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 loss 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 exterior design parameters in the study include building forms, window areas, and building orientations. 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 based on ecological concept.

Keywords: design methodology, building orientation, building form, regional climate, ecology

1. Introduction

1.1. Prelude
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.

On the other hand, 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. This situation has allowed architectural design to be free from adapting to a regional nature system.

Architects have been 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. Architectural design should be concerned not only with interrelationship of space, but also with external factors such as climate.

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.

1.2. General Impact Factors in Architecture

The population growth and indiscrete development of technology have brought rapidly required energy consumption, and the simultaneous destruction of CO₂ diminishing forest regions of the earth. In fact, the combustion of fossil fuels since the industrial revolution has led to an excessive build-up in CO₂ and
these CO₂ 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 greenhouse effects and have a negative influence on the ecosystem.

**Policies and Social Responsibility**

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 policies to actively improve the production and application of renewable energy systems based on an economical purpose. Lim (1999) mentioned that this effort to actively promote energy efficient systems may first come from governments that initiate taxation incentives, introduce energy regulations and codes of practice and promote renewable energy. And, it may be generated by the individual who becomes aware of his or her social responsibility in environmental protection and renewal. Therefore, the policies 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.

**Population Growth**

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. Shea (1988) mentioned that in developing countries, if the population of these countries doubles 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.

**Lack of Commitment towards Energy Use**

Generally, architects and other designers have not considered the climate as a defining inevitable design factor in the modern age after the industrial era. This contrasts with pre-industrial architecture with a unique society and culture without high technology, and with an architectural design that responded to the regional climate conditions. 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 buildings were designed to maintain human comfort by technology which, in turn, created an environmental problem because of higher energy consumption to support mechanical systems in a building.

1.3. The Target of the Study

This study seeks to make a contribution to the development of the design methodology for tall office buildings in relation to regional climate conditions as a resource for architects during the early phases of the design process. The primary aim of this study is to evaluate design factors of a tall office building based on climate conditions by means of measurement of annual energy consumption of a building. It will indicate the consistency of the interrelationship between design factors for a tall office building and regional climate characteristics.

1.4. The Methodology of the Study

To evaluate design factors with climates, this research uses the hypothetical building model based on the measurement of basic design strategies in practice. The model assists the architects in determining external design considerations: building form, window sizes on façades, and building layout in respect to regional climate characteristics at the early stage of the design process. The building model as an experimental study is evaluated by means of computer simulation as the tool for experiments to achieve comparative analysis between the model to be considered and regional climates in the study. This research uses the eQUEST program based on DOE 2.2, and it will be utilized to obtain the expected data between design considerations and energy performance to measure annual energy consumptions in relation to regional climate conditions. This study will develop an integrated method of building design and planning by incorporating heating, cooling and lighting based on sequence of computer simulations in respect to different climate conditions.

2. Approach of a Fundamental Concept

2.1. 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 dependent on mechanical system technology resulted in unnecessary large energy consumption to achieve human comfort. Consequently, these situations led to architectural design becoming dependent on mechanical systems.

2.2. Approach to Ecological Design in Architecture

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, p. 1] The word ecology was introduced by biologist Ernst Haeckel in 1869. Ecology was viewed widely as a branch of biology before the 1970s. Ecologists were enrolled in biology departments and courses for ecology were generally found only in the biological science curricula. It has recently emerged from biology as essentially a new integrative discipline that links physical and biological processes and forms a bridge between natural science and social sciences. The word became part of the general vocabulary for study with natural systems about 1900. [Odum, 1971, pp. 2-3]

Ecology was traditionally the significant practical considerations to survive against a hostile nature in primitive society. All individuals were required to know their environmental system. The great paradox is that industrialized nations have succeeded by temporarily uncoupling humankind from nature through the exploitation of finite, naturally produced fossil fuels that are rapidly being depleted. Yet, civilization still depends on the natural environment, not only for energy and materials but also for the vital life-support process of air and water cycles. Therefore, our survival depends on knowledge and intelligent action to preserve and enhance environmental quality by means of a harmonious rather than disruptive technology.

There are conceptually two macroscopic worlds. One is a natural world which is uncontrolled by humans. The other is a manmade world which can be controlled by humans. The lack of harmony or integration between them results in an unsustainability and unbalanced nature.

Design is a hinge that inevitable connects culture and nature through exchanges of materials, flows of energy, and choices of land use. … Design manifests culture, and culture rests firmly on the foundation of what we believe to be true about the world. … We have used design cleverly in the service of narrowly defined human interests but have neglected its relationship with our fellow creatures. … We define ecological design as any form of design that minimizes environmentally destructive impacts by intergrating itself with living proceses. [Ryn, 1996, pp. 8-18]

Architecture has traditionally concerned itself with problem of architectural aesthetics including regional environment with low-energy societies. Some modern architecture has clearly concerned itself with the conquest of nature by the use of the high-energy societies’ technology. This has resulted in an unbalanced world between humans and nature which negatively affects the long-term survival of all species. Therefore, we need to consciously cultivate a transition from conventional forms of design that have destructive environmental impacts to ecologically sound forms of design.

Therefore, ecological design means a partnership with nature for the long-term all species on the earth and it clearly approaches the design dimension of the environmental crisis. Ryn (1996) described the integrated design concept implies that respects species diversity, minimizes non-renewable resources depletion, preserves nutrient and water cycle, maintains habitat quality, and attends to all the other preconditions of human and ecosystem health. Therefore, the considering ecological concept as the basis of any design can contribute to diminish the environmental negative impacts. The decreasing destructive environmental impacts can explicitly increase positive harmony between human and nature.

2.3. Design Factor based on Ecological Concept

Human life has been most significantly related with a natural system to survive since humans and all species on the earth inextricably need natural resources such as water, soil, and air from nature. By a theory, Homo sapiens began immigrating around the world from Africa some 100,000 years ago. After settlement began in different regions, human life in relation to different natural systems was made necessary to provide for human survival and comfort since mankind in the same environments encounters the same stresses as fauna. In order to provide adequate food and shelter, people who hunted and gathered to survive depended on a profound knowledge of their regional nature’s characteristics. Their survival revolved around seasonal changes and it is demonstrated in their architectural shelters.

Shelters that are built of regional materials and resting comfortably in the landscape can be found all over the world within their different regional environments. Furthermore, when mankind was confronted with more hostile climates in the past, the people tried to protect their bodies’ deficiencies by creating man-made environments and clothing. This was a logical starting point to create more spacious enclosures and the shelter became his most elaborate
defense against hostile climates. Therefore, the primary means of providing human comfort in the different natural conditions was creating their own protection using clothing and shelters.

Different regional climates have provided different types of living environments to adapt, survive and provide comfort from the extreme cold and heat to the savanna. The design of traditional houses is greatly different from region to region according to the natural resources available and the prevailing regional climate.

Although the nature system is very complex, it is obvious that climate is a dominant constituent of nature. Therefore, the design considering climate in architecture might be regarded as a part of the ecological approach. A regional climate physically provides that the architects legitimately begin the architectural expression in relation to building site, since climate is one of the dominant determinations of the regional inhabitant’s lifestyle as well as the landscape’s ecology.

From the preceding studies, the amount of non-renewable energy consumption to create human comfort in a space is clearly linked directly with the amount of destructive environmental impact. Therefore, the design with climate results in the diminishment of the overall energy use of the building through the reduction of mechanical technology. By this fundamental minimizing of the energy requirement, the overall emission of carbon dioxide and other environmentally destructive impacts are reduced, which contributes to a more harmonious relationship between nature and the manmade world for a sustainable future.

2.4. Concept of Energy Performance in a Study

The energy design of an architectural environment to achieve an optimum human comfort can conceptually into divided by 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 issues of artificial energy generation and consumption. (Figure 1)

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 2)

3. Construction of Hypothetical Model

3.1. Architectural Considerations

Table 1 shows the architectural considerations.

<table>
<thead>
<tr>
<th>Factors</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building gross area</td>
<td>2,166,000 square feet</td>
</tr>
<tr>
<td>Building typical floor area</td>
<td>36,100 square feet</td>
</tr>
<tr>
<td>Number of floors</td>
<td>60</td>
</tr>
<tr>
<td>% of Occupied area</td>
<td>70%</td>
</tr>
<tr>
<td>% of Core area</td>
<td>30%</td>
</tr>
<tr>
<td>Lease span depth</td>
<td>45 feet</td>
</tr>
<tr>
<td>Ceiling height</td>
<td>9 feet</td>
</tr>
<tr>
<td>Floor to floor height</td>
<td>13 feet</td>
</tr>
<tr>
<td>Windows</td>
<td>Double insulating ¼ in + ½ in + ¾ in</td>
</tr>
<tr>
<td>Walls</td>
<td>Aluminum (uncoloured) exterior finish</td>
</tr>
<tr>
<td>Core</td>
<td>Utility center core system</td>
</tr>
<tr>
<td>Function</td>
<td>Office with open plan</td>
</tr>
<tr>
<td>Considered building forms</td>
<td>Square, Rectangle (1:1.8 floor ratio), Triangle, and Octagon</td>
</tr>
<tr>
<td>Considered orientations</td>
<td>South, South-East, East, North-East, North, North-West, West, South-West</td>
</tr>
</tbody>
</table>

3.2. Engineering Considerations

Table 2 shows the engineering considerations.
Table 2. Assumption of Engineering Considerations

<table>
<thead>
<tr>
<th>Factors</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>HVAC system</td>
<td>Standard variable air volume system with electric zone reheat, Return air pass by duct, Electric resistance for heating, Chilled water coils for cooling (Chiller type: electric centrifugal hermetic)</td>
</tr>
<tr>
<td>Occupancy schedule</td>
<td>9:00am to 6:00pm, Monday through Friday</td>
</tr>
<tr>
<td>Space requirement</td>
<td>150 sqft per person</td>
</tr>
<tr>
<td>Indoor thermal</td>
<td>72 °F for heating set point, 75 °F for cooling point</td>
</tr>
<tr>
<td>Indoor lighting</td>
<td>50fc for ambient lighting level, Lighting control type: continuous</td>
</tr>
<tr>
<td>Indoor ventilation</td>
<td>20cfm per person for outdoor air requirement in typical space</td>
</tr>
</tbody>
</table>

3.3. Others Considerations

Other considerations are as follows:

- 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 cities in the United States according to climate zones: Chicago/cool, New York/temperate, Phoenix/hot-arid, Miami/hot-humid
- The total annual energy consumption of modelled buildings used for quantitative analysis
- Output data for energy use in buildings indicated as kWh

4. Results of Comparative Analysis

The study explores the integrated energy use characteristics of the design relationship among building forms, window sizes, and building orientations according to different regional climates as follows: (Orientation is constructed as shown in Table 3.)

- Southern layout buildings generally result in lower energy consumption than other considered orientations.
- Compared to the orientation with eight directions depending on climates, the building orientation implication for the square and the rectangular forms would be that buildings with a more southern exposure perform better than those with a more eastern exposure. Even though a southern exposure receives more heat gain and natural daylighting in winter; both east and west facades receive as much solar radiation in summer. The rectangular form generally has lower energy consumption than the square form on a southern exposure, but the arithmetical mean of energy use for the square form is lower than the rectangular form on the other orientations with the mean value for all climates.
- The rectangular form results in higher energy consumption on north-east or south-west layout than on a southern layout and the building orientation implication could be that the south-east or the north-east are better than the east layout for all climates.
- The triangular form generally results in a lower energy consumption on the south-east, north and west layouts. On the other hand, the south, east, and north-west layouts of the triangular form use higher energy for all climates. In addition, the south-west layout of the triangular form uses higher energy in the cooler climate, but this is reversed in a hotter climate.
- The design for octagonal form in tall office buildings can be advantageous with larger window size in all climates. The energy variation according to window glazing variation for the octagonal form is bigger than other considered forms for all climates.
- When looked at results individually, heating and cooling factor variations have an important effect upon total energy in all climates according to different orientations. The lighting variation according to orientation is slight.
- When looked at results synthetically, the harmonic design determination of tall office buildings improves the reduction of the total energy requirement for heating, cooling, and lighting as much as 19.3% to 27.1% in disregard of the offset effect between thermal and lighting performance according to regional climates (Chicago: 19.3%, New York: 27.1%, Phoenix: 26.6%, Miami: 24%).

The integrated information to determine tall office design based on the relationship among building forms, window sizes, and building orientations is shown in Table 4.

5. Conclusion

As a result of the previous 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
Table 3. Configuration of Building Orientation

<table>
<thead>
<tr>
<th>Direction</th>
<th>South</th>
<th>South-East</th>
<th>East</th>
<th>North-East</th>
<th>North</th>
<th>North-West</th>
<th>West</th>
<th>South-West</th>
</tr>
</thead>
<tbody>
<tr>
<td>Square</td>
<td>N</td>
<td>W</td>
<td>E</td>
<td>N</td>
<td>N</td>
<td>W</td>
<td>E</td>
<td>N</td>
</tr>
<tr>
<td>Rectangle</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Triangle</td>
<td>W</td>
<td>E</td>
<td>S</td>
<td>W</td>
<td>E</td>
<td>S</td>
<td>W</td>
<td>E</td>
</tr>
<tr>
<td>Octagon</td>
<td>N</td>
<td>W</td>
<td>E</td>
<td>N</td>
<td>N</td>
<td>W</td>
<td>E</td>
<td>N</td>
</tr>
</tbody>
</table>

Table 4. The Integrated Design Information with Regional Climates

<table>
<thead>
<tr>
<th>Regional Climates</th>
<th>Chicago/Cool</th>
<th>New York/Temperate</th>
<th>Phoenix/Hot-Arid</th>
<th>Miami/Hot-Humid</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-Axis: Energy use (kWhX000,000)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y-axis: Building orientation,</td>
<td>: Square</td>
<td>: Rectangle</td>
<td>: Triangle</td>
<td>: Octagon</td>
</tr>
</tbody>
</table>

Legend: X-Axis: Energy use (kWhX000,000)
Y-axis: Building orientation, : Square : Rectangle : Triangle : Octagon

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.

References