year. Generally, as the number of floors increase, the core also requires more space for elevators, shafts, stairs, and services so that the ratio of rentable space to core space in all three cases is constructed as the same since it is significant for the exact measurement and evaluation in the study. Based on the concept of model construction, the foot print size increases as the number of floors increase as shown in Figure 5.

Table 3. Constructing different size office buildings

Building sizes	Mega	Large	Small
Foot print	220ft X 220ft	190ft X 190ft	155ft X 155ft
Storeys	90	60	30
Typical floor (sqft)	48,400	36,100	24,000
Total area (sqft)	4,356,000	2,166,000	720,750
Rentable ratio (%)	70%	70%	70%
Core ratio (%)	30%	30%	30%
Measured unit	kWh/sqft,yr	kWh/sqft,yr	kWh/sqft,yr

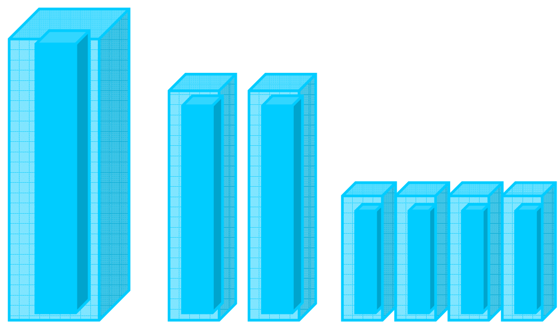


Figure 5. Assumption of Different Size Buildings

From the result, larger size office buildings generally consume less energy than smaller size buildings for all climate conditions and the heating performance especially shows greater different energy use related with building size as shown in Table 6. Otherwise the individual energy use patterns and differences for heating, cooling, and lighting in three modeled tall office buildings are different according to regional characters as shown in Figure 6. To approach optimum spaces in the tall office building design with different climate condition, the understanding of individual energy performance is important.

From the study, integrated energy use is that larger size buildings makes smaller surface area per square foot. Architecturally, this situation reflects the relationship between surface/volume ratio and building design as shown in Table 4. That is, smaller size buildings have large surface/volume ratios than mega size buildings by as much as 47.4%, and they than large size buildings by as much as 27.3% which produces different energy use in building. And it generally makes same energy use patterns according to building orientations as shown in Table 5.

Table 4. Surface area and volume by building size

Building size	Mega size	Large size	Small size
Building surface area(ft^2)	1,078,000	628,900	265,825
Building volume(ft^3)	56,628,000	28,158,000	9,369,750
Surface/volume ratio	0.019	0.022	0.028

Table 5. Energy use pattern between mega and large size office buildings with climate

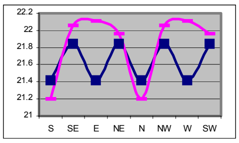
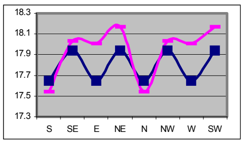
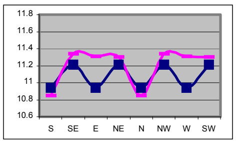
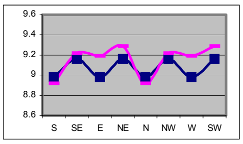
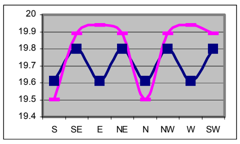
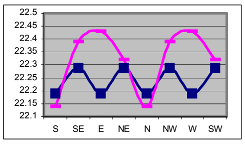
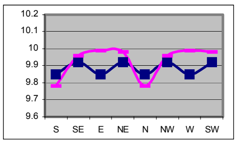
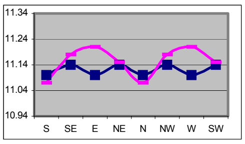
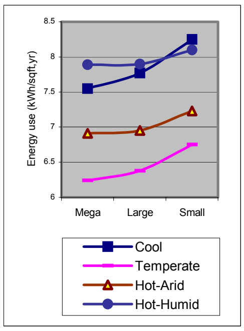
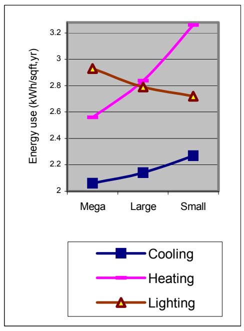
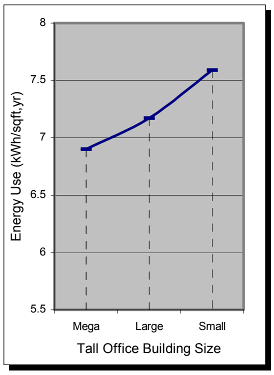
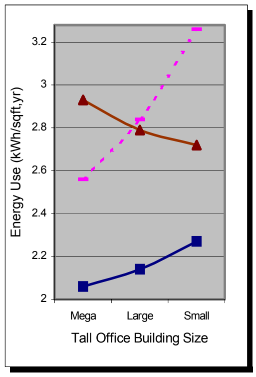
	Cool climate	Temperate climate/
Mega size		
Large size		
	Hot-arid climate	Hot-humid climate/
Mega size		
Large size		
	* X-axis: Orientation, Y-axis: Energy use(kWh) * Legend: Square form, Rectangle form	

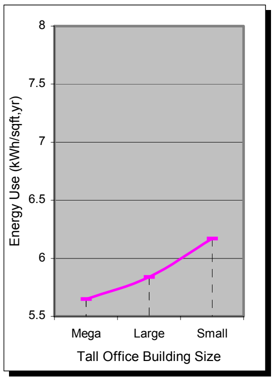
Table 6. Energy use differences between mega and large size office buildings with climate

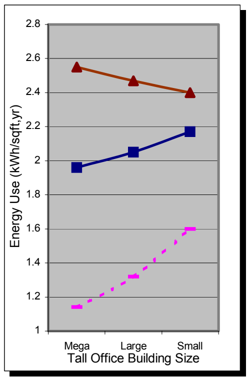
Integrated energy use with regional climate	Individual energy use in cool climate/ Chicago
	



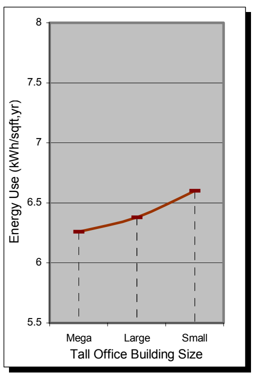


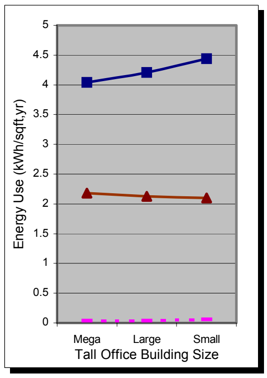
Integrated Energy Use   Individual Energy Use
in Cool Area(Chicago)





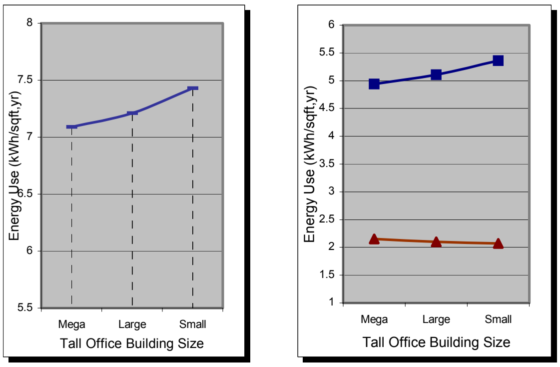
Integrated Energy Use   Individual Energy Use
in Temperate Area(New York)





Integrated Energy Use   Individual Energy Use
in Hot-Arid Area(Phoenix)

In point of architectural design, energy use pattern indicates the condition of space environment which is different according to climate conditions. Therefore, for the optimum spaces in the tall office building's design, the understanding of individual energy performance's character according to different climates is important since it is can support to confirm of the proper architectural design characteristics for regional climate adaptability based on building energy use in climate conditions. From the analysis of the data, the hierarchy of architectural design factors based on building size in cool climate area is heating, lighting, and cooling. In case of temperate climate area, the order is lighting, cooling, and heating. In case of hot-arid climate area and hot-humid climate areas, the order is cooling, lighting, and heating. Therefore, space design must be considered by integrated design factors with climate. From the result, energy use between cool area and hot-humid area is equivalent because of thermal requirement. Therefore, in the design process, building size can be controlled to control the proper spaces with climate. In case of temperate area and hot-arid area, major energy use factor is lighting. Therefore, in design process, window size can be considered to use natural daylighting.



Integrated Energy Use Individual Energy Use
in Hot-Humid Area(Miami)

Legend: 1. ■ : Cooling, 2. ▲: Lighting 3. ■: heating

Figure 6. Energy Use Pattern by Building Sizes

(2) Design Analysis of Lease Span and Building Height

Lease span is a significant design factor to composite tall building space and form. It means the length from exterior window wall to interior structural wall. There are no international standards that determine lease span depths for office buildings, since the determination of optimum lease span depth in tall office buildings have the complicated inter-relationship between external factors - such as local codes, local social & cultural pattern, client & user needs, economical support, local environmental systems and internal factors - such as site size, lobby circulation, modulation for office landscaping, mechanical system efficiency, structural system efficiency, and current technology. For instance, according to regional code or custom, some countries may have a requirement that all offices must have an outside exposure to light and air.

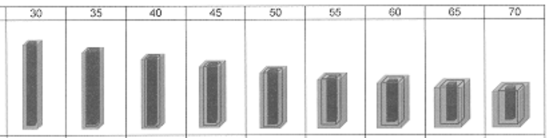
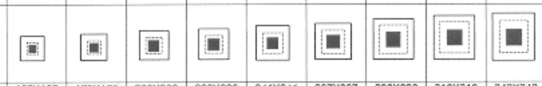
In such cases, office function arrangements may affect the dimension of the lease span. Adherence to this requirement may also affect the aspect ratio of very tall buildings. On the other hand, Rubanenko (1973) points out that flexible floor layout allows quick alteration of the office structure and rearrangements, it is basic considered concept of this experiment.

> …The use of various types of demountable partitions, lighting and air conditioning, sun protection and acoustics will give a possibility to rearrange any unit of the plan (multiple of the adopted planning modules) into separate spaces or part of a lager hall which sometimes can cover almost the entire floor which is in the case of an office landscape. (Rubanenko, 1973)

Based on the assumption that the required building area is the same, lease span determination automatically determines building height and aspect ratio. Furthermore, it effects to land use, that is, higher building height can be proportionally achieved lower land use.

In the architectural space, lease span can be composed by perimeter area and interior area based on environmental system as shown Figure 7. And lease span variation also effects the ratio between perimeter area and interior area from an occupied area as shown in Table 7.

Table 7. Constructing model

Lease span (ft)	30	35	40	45	50	55	60	65	70
Diagram of relationship between lease span and building height									
Diagram of lease span variation									
Considered building units	150X150 @193fl	175X175 @142fl	200X200 @109fl	220X220 @90fl	241X241 @75fl	267X267 @61fl	298X298 @49fl	318X318 @43fl	343X343 @37fl
Building area	(Typical floor area X number of floors) = same								
Building volume	(Typical floor area X building height) = same								

The objective of this experiment is to analyze a tall office building design influenced by the relationship between lease span and building height, under the condition that modeled buildings have the same total building area in relation to a climate adaptability measured by the annual energy consumption.

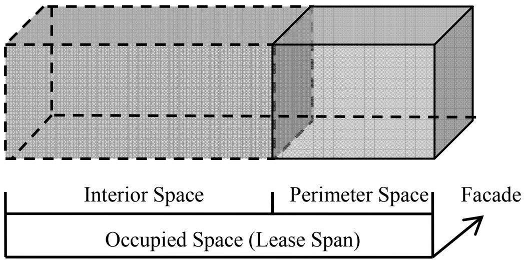


Figure 7. Composition of lease span

From the results of area analysis, a building which has a longer lease span produces a lower building type and a building which has a shorter lease span makes a higher building type under the condition that they have the same building area. For the energy analysis, the total building energy consumption gradually decreased from a building type which has a shorter lease span to a building type which has a longer lease span; that is, a building type which has a shorter lease span (30 to 40 feet) consumed more energy than a building type which has a longer lease span (55 to 70 feet). The shorter lease span building consumes more than 12% to 20% energy in cooler areas and uses more than 10% energy in warmer areas than the longer lease span building. In addition, energy use differences according to building types varies slightly between a building which has a 55 feet lease span and a building which has 70 feet lease span as shown in Table 9.

Based on the assumption that the required building area is the same, lease span determines building height and affects the aspect ratio and surface area in a tall building. Furthermore, leases span variation also affects the ratio between perimeter area and interior area from an occupied area as shown in Table 8. Shorter lease span determination in a design increases the perimeter area and decreases the interior area which simultaneously produces a larger surface area. Longer lease span determination decreases the perimeter area and increases the interior area which results in a smaller surface area. Therefore, from the study, two significant design considerations based on the evaluation of building types in relation to energy use were observed. It is firstly that variation of parameter area and interior area in a space have an effect on energy use in a building. And it is secondary that the surface area affected by the relationship between lease span and building height directly causes the energy use pattern.

Table 8. Analysis of building parameters

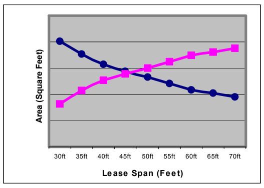
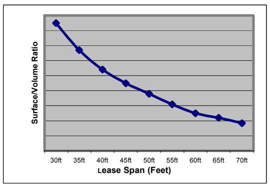
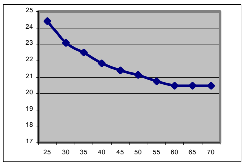
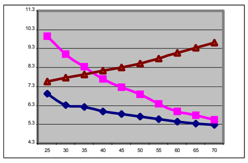
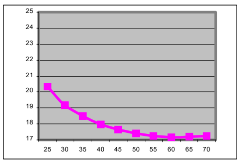
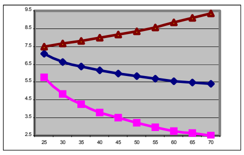
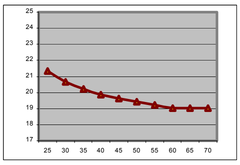
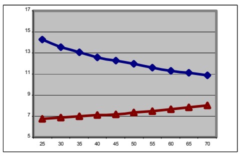
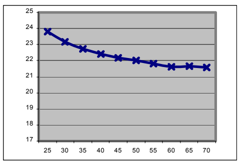
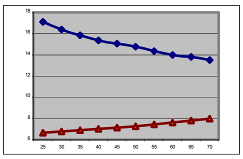
Area variation of parameter and Interior	Surface/Volume ratio
	
* Legend: ● Perimeter area, ■ Interior area	

Table 9. Energy use according to regional climate

	Integrated energy use pattern and Difference by heating, cooling, lighting	Individual energy use pattern and difference by heating, cooling, lighting
Cool		
Temperate		
Hot-arid		
Hot-humid		
	* X-axis: Lease span (ft), Y-axis: Energy use (kWh) * Legend: ■ : Heating, ◆ : Cooling, ▲ : Lighting	

Consequently, the lease span determination is a tall office building directly affects the variation of the relationship between perimeter and interior space, total building height, and building surface area. These factors affect the energy requirement as much as 10.6% to 20.7% in relation to region. The lease span determination is related with architectural expression for aesthetics in building aspect ratio, and it creates an occupied ratio between perimeter and interior space. For determination of the lease span in a tall office building at the first design stage, the design should be compromised based on the relationship of the building height, the occupied space ratio, and energy use. From the analysis, a building which has less than 40 feet lease span can be profitable to create a large perimeter space and to reduce the light load. A building which has more 55feet lease span can be advantageous for reduction of thermal loads, but the lighting load proportionally increases and much of the portion of the interior space is affected. The 1:1 ratio between perimeter and interior space can be created between a building which has 45 feet lease span and a building which has 50 feet lease span.

7. CONCLUSION

As a result of the previous comparison of design consideration for tall office buildings in relation to regional climates, buildings physically need less energy consumption when the architecture is concerned with the regional climate and it produces a more reasonable design strategy. That is, an architectural design and planning creates an internal working environment that is strongly related with regional microclimate. In reality, imbalanced planning (a design's lack of regional characteristics) requires additional environmental resources to control indoor working conditions.

Therefore, the application of integrated regional design information should the first architectural design stage and this research produces the rational. This design methodology focused on regional climate adaptability which simultaneously reduces the destructive environment in nature for sustainability. Consequently, this architectural design language approach must be a starting point to long-term planning.

REFERENCES

Beedle, L. S., (1971) "What's a Tall Building?", ASCE Annual and Environmental Engineering Meeting, St. Louis, MO., Preprint No. 1553 (M20), American Society of Civil Engineering, New York, N. Y., as cite by Council on Tall buildings and Urban Habitat, "Architecture of Tall Building"', *McGraw-Hill Inc.*, N.Y., N.Y., 1995, p. 85

Cho, J. S. (2002) "Design Methodology for Tall Office Buildings: Design Measurement and Integration with Regional Character", *Illinois Institute of Technology*, Chicago, USA

Council on Tall buildings and Urban Habitat, (1995) "Architecture of Tall Building"', *McGraw-Hill Inc.*, N.Y., N.Y., p. 85

Daniels, K. (1997) "The Technology of Ecological Building: Basic Principles and Measures Examples and Ideas" *Birkhauser/Princeton Arch Press*, Germany

Daniels, K. (1998) "Low-tech Light-tech High-tech" *Birkhauser/Princeton Arch Press.*, Germany, 1998, p.17

Olgyay, V. (1963) "Design with Climate: Bioclimatic Approach to Architectural Regionalism, Princeton University, Princeton, New Jerwey, USA

(Data of Submission : 2004. 3.27)