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Development of a Redesign Plan for Moore Hall using Architectural Principles of Green Building and Sustainable Design

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DEVELOPMENT OF A REDESIGN PLAN FOR MOORE HALL USING ARCHITECTURAL PRINCIPLES OF GREEN BUILDING AND SUSTAINABLE DESIGN

by

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An existing in-use office and classroom building on Western Michigan University's main campus was chosen for a redesign project which incorporated study of architectural principles of green building and sustainable design. The study emphasized the central importance of buildings themselves in modern life, their effects on building users and their work, their effects on user relationships with one another and the surrounding environment, and the need to enhance the building's positive, natural, and life-supporting relationship with the total environment including the users.

The redesign problem statement reflected issues and ideas from recent architectural and building construction literature, which emphasized green building and sustainable design. These concepts reflected a great need for buildings to focus on reduction of energy usage and creation of positive environmental interrelationship and reduction of negative structural impact on users and the environment.

A research plan developed for the study based on review of literature annotated the principles to be incorporated in the redesign. A qualitative approach, using interview respondents selected from building users, and semi-structured interview questions, detailing principles incorporated in the redesign, was specified, along with the questions used. User validation of result indicated green building/sustainable factors had been successfully incorporated and largely met with user approval.

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CHAPTER I

INTRODUCTION TO THE STUDY AND THE PROBLEM STATEMENT

1.0 Introduction

Buildings are one of the main aspects of our life today. Any developed nation shows that and reflects it in their buildings and its related technologies. There is always a competition to creating better environments in all kinds of buildings. Ideally this development will continue to provide better places to live and work. These developments need to be balanced between our needs as users and the available technologies, while bearing in mind the surroundings' parameters and problems.

Today changes in the technologies are rapid and complex. Moreover, there are many global issues intervening in their emergence, relevance, and application. These issues include global warming, pollution, and running out of energy sources. Building design and construction must be carried out with respect to these issues and must bring new solutions, such as using new materials, recycling of materials, and conserving energy, to the forefront of our attention and consideration. All of these matters, considered in conjunction with one another, are today called green building or sustainable design (Bobenhausen, 1999; Lewis, 2002; Mir, 2000; Rosenbaum, 2000; Stum, 2000;).

A big change is needed in the way new buildings are constructed--more than simply comfort for the users, health and performance considerations are also now primary concerns. This change of direction is called sustainable design. Green building also considers constructing new buildings that are friendlier to our environment. This trend started first in Europe and from there carried over to the U.S. The use of energy is high now and, with time, the world will face a shortage of energy. One third of the energy used at present in the world goes to buildings' consumption. Most of this energy is absorbed by lighting, heating, and cooling. Thus it seems reasonable to consider that architectural aspects and principles can be brought to bear to save considerable energy worldwide through careful attendance upon how buildings are structured (Aveni, 2001).

Green building provides a necessary solution for shortage in resources of energy. Green building application reduces energy consumption by 20-30 % on winter heating bills and can reduce air conditioning loads. Also, the green building helps building designers take greater advantage of critical natural resources, such as daylight, solar heating, and other related factors, such as natural heating. The green building is certain to have increased future demand from the peoples of the world. A growing body of research indicates that the green building is a powerful tool for designing future buildings with both human and environmental needs in mind USGBC (2003).

Despite the apparently clear logic, in the present time, of meeting the problem of energy shortage coupled with newly available, innovative technologies to help resolve this issue, utilization of green building and sustainable building approaches and acceptance and support of these concepts remain problematic. Preliminary analysis of the problem is indicated in the following sections of this chapter, followed by the problem statement, which acts as a guide for information assembled and concepts generated in Chapters II through V.

1.1 Analysis of the Problem

In this section the fundamental terms and concepts used throughout this study and generating the study's problem or focus issue are specifically considered.

1.1.1 Green Building Definition in Conjunction with the Concept of Sustainability

In order to fully consider the position and role of architecture in helping to resolve energy and environmental problems, while building human environments more compatible with nature, the terms green building and sustainability require some elaboration. The two terms or concepts (green building and sustainable design) are primarily used interchangeably. However, no unified, universally applicable definitions are currently maintained for the terms.

Lewis (2002) emphasized total integration into a composite whole of all design, materials, and systems factors of a building as primarily realizing the concept of "green." The purpose of such integration, moreover, consists of reducing to the lowest possible level the total effects of the building (and I must of course consider that Lewis intended here "negative" or "injurious" effects, though this qualification was not specified) on the environment and on the users of the structure, or in fact, anyone or anything impacted by it. That is to say, any building, in a very real sense, is a global issue, or system of issues, in its own right. Such system includes: "building site, materials selection, energy efficiency, water conservation, construction waste management, indoor air quality, and....landscape, recycling, ozone depletion, transportation, and wastewater control."

Loken (2000) suggested that the "appropriate use of technology and resources could be one working definition. Such a definition could apply to everything from the size of the home (they're too big for the average 2.64-person family) to the materials used to build, to the energy source to heat, cool, and power the space, and even to where it is placed."

Hoyt (2000) of McStain Enterprises, Boulder, Colorado indicated that within his organization the goal is "to build in such a way that we don't diminish the prospects of future generations." An important part of living this philosophy is in looking at the density and diversity of housing developments. Hoyt explained how McStain balances different types of housing units (condominiums, townhouses, single-family, and custom) with open space in its developments. By using this planning approach, McStain is able to create the densities necessary to attract mass transit. "Our whole planning focus gets away from architecture and designs for people."

Custom builder Ron Jones (2000) said being a green builder is as much about how and why you build as it is about what and where you build. Fitting in with the land and surroundings, rather than dominating both, is an integral part of green building. Jones, like other builders, suggested that there are enough shades of green to satisfy every operation. "No one builder can do everything, but everyone can... recognize the opportunities and then customize your efforts to match your own situation."

The concepts of green building and sustainable building correspond well with a growing global vision of concentrating on local needs and action. Thinking globally while acting locally becomes much more than just a cliché. The idea of the sustainable building gains credibility as global warming and the green house effect increase. Continuous adaptation to changes in technology and solution of global problems are needed.

Major elements involved in the concept and development of the green building are building site, water, energy, materials, and indoor environment and overall quality. Other relevant elements are landscape, recycling, ozone depletion, transportation, and dividing water usage into two distinct aspects: water conservation and waste water control.

1.1.2 Green Building in the United States

The U.S. Green Building Council (USGBC) is an organization that encourages the society to build safe and healthy places to live. It is established from more than 2000 companies and organizations. Important contributors are the Council's Leadership in Energy and Environmental Design (LEED), Green Building Rating System, International Green Building Conference and Exposition, membership summits, information exchange, education, and policy advocacy (USGBC, 2002).

Members from different fields and with varying experiences comprise the USGBC. Membership is open for building owners and developers; architectural, engineering; and design firms; contractors and builders; product manufacturers, environmental organizations, colleges, and universities; state and local governments; and federal agencies. The greatest influence of USGBC recently in the country is accelerating the transformation of markets at local levels. Achieving the balance between the concept of art and technologies is another goal of this organization. The participation of members leads to success in achieving goals, from improving the standard of LEED to issuing building codes (USGBC, 2002).

The recent emergence of USGBC chapters and affiliates across the country further accelerates market transformation at the local level. This rich diversity in perspectives and expertise is one of the hallmark traditions of the Council. Another is its consensus-oriented approach to ensure an effective balance between state-of-the-art concepts and technologies with established green building practices. Many of the Council's successes can be attributed to the work of dedicated members who volunteer their time, experience, and expertise to committees working on issues ranging from developing new LEED standards and education programs to "greening" state and local guidelines and building codes (USGBC, 2002).

The first major priority of the Council was to help guide the industry and prevent market confusion by developing a standard definition of high performance green buildings. In 2002, over four percent of all new commercial construction projects in the United States, by square footage, have registered for certification under the Leadership in Energy and Environmental Design (LEED) Rating System. The rapidly expanding portfolio of LEED standards offers third-party validation and recognition of sustainable building achievements supported by training and professional accreditation programs (LEED, 2002).

The main aspect of the LEED Green Building Rating System is to improve the market of the green building by providing the design practices of the building with a rating system. The LEED system is directed toward eventually issuing a standard definition of green building. At present the LEED is a measurement standard for designing the green building. The latest version of LEED is to check the building in the following aspects: Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, and Indoor Environmental Quality. The package of LEED includes introduction concerning the training of LEED and a reference guide for green building. The new package will accelerate the marketing of buildings and facilitate sustainability and building design (LEED, 2002).

1.1.3 Sustainability

The need for sustainable building is growing due to increased global warming and the Green House Canopy. Another reason is the need for more conservation in the use of our energy. Energy used in the building is 30% of all the energy used in our world today, and 60% of the total electricity use. Most of this energy is used for air conditioning and lighting. These two major elements need more attention from the architectural point of view (NSTC, 1993).

Architects need to utilize the sun and its natural light during the day especially in office buildings, which are occupied primarily during the day. Natural light clearly should be used instead of ignoring it or avoiding it. Also, architects need to work with mechanical engineers from the design stage on to develop the air conditioning, using both passive and active methods. They need to use nature as a mentor. The use of natural forces such as wind and the flow of hot and cold air creates important opportunities for them in their designs.

Green building does not necessarily mean greater cost. Options include making competition for the winning design or changing the code. Others believe that the 10% extra cost in the building to make it green could be calculated from the saving in utility bills. Still others maintain that we could actually gain energy or increase our energy supply, rather than consume it, from buildings (Howard, 2002).

1.1.4 Smart Buildings

Smart building, another advanced construction approach, depends on using technologies to control and monitor the use of energy, such as lighting, in the building. Smart buildings integrate computer automation, space age materials, diagnostic sensors, and energy management technology to automate, measure, monitor, and control many different aspects of building function and condition.

1.2 Problem Statement

Approximately one-third of the energy in the earth is used in buildings, and most of this energy goes to the lighting, heating, and cooling. As global development continues to grow, apparently at an ever-increasing rate, current energy resources approach depletion, recurring severe shortages, or increased cost factors associated with their use. Therefore, some solution is needed to resolve this difficulty for humankind, but without interfering with meeting increased human needs (NSTC, 1993).

Using architectural aspects as an important solution component to reduce energy use in future buildings, through daylight orientation, ventilation, building form, microclimate, and green roof, is at present a critical consideration. Investors, developers, architects, engineers, facility managers, researchers, and policy makers need to be encouraged to adapt green building ideas to construction and associated energy needs. Even though several world-acclaimed and famous architects do not think that we need to be green to build our buildings, in view of a surpassing necessity to preserve the environment, conserve energy, and, overall, make human design and construction more compatible with nature, the green, sustainable approach is really the only rational way to design and build our buildings.

The green building today is a suitable and necessary issue for the construction industry to research, explore, and utilize, when appropriate and feasible, as fully as possible. We need also to address this issue from another side, which is simply providing a better place for everyone to live and work. The specific problem addressed for this study was to develop a redesign plan for an existing building which does not incorporate the principles and guiding practices and requirements of green building and sustainable design.

The underlying concept of the plan for redesign was to conform to ideas and recommendations from the study's research concerning green building and sustainable design. It was further intended that the plan should be practical and provide sufficient detail so that its practical value and economic feasibility were clearly and logically specified with technical clarity, so that result of the research and the redesign plan were amenable to validation.

1.3 Scope of the Study

The problem statement for this study, as developed and presented above, is addressed in greater detail in the remaining four chapters. Chapter II, Review of Literature, further establishes the aims and objectives indicated here in Chapter I and provides more extensive analysis of the problem statement and associated issues. Chapter III outlines the research approach and methodology carried out for the study. Chapter IV presents the interpretation of results and validation of the research. And Chapter V presents the summary conclusions and recommendations.

The research, analysis, redesign plan development, validation and interpretation, and summary conclusions, considered together, followed a logical format and sequence. From the review of literature, Chapter II of the study, principles of green building and sustainable design were derived and organized. In Chapter III, the principles governing the redesign of the identified, existing building were presented. Selection of these principles derived from examination of the identified, existing building and determination of how it could be practically rebuilt to incorporate green/sustainable aspects and requirements within a practical, economically, feasible format. All components considered necessary for development and validation processes of the plan were specified with reasonable detail to provide understanding and a foundation for fully carrying out the research: That is, the green/sustainable redesign principles were specified; the existing structure to which the principles were intended for application was appropriately and relevantly described; and the research approach, including questions intended for open-ended interviews, was specified.

Chapter IV presented the redesign with sufficient and appropriate detail correspondent with requirements and specifications determined as necessary and sufficient in Chapter III. The validation process indicated and specified in Chapter III was similarly realized in Chapter IV, inclusive of interpretation of findings and statements of rationale underlying the steps of qualitative research represented in Chapter IV. Chapter V considered the study as a whole in summary fashion, addressing some issues not entirely encompassed by the study, while also directing research attention along similar lines.

CHAPTER II

REVIEW OF LITERATURE SUPPORTING AIMS, OBJECTIVES, AND ANALYSIS OF THE STUDY

2.0 Introduction

More so today than ever before in the history of architecture's contributions to society, architects have both a weighty responsibility and a potentially highly creative opportunity, to seek to maximize the beneficial impact, while at the same time minimizing the injurious or negative effects of their buildings, for the environment, and for all humankind. The elements or factors reasonably thought under architects' control to bring to bear upon creation of structures are considered in this study in terms of relevant ideas from recent writings which are examined here in terms of architectural aspects in green building and sustainable design.

Three major perspectives under this heading help to elaborate upon ideas introduced in Chapter I. Each perspective comments upon and helps to resolve in a particular way the central research problem, as developed and outlined in Chapter I: Consideration of architecture's role in meeting the challenges of sustainability, building green, and thereby contributing to global solutions to human and environmental problems.

2.1 Architectural Aspects in Green Building and Sustainable Design

Architectural aspects are elaborated upon briefly below under three headings: nature as a mentor, guiding principles of green design, and energy efficiency.

2.1.1 The Architects' Responsibility and Role

There is a big responsibility for all parties in the construction area, including architects, to work together in the development of all the tools that support the adoption of sustainable buildings. These tools are products, resources, policy guidance, and educational and marketing tools. But the change cannot occur without help from industry; research organizations; and federal, state, and local government agencies.

Architects and their education play a big role in design and development of sustainable building. Their responsibility in the construction field is to work together to develop LEED products that support the adoption of sustainable building. Cooperation between the construction industries; research organizations; and federal, state, and local government agencies is essential to improve the building environment (USGBC, 2002).

Equally as vital to the architectural role in sustainable design and green building as application of technical expertise and maintenance of a cooperative spirit is respecting natural resources. The best design for building is to allow the owner to use more natural energy sources, such as solar heating, wind, vegetation, and surrounding bodies of water. More natural homes with trees around them have several advantages, such as sheltering the home and reducing the heat of summer, which in turn reduce the load of the air conditioning for the home. Previous studies showed that the sustainable building reduced the energy used for air conditioning. The sustainable design can reduce the winter energy bills by 35% (USGBC, 2002).

Good designers take advantage of surrounding environment factors, such as trees and shading from other buildings, to lower summer temperatures. Planting new trees and shrubs, and ground planting the area near the home reduce its temperature in summer and reduce cold wind effects in winter. During the summer, the planted trees along southwest to northwest can help in reducing the heat of the sun. Study by the Florida Solar Energy Center and Arizona State University indicated that the orientation of building, shading, colors of the surfaces, and proper planning for vegetation can lower the load for air conditioning (USGBC, 2002).

2.1.2 Nature as Mentor

Nature solves most of our problems. The caveman used the cave to protect himself from harmful and dangerous environmental elements, as well as to make his environment as comfortable for his settlement as humanly possible, given the resources and technology of the time. In some ways human habitation has since moved well beyond the conditions of the primitive cave dweller. Certainly our available technologies and resources, which we possess today, would bewilder and astound our forebears. Yet in a very real and important respect, one we must continuously strive to emulate today, the caveman was and regrettably continues as, our master, which is to say, simply, that he continuously struggled, and with notable success, to employ all natural resources at hand; he strove to maximize his access to available daylight, his capture of the force of wind, his control of water supplies, and his maintenance of proper orientation to help him to adapt himself in a particular place.

Today, architectural design has returned to readapt many of humankind's first adaptation and survival principles. The concept of "Sun Wall" is an important method for utilizing the energy of the sun as it directly contacts the exterior of the building. The designer uses both hydronic and photovoltaic solar panels to maximize the use of sun's energy throughout the year. In wintertime, this energy is used to heat the water used in the building's heating system, incorporating residual energy as part of the ventilation system. In summer, the sun's rays act to generate electricity, importantly providing for cooling of the building. The U.S. Department of Energy (DOE) has long advocated and itself employed this method (Aveni, 2001).

Architectural educational institutions focus upon many environmental aspects today in their research and presentation concerning building design. Some question remains, however, whether sustainable design has been yet institutionalized in the field of architecture and the educational departments which should, ideally, support it as a top priority consideration or a fundamental practice. Many architects simply maintain that they must design for the customer alone, which customer and dictates expressed control everything involved. Perhaps more explicitly, architects must defer to the ruling building code, wherein the regulations control all.

2.1.3 Guiding Principles of Green Building Design

Significant to heat and cooling reduction are the choice of materials and construction procedures. Wood framing and the use of wood in general have high insulation advantages over other materials. Wood framing adapts well to future insulation.

The first guiding principle of effective green building is to consider all factors and elements, which contribute to reduction of energy use in the building. Reducing energy use may act as the most significant factor. Three underlying factors are determinants: low energy heat, passive ventilation system, and minimizing heating and cooling needs (Canadian Wood Council, 2001).

Other recommendations that are important to green building are:

- Use recycled materials to reduce solid waste; cut manufacturing energy consumption.
- Save on use of natural resources.
- Use renewable energy, passive-solar heating, and natural cooling when possible to greatly cut resources depletion; meticulous design to minimize overall building size, resources used, and operation costs.
- Construction of low-maintenance, water-efficient landscaping to preserve water resources and lower pesticide use.
- Incorporation of future reuse and adaptability into the design, through choice

of materials and components.

- Incorporate recycling of gray water from sinks, showers, and related sources for irrigation.
- Conscientious-renovation of extant buildings, in itself the most sustainable construction.
- Use energy efficiency building practices, including: high levels of insulation; high performance windows and tight construction; and high efficiency heating and cooling equipment (Wilson, 2000).

These are a few recommendations, which show the efficient use of natural resources that can be cleverly incorporated in the design of the building to reduce cost and increase aesthetics. Not only the use of natural resources but also were it planted and utilized makes a difference.

Related recommendations indicate that preservation of existing vegetation maintains shade and reduces energy use. Preserving and planting trees, especially on the structure's east and west reduce cooling loads; similarly, hedgerows and shrubs block winter winds and channel cooling summer breezes. And finally, use of salvaged materials including lumber, millwork, plumbing, and hardware saves multiple valuable resources (Wilson, 2001).

Even though there are many advantages of Green buildings there a few problems too, just like there are two faces of a coin. Building green buildings should be done in a professional and carefully thought out manner. Improper installations and using wrong resources defeats the purpose of having a green building itself. Problems arise in using green design principles of green building. Stum (2002) noted, "Green products are more likely to be misapplied and poorly installed and utilized by construction and facility operations teams that are conventional products and techniques. Thus, commissioning a green building is absolutely essential – especially if the owner is enrolled in a formal certification process."

As mentioned earlier there should be great focus in the incorporation of green design – this is extremely important. To incorporate rules into the design and implementation a commissioning process is involved. This ingenious process has a formal method of ensuring quality and workmanship. The commissioning process for green building is a formal exacting system of inspection and monitoring which focuses on quality assurance and control process. The process extends from the design phase through the warranty period. Commissioning is intended to ensure that: "all building systems perform interactively according to design intent, that facility staffs are properly trained, and that documentation has been adequately provided" (Stum, 2002).

From an architectural design perspective, commissioning is essential. Without its proper enactment and implementation the green building will fail its purpose. In order to reap the benefits of the green building we have to ensure the quality and proper design, which should meet the exact requirements and specification of the commissions. Moreover, the people who incorporate these methods should be skilled individuals who are experts in their respective fields. If we have the right approach and wrong people implementing it then the whole design and eventually the purpose of green buildings will come crumbling to the ground. "Green-building components will fail to yield their expected benefits without a systematic process for quality control in the selection, specification, and installation of sustainable building features" (Stum, 2002).

In addition to commissions a rating system may also be used, an excellent design rating system would be the Leadership in Energy and Environmental Design (LEED) which is a comprehensive rating system as well as a guide resource for green building and sustainable design. LEED functions through the United States Green Building Council (USGBC).

The commitment of the organization and rating system is that "any building can be sustainable designed and built" (Ervin; cited in Heating/Piping/Air Conditioning Engineering (HPACH, 2000). Four levels of award are indicated:

- First is simply certification then
- Silver and then
- Gold and finally
- Platinum the highest level (LEED, 2000).

An important approach would be to ensure that green building and sustainable design is to use the natural resources available around the structure. For example there are many uses for solar energy – It can be used to heat, to generate electricity or even to cool. Coupled with other natural resources you have a complete building that is cost effective in construction and utilization of the life of the structure. "Integrate passive solar energy efficiency and other renewable energy technologies that can be used to reduce building energy consumption" is designated as "high-performance, whole building." The approach emphasizes examination of building design to understand "how a building interacts with its systems, activities, and surrounding environment." The approach has been tested to reduce operation cost by 63%, energy use by 50%, and cooling load by 43% (Mir, 2000).

A wonderful example would be solar walls or sun walls that have been increasingly important to green construction. The wall is ideally curved possibly more than 100 feet high, and incorporates hydronic and photovoltaic panels. The walls may have electrical production as well as heating capacity (Aveni, 2001).

It is interesting to see that Green design has been around since ancient times. Earlier the designs were used for efficient use and conservation of energy. Only recently there has been some serious research and dwelling over the importance and advantages of green design implementation. Todesco (1998) noted that green building practice and sustainable design are a return to earlier architectural principles that relied on design facets of the building to control heat, cooling, and energy use, prior to vast mechanical, technological capabilities and strategies for achieving these results. The return to design incorporation of natural process access, protection, and utilization of the surrounding environment was instigated by energy consumption and environmental interference problems associated with the modern day tendency to build around the technology and rely upon it for controlling interior space. New sustainable, green approaches using "design optimization" promise 50 % lower CO2 emissions. The overall approach calls for combining optimized architectural design with "full integration with the mechanical design."

Bobenhausen (1999) noted that sustainable/green design depends on adaptation to the specific situation but universal elements exist: Clear definition and holistic understanding of the design problem; introducing integrated, holistic approach at inception of the building setting performance goals; stipulation of the environmental needs and potentials of programmed spaces; and consideration of systems and equipment option only after operational needs and realities are understood and the design scheme is underway.

Successful applications of natural ventilation systems lower costs of energy, improve the indoor environment, and create satisfactions to users unavailable otherwise. Greater cooperation is required between the architect and the mechanical engineer. Systems integration must exist at the highest level; and inclusion of the engineering function on the design team is essential. Cross ventilation and wind tower combinations have been demonstrated to adequately replace air conditioning on virtually any scale. The physiological and psychological benefits of not enclosing users in an air conditioned box are substantial. Direct savings of energy range from 25-40% (Jones & West, 2001).

Natural ventilation further increases health benefits when nighttime air flushing process is used. Natural ventilation enhances lighting options over mechanical, with significantly high user approval over air conditioning. Studies indicate users tend to appreciate greater exposure to temperature fluctuations, especially when individual control such as opening and closing windows is employed.

Understanding of air pressure factors and effects is critical (Jones & West, 2001).

Finally, Leadership in Energy and Environmental Design (LEED) focuses on five core areas of green/sustainable design and building. These are:

- Selecting and maintaining suitable sites that reduce impact on the environment (already used, but in need of enhancement, such as putting up an athletic building on an unused or abandoned athletic track, for example); protect or leave undisturbed the environmental context and reduce surrounding environmental effects such as excessive heat and toxin production;
- Attending to water efficiency and resolving storm and wastewater problems;
- Reducing energy use and benefiting the atmosphere;
- Reuse of materials; and
- Enhancing indoor environmental quality (LEED, 2003).

2.1.4 Energy Efficiency

In addition to green building and sustainable energy efficiency, simple, routine maintenance and building monitoring procedures predictably save 15% or more on energy costs in work environments. The Efficiency and Conservation Authority (EECA) has specified the following:

- Clean light tubes and fittings at least every two years.
- Use 26 mm rather than 38 mm diameter fluorescent tubes.
- Install reflectors in your office light fixtures to reduce number of tubes needed.

- Use daytime cleaning, team cleaning, shorter periods or floor-by-floor cleaning to limit nighttime lighting use.
- Do not use personal heaters in a centrally heated office.
- Ensure that someone is turning off the air-conditioning at the end of the day.
- Turn off all of your office equipment (computers, printers, photocopiers, and lights) at the end of the day (contrary to popular belief, this does no harm).
- [Have an energy management program] incorporated into the company's quality improvement...
- [Conduct] an energy audit ... periodically (EECA, 2002).

Lewis (2002) in a system of green building information projects that: "typical reduction in energy operating cost for a green building is 25-40 % when compared to conventional buildings."

> The construction principle of embodied energy is an overall comprehensive consideration of total energy needed in terms of construction of a building over its lifetime. That is "The energy invested during construction, demolition, and disposal." Approximate calculations are made, that is, projections, for a set period of the building's lifetime, generally a period of fifty years. These calculations, in addition to deriving specific costs associated with a given building, lead more importantly to certain determining generalizations about energy use and prospects for enhancement. (Jacques, 1996)

An interesting find in the following paragraph is the energy consumption of different sectors. Jaques also enumerated these as follows: the largest amount of energy is consumed in end use; energy actually used for construction, the second highest user, is far less important (in terms of energy consumption). For residence building end use energy is 4 times construction energy; 7 times maintenance energy; for offices, indoor climate control alone is 7 times construction energy and 23 times maintenance energy; heating, lighting and air conditioning are the largest energy users; reduction in these together constitute "the most influential energy reduction measures."

It is important to identify the largest consumer of energy. Small upgrades and enhancements can effect the utilization and conversion of electricity. Energy efficiency is enhanced through systematic observation and monitoring of patterns of energy use and the most important end uses of energy. Identifying the largest users of energy is especially critical. Even very slight upgrades in large energy users' efficiency can greatly reduce overall energy consumption. Energy modeling is used on the largest projects with annual energy costs projected at $50,000 per year or more. Maximum demand is calculated. Weather data is applied to the model. In addition to outside temperatures, strength and direction of solar radiation is considered, particularly on the western side. Interior conditions considered include: accommodation density; the required internal temperature range; the rate of fresh air supply; lighting levels in different areas; and operation hours (EECA, 2002).

2.2 Case Studies

2.2.1 Overview

Green buildings have sprouted in the United States recently. The United States

Green Building Council (USGBC) announced in July 2000 the first sustainable green buildings in the United States. The buildings were rated by USGBC according to the LEED criteria. The LEED rating has different levels of evaluation to indicate how much every building achieves according to and derives from sustainable design. The five levels are:

- Platinum
- Gold
- Silver
- Bronze
- Certified.

The first buildings achieving LEED ratings are indicated in the table below, by project name, location, and LEED rating. See Table 1.

Ervin (2000) indicated that green and sustainable buildings were "the only buildings that represent a diverse group of building types and prove that any building can be sustainable designed and built." Another reaction to the buildings found that each was characterized by a highly cooperative design and construction team working out solutions together. Each had a level of innovation for applying sustainable technologies or practices. All the projects exercised good environmental vision with sound economic results, such as construction-cost saving, energy and resource efficiencies, or lower anticipated operating costs (Keppler, 2000).

2.2.2 The Architectural Aspects in the Case Studies

There are many architectural innovations and solutions to make future buildings sustainable and green. Some aspects have been found to be more important

Table 1

The LEED Rating of the First 10 Green Buildings in the USA

Project Name	Location	LEED Rating
Bachelor Enlisted Quarters, Great Lakes Naval Training Center	Great Lakes, IL	Certified
Brengel Technology Center	Milwaukee, WI	Silver
Courthouse Square	Salem, OR	Bronze
Donald Bren School of Environmental Science & Management	Santa Barbara, CA	Platinum
Energy Resource Center	Downey, CA	Certified
Greater Pittsburgh Community Food Bank	Duquesne, PA	Silver
Kandalama Hotel	Damulla, Sri Lanka	Bronze
Project Name	Location	LEED Rating
KSBA Architects Office Building	Pittsburgh, PA	Certified
Nidus Center for Scientific Enterprise	Creve Coeur, MO	Silver
Phillip Merrill Environmental Center	Annapolis, MD	Platinum
Plaza Building	Tucson, AZ	Bronze
Q Building Lab	Skokie, IL	Gold
Steelcase Wood Furniture Manufacturing Plant	Caledonia, MI	Silver
Sundeck Restaurant	Aspen, CO	Bronze
Utah Olympic Oval	Salt Lake City, UT	Certified

than others. The designers of sustainable buildings need to consider the main architectural issues during the design and planning stage. From the case studies we concur that lighting and air conditioning are the two main items consuming most of the energy in the building. Solution and innovation approaches need more concentration in these two aspects in the study of sustainable design. Further description of these aspects is presented below.

2.2.2.1 Day Lighting

Outside, natural lighting is the ideal lighting for doing most of our activities in our lives. Industrial lighting strives to be as close as possible to daylight, because it is natural and is in harmony with our bodies. Also, it corresponds to other elements of the outside environment, such as sun, breeze, and outside views. Any sustainable building, but perhaps especially office buildings, where the interior space is used only during the daytime, needs to come back to the use of natural light, by allowing it to enter the building. Lighting could come from the roof. If the building is only one story such access is very elementary. If the building is multistory, on the other hand, more complex solutions in the design are necessary, in order for the light to pass through each of the floors. One approach to achieving this is illustrated in Figure 1. Light can also pass through the sides of the building, which are preferably in rectangular form, as illustrated in Figure 2 below.

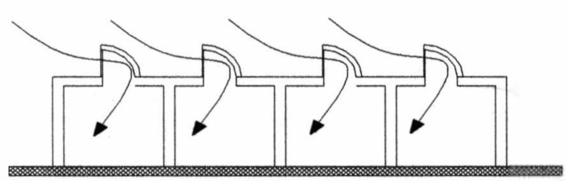

Figure 1. Showing the Use of Daylight From the Roof of One Building or From the Last Floor.

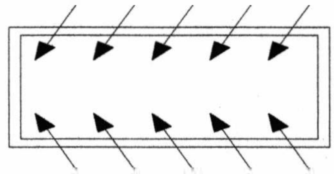

Figure 2. The Lighting From the Sides of the Rectangular Building Is Much Better Than Square Form.

2.2.2.2 Ventilation

Natural ventilation is one of the main aspects that can be utilized in green and sustainable buildings. Appropriate ventilation requires more than simply a mechanical solution. Better access to and utilization of outside air can reduce dependency on mechanically generated sources, and their inherent drawbacks of noise, malfunctioning, and energy consumption. Buildings could depend much more on outside, fresh air ventilation than they tend to do now, especially during the spring and fall. Adapting the sources of fresh air according to individual need is important. Users could, for example, control themselves the opening and closing of their windows. Most office buildings do not do that but instead depend much more completely on mechanical sources of ventilation. Important aspects of ventilation are indicated in Figures 3 and 4.

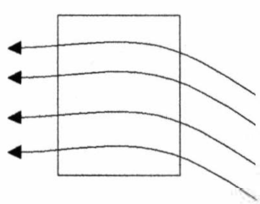

Figure 3. Natural Ventilation.

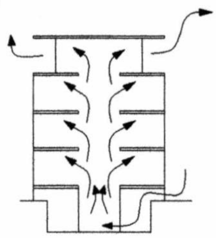

Figure 4. The Best Method and Place for the Air Conditioning Is From Below Flowing Upward.

2.2.2.3 Orientation

The orientation of the building is another aspect to help sustainable buildings get the maximum benefit of natural ventilation and the use of daylight. Building windows could more exactingly be oriented toward the wind or the direction of prevalent breezes. The distribution of the building could be made in a way to control when and how the sunlight enters the building. Generally, higher levels of sunlight are accessible from the southwest to the northwest. Room and window orientation, especially in colder climates, to best avail interior spaces of this heat and light source is a crucial and basic step.

The side of the building oriented toward heat and light source could be made longer and possibly higher than other sides, and with more adjacent open space, to maximize the desired effect. Simple observations concerning transitions in the sun's effect can readily be transposed into design accommodations. For example, in summer the rays of the sun strike the earth in a more vertical fashion during the day, and at close to a ninety-degree angle at sunset. The projection or overhang of the roof can greatly help to avoid the heat and light effects during the day in summer. In winter the smaller sun angle in reference to earth demands that more sunlight is accessed from morning until sunset. Figure 5 refers to aspects of this situation.

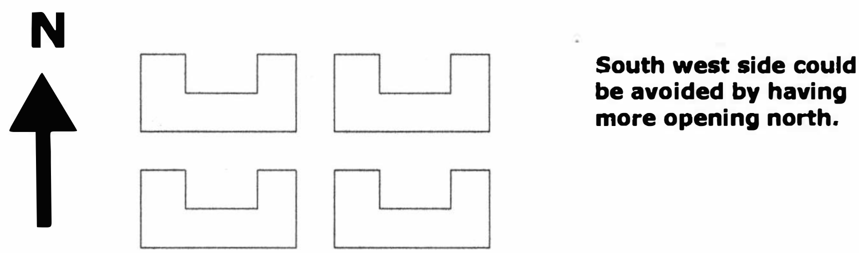

Figure 5. Building Orientation.

2.2.2.4 Building Form

The building forms are another important aspect in this matter. It is well known that the area and the shape of the land both limit and inspire the designer. The design must seek the best form according to consideration of the site's natural aspects. A basic example: The building could incorporate two rectangles instead of a square in order to allow the sunlight to better enter the building. Or more openings in the building could transform sides into rectangular strips within the square form, as illustrated in Figure 6.

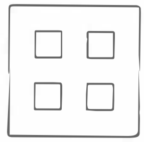

Figure 6. Converting the Square to Rectangular Shape.

2.2.2.5 Microclimate

Any project's microclimate is definitely not exactly the same as any others. Architects need to visit and survey the site and take notes as to what is the natural effect in the particular site, such as the amount of shade from adjacent buildings, the surrounding bodies of water, trees, sunlight, and so on. They need to consider and take advantage of all these aspects in the design concept. These aspects appear in Figure 7.

Figure 7 illiterates treating the wind temperature and moisture before they reach the building by landscaping solutions, such as trees, shadow, and water bodies.

2.3 Building Manual

Proper use of sustainable and green buildings can be a complex matter requiring considerable explanation to the users. Such explanation could be readily compiled in manual form. The manual also could annotate utilities cost projections for the building.

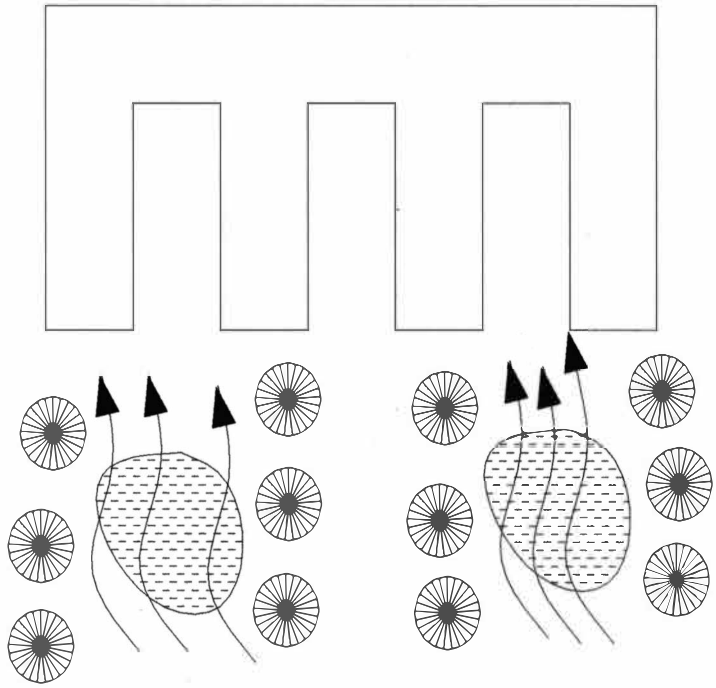

Figure 7. Landscaping Around the Building.

2.4 Air Circulation Inside the Building

Kibert (1999) stated that the Gerling Insurance Company Building in Nurnberg, Germany uses the solar heating and cooling which uses the natural forces to move the air inside the building. This project was designed be the architect, Seegy and Bisch who worked with Dr. Majid of the University of Stuttgart to study the movement of air around the building and to utilize it. The savings in (HVAC) were about 40 percent of conventional office building in Germany. He also lists these three principles for the successful building sustainable design:

- Excellent in planning.
- Design for adaptable, durable, structures.
- Extensive application of passive energy.
- Incorporation of high-efficiency energy-consuming system.
- The use of renewable energy systems.

Kibert beautifully elaborates the utilization of natural resources like the force of the wind to increase the circulation of air to conserve energy efficiently control the temperature of the building structure. Not only was he able to use an alternate source of energy with better planning and design that is cleaner, but was able to effectively reduce the cost by a forty percent margin.

It is interesting to see that in early times in the gulf countries we utilized a similar concept called the wind catcher which uses a tall minaret that works on the concept of pressure. The wind get trapped by the tall tower and it is the pushed downwards to provide an excellent yet efficient way to ventilate, aerate, circulate and increase the flow of air.

2.5 Window System

Today, with the new technology and advancements in glazing research there is practically no limitation in glazing technology. The only limitation that remains in glazing technology today is the glass thickness and the force of the wind. Double-glazing is a much better alternative in increasing the insulation of the building to keep the temperature constant inside than the effect of variation of temperature from the outside. Another advantage of double-glazing is that it increases the depth of the glass, which in turn increases the resistance of the wind force on the glass surface.

Design of vertical glazing is based on the following equation:

$$F_{gw} \leq F_{ga}$$

F_{gw} is the wind load and F_{ga} is the maximum allowable load.

International Energy Agency (IEA, 1999) stated that:

> Artificial lighting represents a major part of the overall energy consumption in non-residential building. However, more daylight conscious architectural solutions and the introduction of innovative daylight systems and efficient lighting controls can displace a considerable part of this electricity consumption by utilizing the natural resources offered by daylight. With the new glazing technologies of highly insulating windowpanes, there is *no longer any thermal reasons for limitations of the window area*, so one obvious way of getting more daylight is to increase the window size. Therefore, today the major challenge is to control the direct solar radiation and to improve the distribution of daylight in the spaces behind the facades.

Today, 3M Ultraflex Window System is an exceptional product in the market that can be used in green buildings.

> Chiller conversions will experience a loss in cooling capacity, an efficiency drop that could reach 15%. Because the 3M Ultraflex Window film can cut heat gain from 19- 76%. An application of Scotchtint window film may allow the building owner to maintain the level of cooling comfort for tenant without adding expensive cooling capacity or increase annual energy costs from additional chiller run time. (Costal Application System, 2003)

The openable window needs to meet the minimum requirement of the ventilation code which is not less than 1/20 of the total floor area (building code and standards).

2.6 Users' Productivity in Green Building

There are many studies like the one below that explains about office building lighting, heating and cooling and their effects on the employees' productivity. It is the psychological effect that enhances the workers efficiency and competence by providing a cleaner, well-lit and comfortable environment. A worker who works in a comfortable habitat will perform a lot better than the one who has to adjust in order to meet the level of efficiency required by the firm.

Some improvements such as window size, natural ventilation, openness, and flora - fauna can enhance their environment and work. According to a study by the Rocky Mountain Institute (as shown in Figure 8):

> Productivity gains of 6 to 16 percent, including decrease absenteeism and improved quality of work, have been reported as resulting from energy-efficient design. Since companies spend an average of 70 times as much money (per square foot per year) on employee salaries as on energy, an increase of just *1 percent* in productivity can result in savings that exceed the company's *entire* energy bill. (1998)

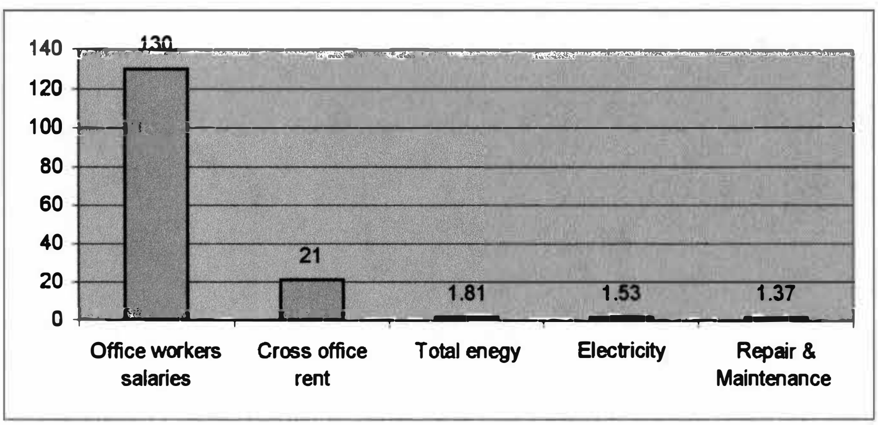

Figure 8. Average Annual Commercial Expenditure (Dollars per Square Foot).

2.7 Life Cycle Assessment

The National Institute of Standard and Technology (NIST) use the best tool for rating the energy and environmental performance of buildings and structures, which is the LEED method. Commercial buildings use 38% of the United States energy consumption during its operation, and 65% of all 1997 Municipal Waste. Therefore, early study for these buildings during the design stage can help a lot to lower the energy consumption and keep our environment clean. LEED defines the 5 following environmental impacts that they need to track in their rating:

- *Sustainable Sites (SS)*: site selection, and resources protection.
- *Water Efficiency (WE)*: storm water, and waste water.
- *Energy and Atmosphere (EA)*: optimize energy performance, Renewable energy, and green power.
- *Materials and Resources (MR)*: construction waste management, recycling materials, and local/regional materials.
- *Indoor Air Quality (IAQ)*: indoor environmental quality, and low emitting materials.

"Life Cycle Assessment is a valuable methodology for simulation of impacts from utilization of the LEED program" (NIST, 2000).

A study was done in University of Michigan, Ann Arbor for 2,450 residential homes, Standard Home, to find out the total life cycle energy consumption over 50 years. They found out that "total life cycle energy of a new residential home can be reduced by a factor of 2.8 by making incremental design changes that reduce the embodied energy, and the use-phase energy consumption of the home. This was achieved largely with an improvel thermal envelope, and an improvel HVAC system, and with energy efficient applications" (Blanchard, 1998).

2.8 Western Michigan University (WMU) and Sustainability

Western Michigan University (WMU) adapts the concept of sustainable design that has been explained before in this document. The university projects have included items such as recycling materials, energy efficient lighting or HVAC systems, and natural stormwater management systems. A Sustainable Design Committee was established on 11/12/2001 which consisted of members from the Facilities and Physical Plant and faculty members from the university.

Christofer Pyzik, who is one of the staff in the Campus Architectural and Interior Design, was appointed the head of the committee. They organized a new WMU Facility Life Cycle Design Guideline for future projects and to educate the community as well as students about Sustainability (see Appendix). All the projects were made to follow all these guidelines, which incorporate the LEED and various WMU specific criteria. "We are still working in the development of these guidelines" (Pyzik, 2003).

After all the current literature review about green buildings and sustainable design, some aspects are driven from them. Then, a comparison of this list with the first 10 green buildings in the United States is developed (see Table 2).

The following principle from the green building/sustainable design research carried out for this study and applied to the redesign plan for Moore Hall are recommended for the suggested program of development of buildings on Western Michigan University's campus. Each of these principles was invaluable for development of a coordinated and harmonious rebuilding design, and should similarly prove useful in related context as suggested in this section of the study.

2.9 Conclusion

Aspects of green building/sustainable design have been discussed and summarized in this chapter. Green buildings are the way to the future. If properly implemented, Green buildings can be extremely efficient and highly cost effective. These aspects or principles form the basis of the study's methodology as specified in Chapter III.

2.9.1 Architectural Aspects in Green Building and Sustainable Design From the Literature Review

After all the current literature review about green buildings and sustainable design, some aspects have been derived from there. Following are the key architectural aspects and the related features in the order that have been discussed above.

1. Respect for natural resources.
2. Use of natural renewable energy sources.
3. Use of naturally occurring vegetation.
4. Use of the "sun wall" and hydronic and photovoltaic solar panels.

5. Architectural institutionalization of green building/sustainable design.
6. Consideration of all factors, which contribute to energy use reduction.
7. Use of low energy heat, passive ventilation system, and minimizing heating and cooling needs.
8. Emphasis on choice of materials and construction procedures.
9. Use of recycling materials.
10. Reduction of use of natural resources.
11. Meticulous design to reduce building size and operation cost.
12. Incorporate future reuse and adaptability into the design.
13. Practices: high insulation levels, high performance windows, tight construction, high efficiency cooling and heating.
14. Integrating of passive solar energy and other renewable technonogies.
15. Ensure that design incorporates maximum positive integration with the environment.
16. Conscientious renovation of extant building (the most sustainable construction).
17. Operation cost reduction by 63%, energy use by 50%, cooling load by 43%.
18. Clear definition and holistic understanding of design problem.
19. Holistic performance goal from building's inception.
20. Stipulation of environmental needs and potentials of programmed spaces.
21. Systems and equipment option considered only after operational needs and realities specified and design scheme started.

22. Increase cooperation between architect and mechanical engineer.
23. Inclusion of engineering function on the design team.
24. Natural ventilation systems.
25. Use of cross ventilation and wind tower combinations to replace air conditioning.
26. Adaptation to natural temperature fluctuations, including individual user control.
27. Selection of building site to reduce environmental impact.
28. Leave the surrounding environment undisturbed.
29. Reduce environmental effects of excessive heat and toxin production.
30. Consideration of embodied energy: energy invested during Construction, demolition, and disposal (over the 50 year lifetime).
31. Largest amount of energy for end use.
32. Construction energy use is second.
33. For residence end use is 4 times construction, 7 times maintenance.
34. For office indoor climate control is 7 times construction 23 times maintenance.
35. Systematic monitoring of energy wastage.
36. Green and sustainable buildings are a diverse group.
37. Any building can be sustainably designed and built.
38. Good economic result.
39. Lighting and air conditioning consume most energy.
40. Natural lighting most appropriate for office building due to daytime use.

41. Roof and wall access to light, rectangular form preferred.

42. Non-mechanical natural ventilation reduces noise, malfunctioning, and energy consumption.

43. Low maintenance, water-efficient landscaping to save water and reduce landscaping to save water and reduce pesticides.

44. Orientation for fresh air and daylight (to wind, and sun).

CHAPTER III

RESEARCH METHODOLOGY

3.0 Introduction

The architect plays a very robust roll especially in the design phase to enhance the application of green buildings. Interestingly, in all my previous readings and research, I have never actually come across any architectural principals in green buildings and sustainable design. I am sure this will help resolve a lot of problems in the development and progression of green buildings and sustainable design.

It is my strong belief, that we should do concentrated study in the architectural field of green building the way my research is focused on. In my research I will provide the six principals that will inadvertently cover all the aspects of the design of green buildings. Finally, the validation process will be as follows:

- To make the aspects more valuable the Aspects will be validated with the occurrences in the LEED's rating case studies.
- Then we take the aspects and compare it with the six principals to validate the principals itself.
- These six principals will be used to redesign the Moore Hall building as an application to the principals.
- Finally, the interview with the building tenants to discuss the redesign

plans and to understand the responses.

3.1 Correlation of Architectural Aspects and the Occurrences in LEED's Cases

The following table will give a point-to-point basis of the numerous architectural aspects, their occurrences in the LEED's rating case studies and their respective percentages. These LEED's percentages are being used to corroborate and confirm the various architectural aspects.

All these architectural aspects have been derived from the literature review that has been described in Chapter II. As we advance into Chapter III we will mention the six architectural principals in green building and sustainable design. The combination of data from both of these chapters will be used to authenticate the six architectural principals, which is the foremost goal of this research.

Table 2

Correlations of Architectural Aspects and the Occurrences in LEED's Cases

Aspect	**Architectural Aspects description**	**No. Of Occurrences in LEED's cases**	**Percentage Of Occurrence in LEED's cases**
1	Respect for natural resources.	10	10
2	Use of natural renewable energy sources.	10	100
3	Use of naturally occurring vegetation.	10	100
4	Use of the "sun wall" and hydronic and photovoltaic solar panels.	2	20

Aspect	Architectural Aspects description	No. Of Occurrences in LEED's cases	Percentage Of Occurrence in LEED's cases
5	Architectural institutionalization of green building/sustainable design.	10	100
6	Consideration of all factors, which contribute to energy use reduction.	10	100
7	Use of low energy heat, passive ventilation system, and minimizing heating and cooling needs.	10	100
8	Emphasis on choice of materials and construction procedures.	10	100
9	Reduction of use of natural resources.	10	100
10	Meticulous design to reduce building size and operation cost.	10	100
11	Incorporate future reuse and adaptability into the design.	10	100
12	Practices: high insulation levels, high performance windows, tight construction, high efficiency cooling and heating.	10	100
13	Integration of passive solar energy and other renewable technologies.	4	40
14	Ensure that design incorporates maximum positive integration with the environment.	10	100
15	Conscientious renovation of extant buildings (the most sustainable construction)	2	20
16	Clear definition and holistic understanding of design problem.	10	100
17	Holistic performance goal from building's inception.	10	100
18	Stipulation of environmental needs and potentials of programmed spaces.	10	100
19	Systems and equipment option considered only after operational needs and realities specified and design scheme started.	10	100

Aspect	Architectural Aspects description	No. Of Occurrences in LEED's cases	Percentage Of Occurrence in LEED's cases
20	Increased cooperation between architect and mechanical engineer.	10	100
21	Inclusion of engineering function on the design team.	10	100
22	Natural ventilation systems.	4	40
23	Use of cross ventilation and wind tower combinations to replace air conditioning.	2	20
24	Adaptation to natural temperature fluctuations, including individual user control.	3	30
25	Selection of building sites to reduce environmental impact.	9	90
26	Leave the surrounding environment undisturbed.	10	100
27	Reduce environmental effects of excessive heat and toxin production.	10	100
28	Consideration of embodied energy: energy invested during construction, demolition, and disposal (over the 50 year lifetime).	10	100
29	Largest amount of energy for end use.	10	100
30	For office indoor climate control is 7 times construction 23 times maintenance.	10	100
31	Systematic monitoring of energy wastage.	10	100
32	Good economic result.	10	100
33	Lighting and air conditioning consume most energy.	10	100
34	Natural lighting most appropriate for office building due to daytime use.	10	100
35	Roof and wall access to light, rectangular form preferred.	10	100

Aspect	Architectural Aspects description	No. Of Occurrences in LEED's cases	Percentage Of Occurrence in LEED's cases
36	Non-mechanical natural ventilation reduces noise, malfunctioning, & energy consumption.	4	40
37	Orientation for fresh air and daylight (to wind, and sun)	10	100
38	Any building can be sustainable designed and built.	10	100

3.2 Development Principles and Factors of the Redesign Plan

Architectural principles and associated factors related to green building and sustainable design were developed, as the basis for redesign of Moore Hall, from information provided in the review of literature. These principles and factors are specifically considered in this section. They will also be reconsidered later, in the succeeding chapters of this study from the perspective of reaction to and evaluation of their incorporation within the completed redesign plan (as presented in Chapter IV):

1. The first principle forming the basis of the redesign plan is to utilize as fully as possible available natural daylight for illuminating interior space of the building, whenever feasible within practicable limits, with equal emphasis on classrooms, corridors, offices, and courtyards (see Figures 1 & 2).
2. The second principle is provision of maximum usable levels of fresh air from the outside to all interior space, maximum circulation of the fresh air throughout the building, and efficient exhaust of depleted air

from the building back into the outside environment. Thus, a system of healthful, refreshing, and economical natural air conditioning is realized (see Figure 3).

3. The third principle is maximum practical utilization of smart building technology to monitor and control the most efficient use of the building.
4. The fourth principle is self-generation of electric power for the building from solar sources.
5. The fifth principle is use of the courtyard system to create a central area of openness, visibility, natural light, connection with the natural environment, and pleasant surroundings for building users and their activities (see Figure 10).
6. The sixth and most encompassing principle, from which most of the impetus of the other five principles is derived, is that all aspects of redesign should contribute, to the greatest extent possible within practical limits, to the use of naturally occurring energy sources readily available from the immediate environment, and to the reduction or elimination, when possible, of use of conventional, costly energy sources, such as burning of fossil fuels, thus reducing overall energy use.

This principle corresponds to and helps to fulfill the overarching goal of green building and sustainable design, which is reduction in overall energy use and cost.

The working guideline for this fulfillment is that through application of redesign to Moore Hall, total energy cost should be reduced by 40-55%.

Mentioned above we have already validated the Architectural aspects. Now, we will use those architectural aspects and compare them to the six principals in order to authenticate them. In the table below we individually take the architectural aspects and compare them separately to the six principals, which in turn are validated. The six principals is a small number, which are easy to handle, track and apply, and is convenient for all the people who will work in the field of green building and sustainable design.

Table 3

Comparison of the Architectural Aspects and the Six Principles

Aspect	Architectural Aspects description	Occurrence in the Six Principles
1	Respect for natural resources.	1, 2,4, 5, 6
2	Use of natural renewable energy sources.	1, 4, 5, 6
3	Use of naturally occurring vegetation.	5,6
4	Use of the "sun wall" and hydronic and photovoltaic solar panels.	4,6
5	Architectural institutionalization of green building/sustainable design.	1-6
6	Consideration of all factors, which contribute to energy use reduction.	1-6
7	Use of low energy heat, passive ventilation system, and minimizing heating and cooling needs.	1,2,5,6

Aspect	Architectural Aspects description	Occurrence in the Sixth Principles
8	Emphasis on choice of materials and construction procedures.	1-6
9	Reduction of use of natural resources.	1-6
10	Meticulous design to reduce building size and operation cost.	1-6
11	Incorporate future reuse and adaptability into the design.	1-6
12	Practices: high insulation levels, high performance windows, tight construction, high efficiency cooling and heating.	1,5
13	Integration of passive solar energy and other renewable technologies.	1,2,4
14	Ensure that design incorporates maximum positive integration with the environment.	1-6
15	Conscientious renovation of extant buildings (the most sustainable construction)	N/A
16	Clear definition and holistic understanding of design problem.	1-6
17	Holistic performance goal from building's inception.	1-6
18	Stipulation of environmental needs and potentials of programmed spaces.	1-6
19	Systems and equipment option considered only after operational needs and realities specified and design scheme started.	1-6
20	Increased cooperation between architect and mechanical engineer.	2,6
21	Inclusion of engineering function on the design team.	1-6
22	Natural ventilation systems.	2,6
23	Use of cross ventilation and wind tower combinations to replace air conditioning.	2,6
24	Adaptation to natural temperature fluctuations, including individual user control.	3

Aspect	Architectural Aspects description	Occurrence in the Sixth Principles
25	Selection of building sites to reduce environmental impact.	1,2,6
26	Leave the surrounding environment undisturbed.	1-6
27	Reduce environmental effects of excessive heat and toxin production.	1-6
28	Consideration of embodied energy: energy invested during construction, demolition, and disposal (over the 50 year lifetime).	1-6
29	Largest amount of energy for end use.	1,2,3,4,6
30	For office indoor climate control is 7 times construction 23 times maintenance.	1,2,3,4
31	Systematic monitoring of energy wastage.	3
32	Good economic result.	1-6
33	Lighting and air conditioning consume most energy.	1-6
43	Natural lighting most appropriate for office building due to daytime use.	1
35	Roof and wall access to light, rectangular form preferred.	1-6
36	Non-mechanical natural ventilation reduces noise, malfunctioning, & energy consumption.	2
37	Orientation for fresh air and daylight (to wind, and sun)	1,2
38	Any building can be sustainably designed and built.	1-6

3.3 Description of Moore Hall (047) as It Currently Exists

Moore Hall is located on the campus of Western Michigan University (WMU) at North VandeGiessen. It was originally built as a women's dormitory with community bathrooms in March 1962. The building was named after Grace and Mary Moore, sisters and longtime members of the WMU staff. The current usage now is for classrooms and offices. This building has 5 floors. It has roughly 71,206 square feet. Building Coordinator is Ms. Marilyn Duke of the Academic Skills Center (see Figure 8).

Figure 9. View of Moore Hall.

The Anthropology Department takes up one whole corridor on the first floor; the Academic Skills Center is on the other corridor. Classrooms take up the remainder of that floor. The basement has three classrooms, utilized by the departments in the building.

Also on the first floor is an audio/video storage room for the Anthropology Department. The Anthropology Department also uses the basement for archaeology laboratory space and storage space for the archaeology collections that the department possesses. Originally, the building was connected to another dormitory with an underground corridor. This corridor was used both to bring food from a kitchen in the other building to Moore and to allow the occupants to access the dining facility from inside. The entrance to the other building, Burnham Hall, is now blocked. The corridor/tunnel itself, however, is used as an archaeology lab, but has extremely poor heating.

The building is not hooked up to the main heating supply. There is a very large heating unit attached to the ceiling of the building, but it is not very efficient. For the building to stay warm, the unit must run constantly in cold weather.

There are no bathrooms in the basement. On the first floor there are both men's and women's restrooms. On the second and fourth floors, there are only men's restrooms, and on the third floor there is a women's restroom. All the restrooms are old converted community shower rooms; the mirrors along whole walls, however, are very nice and attractive, according to at least one user (Yolanda, 2003).

The offices are old dorm rooms, each office having a tiny little closet. The office corridor does have a big window at the end wall with a heater along it. The user providing information above stated that: "In Moore hall, because there was light and the window was fairly wide, I would often sit on the heater while I was waiting for a class to start or I would just sit there and read. My office was Moore 105 (between office 118 and the exit). That is probably my favorite place" (Yolanda, 2003). Moore Hall as it currently appears (from the entrance) is depicted in Figure 10.

Figure 10. Another View of Moore Hall Building.

3.4 Old Building Design

The existing building design is simple and reasonable for an earlier time. Green building aspects were not considered when the architect began to design this building. For example, the corridors are long, not well lighted, and neither convenient nor attractive for passing along them. Also, artificial light is constantly needed during both day and night. The offices have small windows that do not allow sufficient light to enter the room and substitute for the artificial lighting. Diagrams of the original floor plans are provided in Figures 11 and 12.

3.5 Validation of the Redesign

The proposed redesign of Moore Hall, as realized in terms of the principles and associated factors of green building and sustainable design theory, developed in Chapter Two and applied in this chapter to the redesign component of this study's research project, is validated in terms of current users' responses to the redesign. Responses follow from a set of interviews questions specifically focused on the researcher's intentions, as derived from review of relevant literature of green building and sustainable design and as evidenced or realized within the total redesign package, and subjected to user examination.

This approach to validation corresponds with a qualitative research initiative perspective according to which gaps in measurement of achievement, realization, or results interpretation, due to critical factors not readily open to quantitative "scientific measurement" must be addressed (for example, user perception of result in conjunction with satisfaction) and relevant information understood (Keeves, 1997).

3.6 Process of Interpretation of Findings

Findings of the study, primarily in terms of validity claims constructed from potential user response to the overall redesign subjected to their review and analysis, and as focused through researcher-articulated interview questions, are interpreted

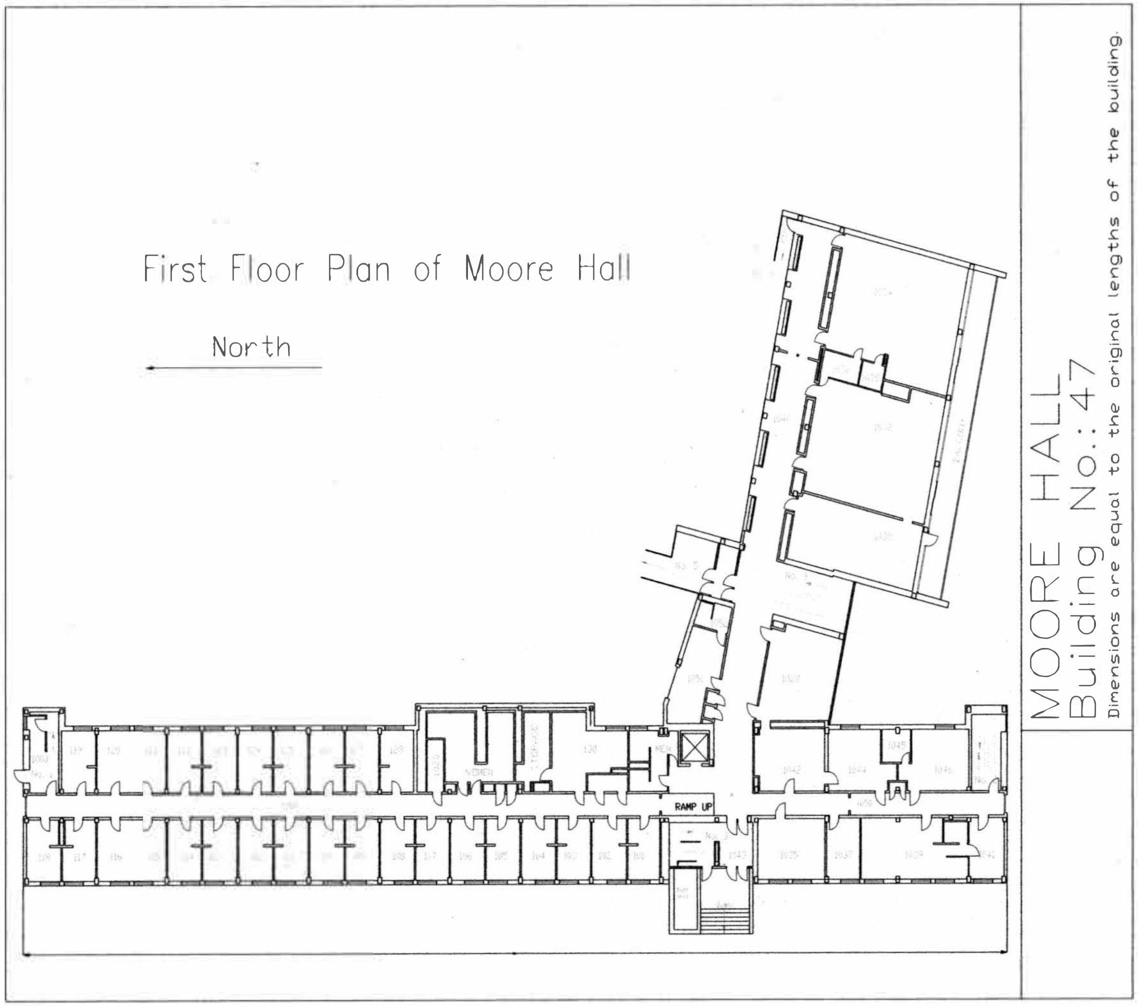

Figure 11. Old Ground Plan of Moore Hall.

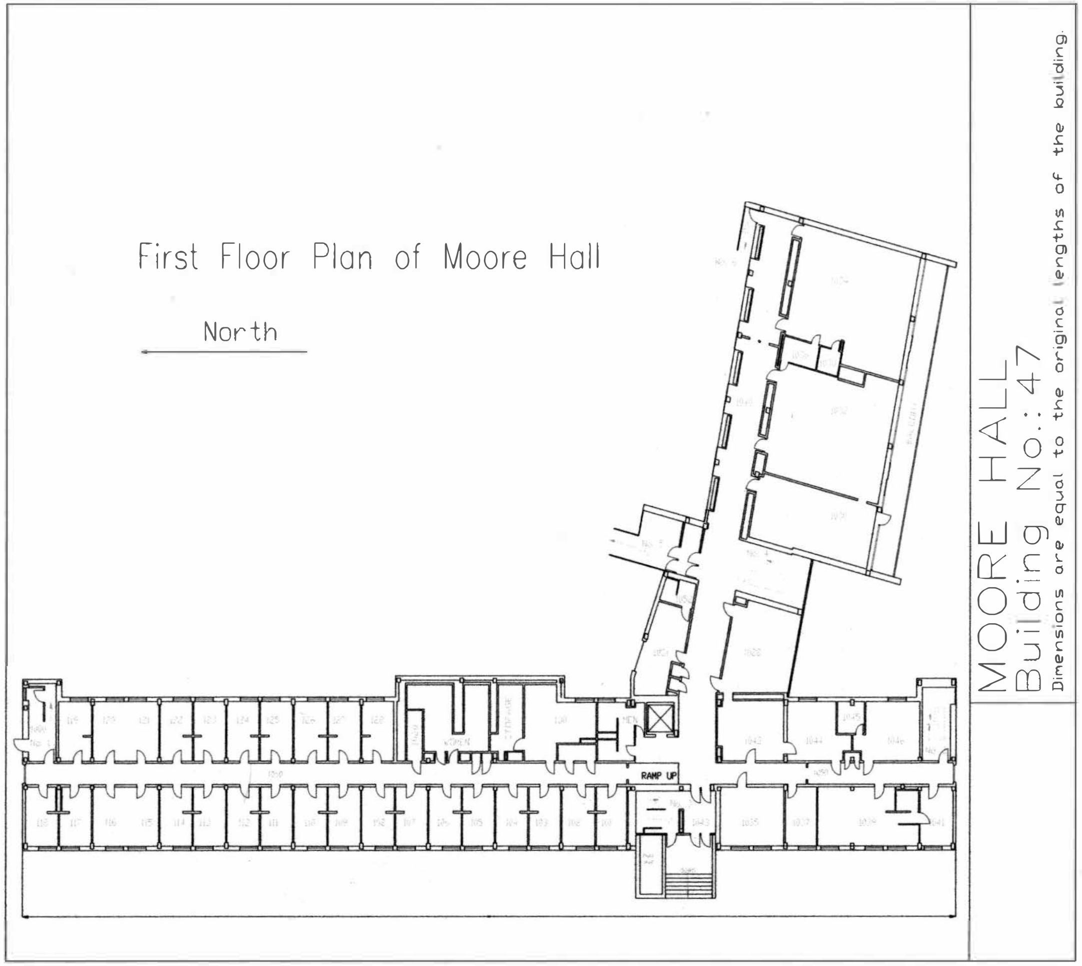

Figure 12. Old Typical Plan of Moore Hall.

from a qualitative perspective, striving to disclose both deeper and conjoining levels of respondent (user) reaction and meaning. Focusing on meaning within respondent disclosure (in relation to intentions and achievement of the redesign, in view of analysis of relevant literature) is intended to lead to further elaboration of this study's result in terms of architectural design achievement, but also, just as importantly, works toward productive user-environment interaction: "Once validity claims are reconstructed at various levels of backgrounding and foregrounding, many subtle forms of analysis are opened up" (Carspecken, 1996).

CHAPTER IV

ANALYSIS, RESULT, AND VALIDATION

4.0 Introduction

From analysis of Moore Hall in its present state, based upon review of literature and research methodology considerations, a redesign plan was formulated and developed. Procedures for validation of the redesign, incorporating Moore Hall user response to the plan, were also developed. In this chapter the redesign plan is presented along with user response, interpretation of user response, and a conclusion which derives relationship among the redesign principles indicated from various perspectives in Chapters I through III and derives, to a limited extent, the significance of such relationship.

4.1 The Redesign Plan of Moore Hall

The redesign plan of Moore Hall attempts to realize the six principles and associated factors for redesign as specified in Chapter III.

4.1.1 First Principle

To realize the first principle, maximum use of natural daylight, the rooms and corridors were reoriented to position them for maximum exposure to sunlight. Rooms were oriented to the west with corridors running along the back (east side). The first assemblage of rooms per floor (furthest west) thus faced the immediate western exterior. The second assemblage, per floor, faced the central open courtyard. All of the windows were greatly enlarged and windows were added.

The corridors are fully exposed to natural light on the east facing side with floor to ceiling windows toward the exterior or central courtyard. Large windows at the north end of the corridors also allow light. Natural light also passes through the south side of the corridors via the adjacent rooms or areas. The corridors themselves feed facing and adjacent rooms with natural light.

4.1.2 Second Principle

To realize the second principle of provision of maximum levels of fresh outside air to interior space of the building, three wind catchers were added to allow fresh air to enter and circulate through the building, naturally maintaining air conditioning.

4.1.3 Third Principle

To realize the third principle, use of smart building technology to monitor and control the most efficient use of the building, occupancy sensors were installed to provide lighting only when the space is being used. Individual controls for adjustment of environmental factors by each user within a set range or predetermined parameters were installed. And much more efficient, sensitive, and controllable systems of mechanically produced air conditioning and heating were specified.

4.1.4 Fourth Principle

To realize the fourth principle of self-generation of some of the electric power for the building from solar sources, solar panels were installed across the roof's surface, transmitting energy to a complementary solar generator, also added.

4.1.5 Fifth Principle

To realize the fifth principle, creation within the building of a natural environment of openness, visibility, access to natural light and fresh air, and pleasant surroundings, two courtyards were added, both totally accessible to all building users at all times. The main courtyard occupies the central space of the building. All corridors, except for basement level, run around the central courtyard. The central courtyard features two fountains, surrounding trees, and seating areas, with tables and benches, and possibly, as a later provision, addition of sculptures. The smaller courtyard is located on the south interior of the building, with seating, tables, vegetation, and openness to the sky.

4.1.6 Sixth Principle

To realize the sixth and most encompassing principle of the redesign, maximization of utilization of naturally occurring energy, and minimization of conventional energy use, significantly reducing energy cost, use of electricity was more efficiently monitored and controlled for, solar energy was introduced, windows were greatly increased in number and size and were specified for greater insulation and light transmission, and much more advanced, more controllable heating and cooling systems were introduced.

4.2 Windows Specifications

In the following diagrams I make use of large windows. The explicit design I chose was Chicago style and the perfect glass for this design would be the Solarban 60 (3) Solexia which is manufactured by PPG – Pittsburg Plate Glass. This extraordinary product is also available by corning and Pilkington (flow glass). The features of the glass are as follows:

1. The Fixed part: or the larger area of the glass which measure 8′ X 8′ and
2. The Movable: or the smaller side portions which measure 2.1′X 8′
3. The complete glass has a uniform thickness ¼″X ¼″ and a gap of ½″.
4. The openable windows are 2.8′X 2.1′ each, which are more than 1/20 of the room area. This can bring enough fresh air to the room according to the standards regulations.

4.3 Redesign Plan Concept

I would like to take this opportunity to illustrate my design and how this architectural principal could be applied to Moore hall or as a matter of fact any other building out there. It is this research that I believe will open the doors for the application of my design principals.

In this design I have used two courtyards and both of them play an important role. They not only compliment the overall structure but also remove the standard picture of square structured buildings, so visitors or guests can experience a sense of openness and visibility to the outside environment. The lively greenery gives a soothing feeling and increases the level of comfort. The courtyard on the whole makes the building livelier and the people visiting it feel more welcomed (see Figures 13-15).

Also, I treat each room equally with adequate natural lighting and give detailed attention so that users are pleased and satisfied. Common areas are provided where possible so people can unwind and enjoy their free time. The corridors have been redesigned for liveliness compared to the old buildings dull walkways. Strategically placed water bodies give the whole structure a complete feeling to users. Wind catcher is used to provide fresh air and better ventilation; this not only saves energy but also provides adequate cooling when required.

Moreover, the use of Smart technology is integrated into the building to monitor the presence of people in rooms, this allows for automatic switching which is an excellent investment for conserving energy. With this technology, every room can also be personalized to fit the tenant's environment that brings an individual sensation.

4.4 Interviews: User Validation and Responses to the Redesign

Interview responses of users of Moore Hall to the redesign plan of Moore Hall, derived from their prior examination of the plan and their prior examination of

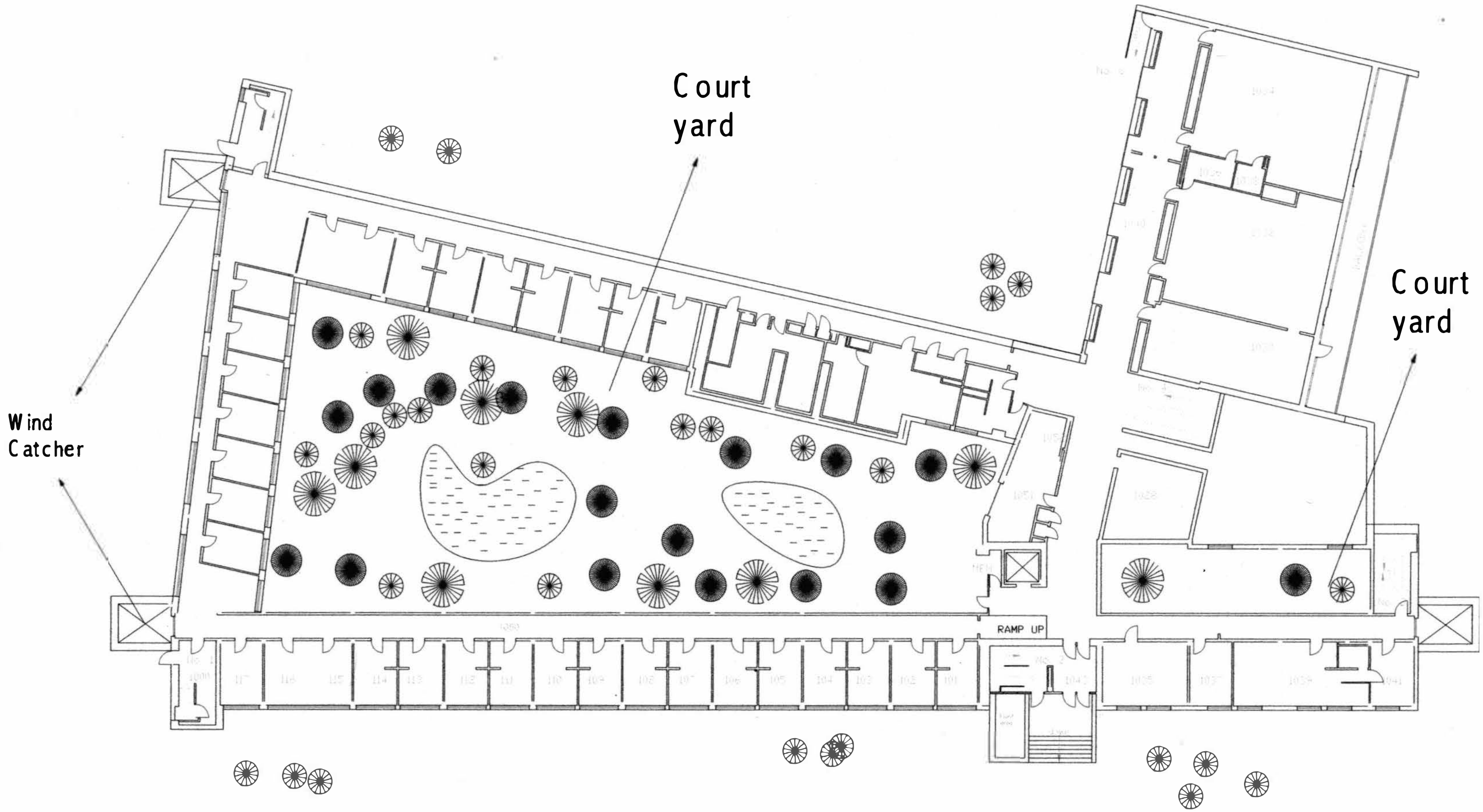

Figure 13. New Ground Plan of Moore Hall.

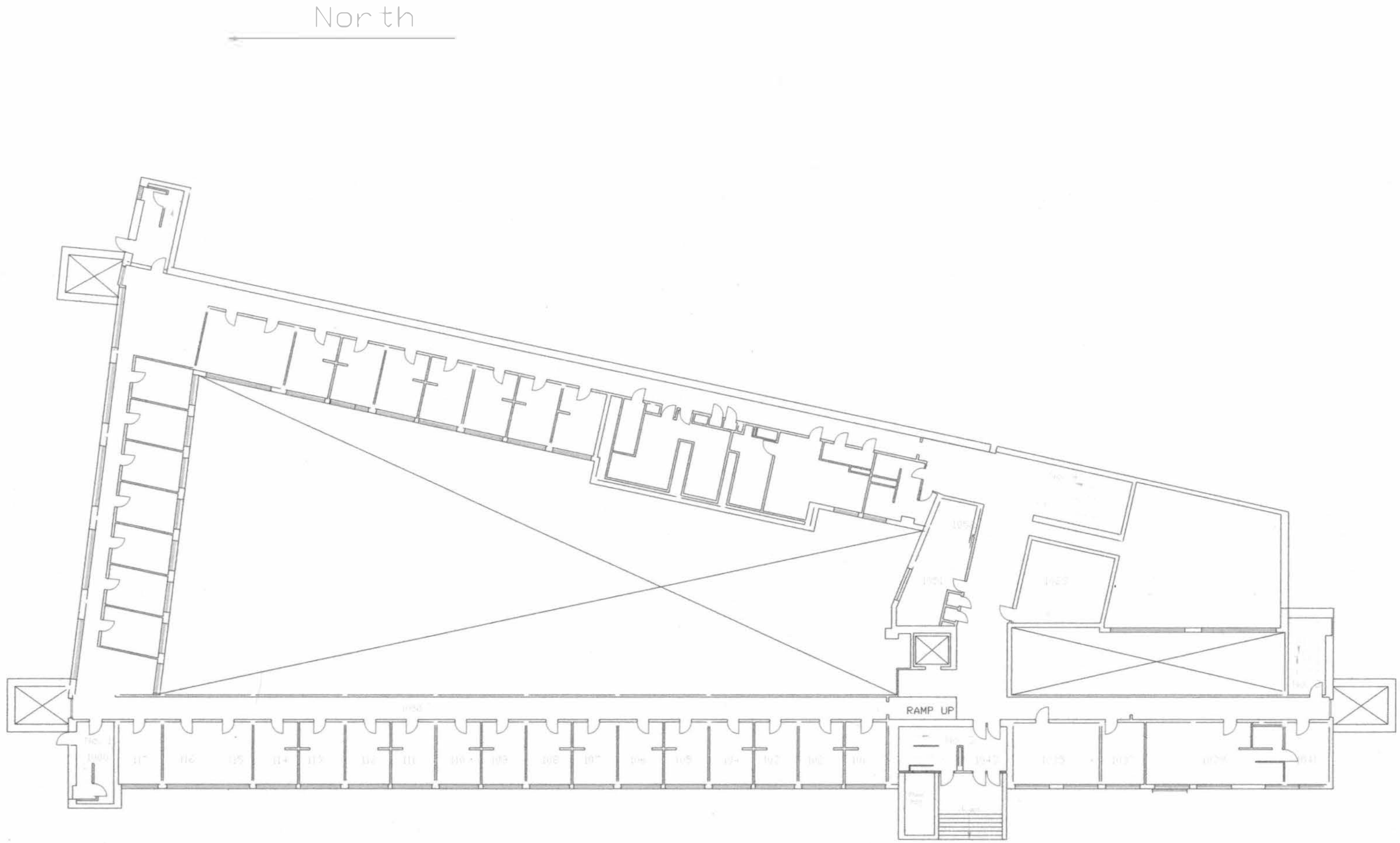

Figure 14. New Typical Plan of Moore Hall.

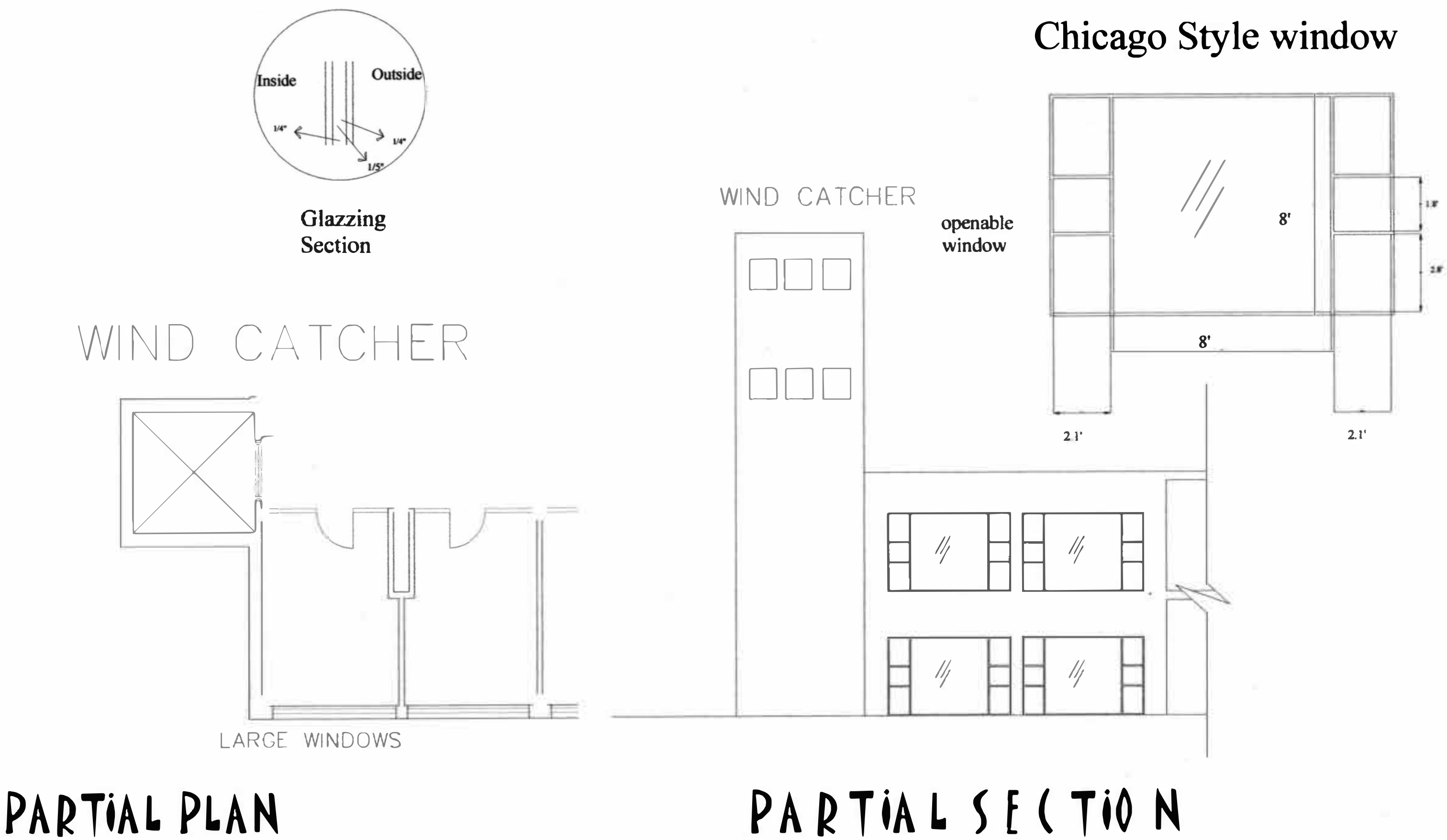

Figure 15. Partial Elevation of Moore Hall.

the four interview questions as specified in Chapter III, are next provided. Responses are given for each of the respondents, for each question. For convenience to the reader and clarity of understanding responses made concerning the data, each question is stated in full, followed by all the responses made to that question, in their full texts. Interpretation then follows in the next section, 4.3, interpretation of results.

4.4.1 Responses to Interview Questions

Q-1 In the structural redesign of Moore Hall I have developed a very important and basic component. It is a substantial reorientation of all elements of working space in relation to available daylight or sunlight. That is, through my new design I have repositioned the rooms and the corridors so that they receive maximum concentration of available sunlight and allow maximum visibility from within to the surrounding outside environment. Corridors also are a critical factor for receiving maximum exposure to sunlight and, in the case of the exterior corridors, allowing maximum visibility of the surroundings. Given the basic characteristics of the structural reorientation of my redesign, primarily with emphasis on greatly increased receiving of daylight or sunlight, and greatly increased availability of visual access to the surrounding environment, can you imaginatively place yourself for a moment within the new conditions and indicate differences you might project for yourself in terms of how you would relate to other users of the building and also in terms of possible differences in how you would act or perform in relation to your job?

R-1 It is a very good idea for anyone to work in a very high tech building like the new one. The new layout of the building is less institutional but I accept that if I work in a green building I will feel happier. To have bigger windows is much better for me because much more daylight goes into my room. Too much sun in the west side in summer is a problem for me. [I explained to him that some advanced window system could solve the problem, but he cannot have everything at the same time. If he gets the sun in winter, spring, and summer he needs to understand that some disadvantages may occur] If it will be solved by proper insulation and good window system it may be ok.

I personally like the sun in the morning. So, I like the rooms, which are oriented to the east side. People are different, and we should give them the choice to choose which side they prefer, the east sun in the morning or the west one in the afternoon. It is a good idea to have both solutions in the new design plan.

The corridors are a good idea to be opened toward the courtyard. Besides, the existing of the courtyard itself is a new and nice idea.

R-2 The new layout makes long distance walking necessary for anyone from the sides of the building to see another colleague in the other side in the same floor. I think we will have less feeling of community and communication about seeing each other. So, the sense of community is less in the new design but it is acceptable if each department at least has the whole floor with all their needs and they do not go from one floor to the other. The bigger window is better for me to get more view to the outside area and more sunlight. But the view in the east side is more pleasant to me, more than the west side.

R-3 The new design is fluid and linear. I like the idea of continuous flow around the courtyard. Even just how the people perceive the workspace, it gives the feeling of being together more than the old one. I like the new design, and I show it to many people and they like it. The new design will have the same rooms but there are much more open spaces, more workability, and better feeling with working with other people. I personally like my room to be in the west side. I like the idea of the wind catcher and the accessibility to the courtyard because some courtyards are designed to be closed and unreachable. I like to walk in the courtyard in my lunchtime and get some fresh air there. My productivity will increase for the long run in the new building.

Q-2 An inspiring and overarching concept guiding my projected redesign of Moore Hall is the idea of the "Smart Building". This term, from a technical architectural perspective, refers to maximum possible incorporation, given whatever intervening factors or contingencies exist, of available relevant technology, for control and monitoring of the use of the building; for example, the use of lighting, and providing of heating and cooling. In my redesign I used diagnostic sensors to limit and control the use of lighting, and thus usage levels of energy resources. For heating I added solar cell panels to access sunlight and reduce consumption of energy, which directly or indirectly depend on fuel consumption. For cooling I specified an automatically functioning system temperature sensing and control. These sensors work to maintain constant desired temperatures while avoiding costly fluctuations in temperature and unregulated demands on the system. From your own personal perspective, what understanding do you have of how automatic regulation contributes to conservation of resources? Comment upon how removing or reducing the element of human or individual interaction will affect the building functions, such as provision of light and heat, control cost, and contribution to the building's capacity for internal self-regulation, ultimately making the building more compatible with more of a self-sustaining facet of, the environment as a whole. Comment upon your perception of how the idea and function of the smart building supports your own individual concerns for working with, rather than against, the surrounding, enclosing natural environment?

R-1 It is much better to have individual control within some parameters or ranges. For example, the best cooling temperature is from 75 - 66 and the heating one is from 68 -72. The fresh air must be forced to the building and there should not be individual control of it. The rooms in the existing building have a very bad smell (nasty) because the ventilation system and the fresh air do not come to those rooms. The best idea is to have an integrated heating and cooling system. It is also a good idea to control the individual areas, but the common spaces like corridors and sitting areas need to be fixed without any interfering from the individuals.

R-2 I support all those ideas and most of the people here will too. My friends and I like the ideas of a courtyard, increase of sunlight, and the wind catcher. The common areas in the new design, which have more sunlight, are a very good idea. It is an important place for the students to congregate, feel comfortable, relax, and look out to the open areas.

R-3 I generally understand and appreciate each of your ideas and I think it is a result of all of the development in the architecture field. The sun hit the existing building from the east and from the west direction. So, I like keeping the same concept for making the building rectangular running from the south to the north in order to expose the building to the east and west sides. I think it is a good idea for a building to have more sources of energy and I like the concept of occupancy sensors. Also, I think the corridors in the new design will have more daylight, more than the old design.

Q-3 In my redesign plan for Moore Hall, in conjunction with the concept of smart building identified in question two (that is, incorporation of technology to establish the building as a self-regulating, self-sustaining, environmentally compatible system) individual control of designated space is also available and emphasized. Comment upon your understanding of how such individual control provision can work compatibly with the overarching system of smart building and self-regulation? What attitude, type of knowledge, and shared commitments do you envision or foresee as essential on the parts of building users for overcoming what otherwise could be viewed as a contradiction or conflict between individual user discretion and smart building self-monitoring and self-control?

R-1 There are differences in knowledge between people. Some of them like and know how to use the new technologies, but some others do not know how to use the fax machine. The old people in this building who have the highest positions in their departments do not know all this high technology stuff. If this building will be built after 10 years, these people may be replaced by new generations to use a high tech building and its components.

R-2 I think I like to control my room and most of the people will too. I like to have the choice to move its temperature up and down until I reach the desired one. The common places must not be opened to the people to control. Everyone will impose his own control to the others and the people are not equal or the same.

R-3 I am an old fashion person and it takes time for me to get used to the new design and new ideas. The building, which turns off the light by itself when nobody is using it, is a great idea and needed. People need to be told what to do. We learn slowly. And most of the people will follow what they are asked to do. It takes time to make the change. If the evidence could be shown to the people about how much they are wasting, they will see the logic and support it. You have to have the balance between automating everything and individual control. I don't think that the people will feel comfortable without reaching for the control. It is a good idea to have some individual control in some way. But you do not want to make it too easy so people will play with the system all the time. I know it is the tough part of your job to make the balance.

Q-4 Using daylight in preference to artificial light, providing greatly increased ventilation and access to sources of fresh air, and expanding open and free space are all aspects of new building design that help to preserve resources, energy, and the natural environment, while at the same time increasing the livability of the structured environment. How do these matters relate to your concerns and the care you are willing to provide to assist nature and preserve resources?

R-1 It is a good idea to save energy. I like the idea of using the daylight and sunlight and I hate the ugly fluorescent light in my office. I know that my friend is using a geothermal furnace to heat his house. The initial cost was 3-4 times the typical method, but he cut a lot of the utility bills in the long run. He did that to save some money and I think it is the only purpose to push him to do that. This matter needs to be controlled by the government and introduce the alternatives.

R-2 It is a good idea to save the energy for the new generations coming. All these ideas are good and I personally support that.

R-3 I certainly can see the value and believe in those values of conserving energy and conserving the resources. It is important and more important as we move to the future. People are wasteful and if the building will be done in a way to save the energy, I think it is the right way to do it. My room here is hot and I cannot control the heating. So, what I do is open the window to cool the room and get some fresh air. I know I wasted some energy when I do that.

4.5 Interpretation of Results

4.5.1 Rationale From Qualitative Research Theory

User research findings result concerning responses to the redesign of Moore Hall, expressed in this study primarily within the confines of interview questions posed by the researcher to them, indicate the validity of the redesign plan. Validation by the users of the appropriateness value, and overall rationality and feasibility of the redesign as presented in this study is an important indicator that the redesign project makes a contribution to social knowledge of commitments set fourth in the study and that the study itself in turn derives from and is correspondent with accepted knowledge and theory as currently expressed within the discipline of architectural design.

Such validation of construction of social knowledge contributes toward satisfaction of overall measurement validity of the extent to which redesign intentions have been achieved. This approach to validation, especially within circumstances which disallow quantitative measure to a great extent, help to indicate "causal linkages" (Keeves, 1997, p. 827) among the various elements played upon in the study: sustainable design and green building description and theory. The researcher's analysis of this information and application of it to a problem of redesign; the completed redesign project; the potential users' consideration of these elements and expressed reaction to them; and; finally, researchers overall interpretations and conclusions.

4.5.2 Interpretation

Q-1 The first interview question asks respondents to imaginatively place themselves within the redesign concepts and respond to the reorientation of rooms and corridors, as well as the increased visibility and openness to the new courtyard space. Two of the three respondents commented favorably on the new design. R-1 believed he would be happier with more openness, space, and exposure to light, but had certain reservations about intensity of sunlight from the west during the summer. R-2 seemed mostly negative. The central courtyard would prevent simple crossing over to the other side of the hallway. For many offices it would be necessary to walk around the perimeter of the courtyard to the other side of the building. The sense of close community would be reduced it was felt. Greater visibility and light, overall, was considered beneficial, however. R-3 gave positive, subjective support to the new design, emphasizing fluidity of the connected space and free open access to the courtyard. The overall design seemed to enhance the environment for work and for working with others.

Q-2 The second interview question, concerning the concept of the "Smart Building" asked respondents to comment upon how automatic controls or capacity for control built into design corresponded to their own concern for working in harmony with the natural environment. The first respondent took issue with reduction of individual control, somewhat, but felt individual control should be within established parameters. Also, ventilation, forced fresh air, and the condition of common areas should not be subject to individual control. The second respondent returned more to the first question, this time emphasizing positive reactions to the courtyard (where friends could congregate) the wind catcher, and increased available light. The third respondent also returned more to question one, indicating an understanding of architectural principles involved, as well as new technical capacity, such as the occupancy sensors.

Q-3 The third interview question asked respondents to consider certain trade-offs in the new design between utilizing individual discretion and relying on smart building self-regulation.

Respondent one used the question to comment upon perceptions of generational differences among users in response to technology, willingness to use it, or learn to use it correctly, and the fact that an older, less technological group occupied most positions of power and set the course for others to follow. The best interpretation of all this might be that: no matter the level of environmental and technological excellence and completeness, the issues of individual control and cooperation remain critical. Respondent two sided clearly with individual control except for common areas. Respondent three initially answered as though wanting to self-select himself as part of the "older less technical" group identified by respondent one. However, what this meant for the respondent was that individual control could not be counted upon and persons involved needed to be educated concerning the logic and advantages of the new system. This would be a tough part of the new design concept: leaving some limits for individual control, but mostly relying on technical automatic processes inherent to the building.

Q-4 Question four was a summary question, putting together the green building and sustainable advantages of the new design along with the individual sense of responsibility for caring for and cooperating with the natural environment. Respondent one emphasized the need to save energy and by extension, money. Technology must be allowed to carry out these functions in our society. Other than individual consent, however, the matters of environmental consideration and beneficial interaction were likely go well beyond individual discretion and require cooperative effort under government control.

Respondent two simply stated support for saving energy for new generations. Respondent three corroborated the value of self-monitoring, self-controlling technical systems in buildings, to conserve energy and resources.

4.6 Validation of the Redesign

The proposed redesign of Moore Hall, as realized in terms of the principles and associated factors of green building and sustainable design theory, developed in chapter two and applied in chapter three to the redesign component of this study's research project, is validated in terms of current users' responses to the redesign. Responses follow from a set of interviews questions specifically focused on the researcher's intentions as derived from review of relevant literature of green building and sustainable design and as evidenced or realized within the total redesign package, and subjected to user examination.

This approach to validation corresponds with a qualitative research initiative perspective according to which gaps in measurement of achievement, or result realization, or results interpretation due to critical factors not readily open to quantitative "scientific measurement" (Keeves, 1997, p, 827) must be addressed (for example, user perception of result in conjunction with satisfaction) and relevant information understood.

CHAPTER V

CONCLUSION AND RECOMMENDATIONS

5.0 Conclusions

In the redesign project of Moore Hall architectural principle and practices of green building and sustainable design were used to recreate an existing, in-use structure so that the structure was importantly enhanced in terms of supporting user experience of interaction with the structural environment, in terms of favorable correspondence with the natural, surrounding environment, and in terms of realizing important resource and energy savings.

Extensive review and analysis of green building/sustainable design literature was carried out. Principles and design factors relevant to the problems and issues addressed in the study were extracted for incorporation within the redesign plan.

The redesign significantly reoriented the floor plans to increase natural light and visibility, smart building control and monitoring, access to the natural environment, much more efficient electrical and heating access, and incorporated solar power generation. Energy use reduction estimates were in the 40-50% range.

The finished project in the form of architectural plans was reviewed by selected users. Their responses, registered in semi-structured interviews, corresponded with the intentions of the study, and overall gave positive affirmation of results.

The main achievements of the redesign: Energy saving, increase compatibility access to natural factors conducive to human life natural air, sunlight, warmth, cooling, and extension of the visible range (both of exterior environment and within the structure) were largely endorsed by users.

Two problems, however, emerged during the completion of the design. These are installation of moveable or retractable roof for the courtyards and incorporated of wind-powered generation of electrical and rain water usage. These factors require additional research and consideration for feasibility.

5.1 Recommendations

The primary recommendation of the study is that similar redesign plans should be initiated for buildings on Western Michigan University's main campus. Possibly the redesign projects could compete for national design awards and initiate funding for initiating a program of redevelopment of buildings according to green/sustainable principles.

The following principle from the green building/sustainable design research carried out for this study and applied to the redesign plan for Moore Hall are recommended for the suggested program of development of buildings on Western Michigan University's campus. Each of these principles was invaluable for development of a coordinated and harmonious rebuilding design, and should similarly prove useful in related context as suggested in this section of the study.

Green building/sustainable design principle:

1- Respect for natural resources.

2- Use of natural renewable energy sources.
3- Use of naturally occurring vegetation.
4- Use of the "sun wall" and hydronic and photovoltaic solar panels.
5- Consideration of all factors, which contribute to energy use reduction.
6- Use of low energy heat, passive ventilation system, and minimizing heating and cooling needs.
7- Reduction of use of natural resources.
8- Meticulous design to reduce building size and operation cost.
9- Practices: high insulation levels, high performance windows, tight construction, high efficiency cooling and heating.
10- Ensure that design incorporates maximum positive integration with the environment.
11- Operation cost reduction by 63%, energy use by 50%, cooling load by 43%.
12- Clear definition and holistic understanding of design problem.
13- Holistic performance goal from building's inception.
14- Stipulation of environmental needs and potentials of programmed spaces.
15- Systems and equipment option considered only after operational needs and realities specified and design scheme started.
16- Natural ventilation systems.
17- Use of cross ventilation and wind tower combinations to replace air

conditioning.

18- Adaptation to natural temperature fluctuations, including individual user control.

19- Leave the surrounding environment undisturbed.

20- Reduce environmental effects of excessive heat and toxin production.

21- Construction, demolition, and disposal (over the 50 year lifetime).

22- Largest amount of energy for end use.

23- Construction energy use is second.

24- For residence end use is 4 times construction, 7 times maintenance.

25- For office indoor climate control is 7 times construction 23 times maintenance.

26- Systematic monitoring of energy wastage.

27- Any building can be sustainably designed and built.

28- Lighting and air conditioning consume most energy.

29- Natural lighting most appropriate for office building due to daytime use.

30- Roof and wall access to light, rectangular form preferred.

31- Non-mechanical natural ventilation reduces noise, malfunctioning, energy consumption.

32- Orientation for fresh air and daylight (to wind, and sun).

The following principles were not considered for the redesign of Moore Hall, due to limitation of the study. These principles are highly recommended for incorporation within the green building/sustainable design redevelopment of buildings on Western Michigan University's campus, as indicated in this section. The principles are listed below:

1- Architectural cooperative effort with industry, research organizations, federal, state, local government to develop green building tools.
2- Architectural institutionalization of green building/sustainable design.
3- Emphasis on choice of materials and construction procedures.
4- Use of recycling materials.
5- Reduction of manufacturing energy consumption.
6- Low-maintenance, water-efficient landscaping to save water and reduce pesticides.
7- Incorporate future reuse and adaptability into the design.
8- Recycling of gray water.
9- Conscientious renovation of extant buildings (the most sustainable construction).
10- Use of salvaged materials.
11- Use of commissioning to avoid misapplication and poorly installed products and techniques.
12- Commissioning from design through the warranty.
13- Use of large, curved sun wall for both heat and electrical generation.
14- Increased cooperation between architect and mechanical engineer.
15- Inclusion of engineering function on the design team.

16- Understanding of air pressure factors and effects.

17- Water efficiency and resolving storm and wastewater problems.

Consideration of embodied energy: energy invested during construction, demolition, and disposal (over the 50 year lifetime). Any building can be sustainably designed and built.

The concluding recommendation of this study is that my redesign of Moore Hall should be reviewed and graded by professional architectural experts in the field of green building/sustainable design. The redesign plan should also be rated by the United States Green Building Council (USGBC) and Leadership and Energy Efficiency Design (LEED). Similar recommendation would follow for suggested applications of this study for other Western Michigan University building. However, for future application, the involvement of such expert idea and monitoring agency input would be sought from inception of the redesign or design process.

5.2 Overall Recommendation for the Study and Summary

The overall recommendation for the study are summarized as:

- Extend green/sustainable redevelopment to other campus buildings.
- Consult with architectural experts from design inception.
- Evaluation by green/sustainable agencies and relevant architectural

For further study in the field of Green design for this particular building there are some aspects that could enhance the whole building structure. In order to have a better picture for practical application these options could be utilized:

1. Life cycle assessment
2. Water efficiency with the integration of storm water and waste water systems
3. Building Energy Modeling and Simulation
4. Materials selection such as recycling material with local and regional materials also deconstruction of the old materials.
5. Advanced study in the courtyard – to make a movable roof that opens in summer and closes in winter.

APPENDIX

WMU Facility Life Cycle Design Guidlines

(Morris, 2001)

WMU Facility Life Cycle Design Guidelines

(Design Goals & Design Process adopted 11/12/01 by Standards Review Committee)
DRAFT 10/4/02 (Proposed revisions in blue)

A. Design Goals

1. Reduce building life cycle costs, direct and indirect, relating to energy use, maintenance, waste disposal and occupant health & productivity.
2. Reduce building environmental impacts
3. Improve indoor environmental quality

B. Design Process

1. The Project Design Team is to determine design strategies appropriate for project program, site and budget.

2. US Green Building Council LEED Rating System is to be used on all projects over $1 million cost as a performance standard and design tool/ checklist. The highest rating level that is feasible should be achieved, with the LEED Certified level as the minimum requirement. All projects ~~under $1 million cost~~ are to ~~use~~ follow the Design Guidelines listed below, which incorporate LEED and WMU specific criteria.

3. Evaluate life cycle costs of design alternatives to reduce facility costs. Use Life Cycle cost analysis tools, including energy simulation/modeling software, on projects greater than $1 million cost ~~to evaluate design alternatives and reduce facility costs.~~ Life cycle cost saving strategies used should have maximum payback period of 5-10 years.

3. Architectural/Engineering consultants are to include the above services in the Professional Services Agreement.

C. Design Guidelines

<u>Energy Use</u>

1. Integrate Buildings with the Site: Consider local climate & site influences on building energy use. Utilize "free" energy sources where feasible, such as solar energy, daylight, exterior temperature variations and winds.

2. Optimize Energy Performance: Select building envelope, mechanical and electrical systems for improved energy efficiency. Typical strategies & technologies:

•Building Envelope
  Control & utilization of solar heat gain
  Daylighting of interior spaces
  High performance windows/glazing
  Optimized insulation values
  Reduced air infiltration

•Mechanical Systems
  High efficiency equipment
  Direct Digital Control System (DDC) for HVAC

Occupancy sensors/CO2 monitoring
Heat recovery systems
Economizer cycle cooling
Zoning of HVAC system based on building orientations & loads
Variable speed drives on motors and fans
Low flow plumbing fixtures
Time of day scheduling
Separate controls for individual spaces, where feasible

•Electrical Systems
High efficiency lighting fixtures (no incandescent)
Occupancy sensors
Daylight sensors
Separate ambient and task lighting
Lighting dimmers

3. CFC/HCFC/Halon Reduction: Avoid use of these products in HVAC refrigerants and fire suppression systems.

4. Building Systems Commissioning: Key mechanical & electrical systems are to go thru a Commissioning process, which includes the following:
   •Inspection & testing for functional performance in accordance with project objectives & University guidelines.
   •Documentation of criteria, inspections/testing & acceptance
   •Training of WMU operations & maintenance staff

   All projects shall implement a Commissioning plan, with the scope to be determined by the project team.

<u>Building Materials</u>

1. Recycled Content Materials: Use materials with post-consumer or post-industrial recycled content where feasible. Common products with recycled content include structural steel, aluminum windows, gypsum board, acoustical ceiling tiles, rubber floor tiles, carpeting and toilet partitions.

2. Durable & Flexible Materials: Utilize components and systems which are durable and easy to maintain. Where feasible, use materials which provide flexibility for future changes and modifications to occur.

3. Renewable Materials: Consider use of products that are comprised of raw materials that are in abundant supply or come from renewable sources. When feasible, obtain wood products from suppliers certified as utilizing sustainable harvesting methods.

4. Local Materials: Use products produced regionally where possible. See WMU General Requirements for use of Michigan products.

5. Construction Waste Management: Contractors are to develop a plan for sorting, storing & recycling of waste materials on projects. "Waste Spec" is to be used as a specification for

this work. All projects shall implement a Construction Waste Management Plan, with the scope to be determined by the project team.

6. Recycling Facilities: Plan for convenient areas in buildings for sorting & storage of recyclable items by the building occupants. See WMU Recycling Coordinator for type of items to be recycled & number of bins needed.

Indoor Environmental Quality

1. Design for Human Health: Consider environmental needs of people in terms of daylight, ventilation, exterior views and thermal/acoustic/visual comfort for interior spaces.

2. Ventilation Requirements: Optimize the amount of fresh air provided to building spaces. Connect occupancy sensors & carbon dioxide monitors to HVAC systems, where feasible.

3. Low Emitting Materials: Utilize finish materials which have low levels of volatile organic compound off-gassing. Typical recommended maximum levels:
   •Carpeting: 0.5 mg/sq. meter/hr., adhesives 10 mg/sq. meter/hr.
   •Hard Flooring Adhesives: 150 g/L
   •Interior Paints: Non-flat 150 g/L, flat 50 g/L
   •Sealants: 420 g/L

4. Construction Air Quality Management: Protect ductwork and equipment from contamination during construction. Flush out building spaces with 100% fresh air & replace filters in equipment prior to occupancy.

Site Work

1. Minimize Site Disturbance: Consider the impact of project on the surrounding ecosystem. Investigate methods to minimize impacts on natural habitats and watersheds.

2. Stormwater Management: Limit off site storm water runoff and employ methods to increase on-site infiltration. See WMU Campus Stormwater Plan.

3. Alternative Transportation: Provide site facilities to encourage pedestrian, bicycle and bus transport, where feasible.

4. Light Pollution Reduction: Minimize site lighting levels & off-site light spillover/ glare, while *providing for adequate levels for security and wayfinding.*

5. Water Efficient Landscaping: Utilize drought resistant plant materials and low flow irrigation techniques, where feasible. Consider use of native plant species.

6. Erosion & Sedimentation Control: Employ techniques such as silt fencing, sediment traps/filters, topsoil stockpiling and slope stabilization to minimize erosion of soil during construction.

D. References

General
US Green Building Council- LEED Green Building Rating System, www.usgbc.org.

Energy Use
•ASHRAE Standard 90.1-1999 Energy Standard for Buildings except Low Rise Residential Buildings
•US DOE/EPA Energy Star Guidelines

Building Materials
•EPA Comprehensive Guide for Procurement of Products Containing Recovered Materials; Recovered Materials Advisory Notice III; Final rule (1/19/00) 40 CFR Part 247
•Forest Stewardship Council Guidelines
•Triangle J Council of Governments, "Waste Spec"- Model Specification for Construction Waste Reduction.

Indoor Environmental Quality
•ASHRAE 62-1999: Ventilation for Acceptable Air Quality
•ASHRAE Standard 55-1992, Addenda 1995- Thermal Environment Conditions for Human Occupancy, Including ANSI/ASHRAE Addendum 55a-1995
•Sheet Metal & Air Conditioning National Contractors Association (SMACNA) IAQ Guidelines for Occupied Buildings Under Construction, 1995
•South Coast Air Quality Management District Rule No. 1168- Adhesive Applications
•Bay Area Resources Board Regulation 8, Rule 51- Adhesive and Sealant Products
•Green Seal Paints and Coatings Requirements- Paints (GS-11), First Edition, 5/20/1993
•Carpet and Rug Institute Green Label Indoor Air Quality Test Program

Site Work
•EPA Storm water Management for Construction Activities: Developing Pollution Prevention Plans and Best Management Practices
•IESNA Recommended Practice Manual: Lighting for Exterior Environments (RP-33-99)

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