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A PROTOTYPE FOR GREEN BUILDING DESIGN

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ABSTRACT:
The process of creating a green building is different from the conventional design/build process. The design team will get the best results by using a whole building design process from the early stage of the design process. A Whole building design process considers all building components and systems during the design phase and integrates them to work together.
This paper is a comprehensive study of both principles and constrains of green building design for two selected projects. It aims to develop a design prototype that acts as a framework for green buildings design. The resulted prototype may help in practicing more green design and construction methods by separating function and structure, expected and actual behavior of a green building throughout the whole design/construction process from the early conceptual design stages.
Conference Topic:
Keywords:
Green Buildings, Design Prototype, Design Constrains, Green Principles

1. INTRODUCTION:

Green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from sitting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. (U.S. EP,2009) These principles of green buildings are key elements in developing design practices for more ecological built environments.

A design prototype is a conceptual schema for representing a class of generalized grouping of elements, designed from like design cases, which provides the basis for the commencement and continuation of design. (Gero,1994).

This paper is a comprehensive study of both principles and constrains of green building design for two selected projects. It aims to develop a design prototype that acts as a framework for green buildings design. The resulted prototype may help in practicing more green design and construction methods by separating function and structure, expected and actual behavior of a green building throughout the whole design/construction process from the early conceptual design stages.

1.1. Research Methodology

The research starts with a brief theoretical review of design process as a model-based activity. It defines main attributes used in the proposed design prototype. The second and third parts of the paper presents the two selected case studies, theses studies emphasize on clarifying design process and design constrains for the tow selected cases . This comprehensive study aims to develop a design prototype for green building design which will be discussed at the final part of the research.

1.2. Research Objective

This research aims to suggest a model for green building design. A general design prototype schema by Gero J.S (Gero, 1990) is used as a theoretical model for the proposed model for green buildings design. Two green building projects are used as case studies, Herman miller marketplace, 2002, Zeeland, MI and NRG manufacturing facility, 2004, Hinesburg, VT. The purpose of analyzing the two case studies is to identify a green design prototype main attributes:

The suggested case studies are also examined to identify design techniques used during design and evaluation processes, techniques that distinguish green building design process from general conventional buildings design process. The tow selected project are LEED[1] certified projects and are classified as High Performance Buildings by the Office of Energy Efficiency and Renewable Energy (EERE). Both buildings are owned by private corporations which highlights the role of client beside designer and user in the design process.

1.3. Theoretical Background

1.3.1 What is design?

Design refers to the human endeavor of shaping objects to purposes. (Perkins, 1986). Perkins also defined four questions that help in developing any design:

What is the purpose?

What is the structure?

What are model cases of it?

And, what are arguments that explain and evaluate it?

In his book "The Science of the Artificial", Herbert A. Simon emphasizes on both the description, or the structure, and the function, or the purpose, as major objectives of any design activity: "Description of an artifact in terms of its organization and functioning, is a major objective of invention and design activity" (Simon,1969)

As shown previously, the design process depends on specifying a relationship between the structure or the organization of an object or artifact and the function or behavior that satisfies a purpose representing the design goal.

1.3.2 Design models:

Although there are designers who claim design is a mysterious activity not amenable to scientific examination, there is continue to be research into design. There are publications by

1 LEED is a rating system developed by the U. S. Green Building Council for the design, construction and operation of high performance green buildings. LEED gives building owners and operators the tools they need to have an immediate and measurable impact on their buildings' performance. LEED system evaluates performance in five key areas of human and environmental health: sustainable site development, water savings, energy efficiency, materials selection and indoor environmental quality. The rating system consists of six credit categories. Project should cover particular requirement to earn number of points. According to the total earned point, project is classified as certificated, silver, gold or platinum LEED project.

designers on how to design dating back to Roman times, notably by Vitruvius, the nineteenth century design thinkers commenced work on articulating design as a process (Gero, 2006).

Beginning in the 1960s, serious attempts have been made to improve the results of design by encouraging designers to follow certain procedures or methods (Gero, 1990). These methods constitute techniques to produce results to be used by designers.

There has been widespread agreement on the three phase-design model. The phases are: Analysis, Synthesis and Evaluation (Lawson, 2005). The first stage is to diagnose, define, and prepare which is necessary to understand the problem and to define a statement of goals. The second task involves finding solutions and the third task concerns judging the validity of solutions relative to the goals and selecting among alternatives.

Another design model is developed by Gero J.S. The model connects structure and function to the purpose of the design problem to help developing design process in its early stages. (Figure1) Gero defines his design prototype as: "a conceptual schema for representing a class of generalized grouping of elements, designed from like design cases, which provides the basis for the commencement and continuation of design" (Gero, 2003). This prototype suggests that designers form their individual design experiences into generalized concepts or group of concepts at many different levels of abstraction.

The design prototype schema, developed by Gero, separates function, structure, expected behavior and actual behavior. The required behavior is the expected function of a design. While the actual behavior is the actual function resulted from the design synthesis. The required behavior is defined by analyzing design purpose or design goal, while the actual behavior is resulting from the design synthesis and its structural and functional properties. The predicted behavior of the structure can be compared with the expected behavior required to determine if the synthesized structure is capable of producing the required functions. The comparison process is termed evaluation.

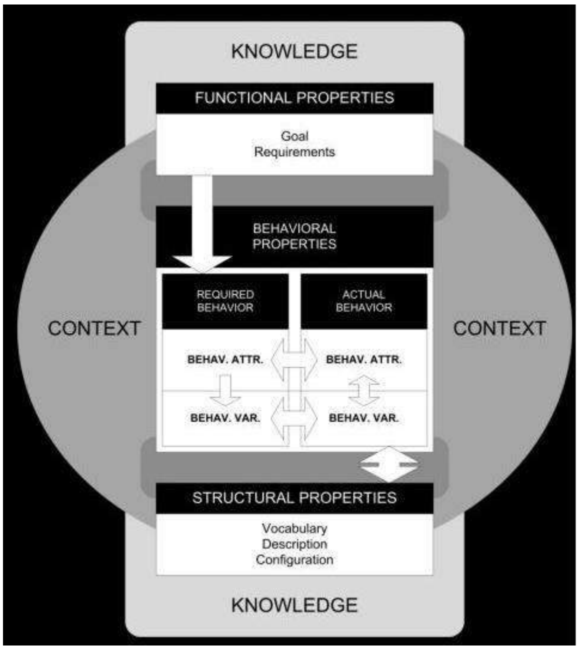


Fig.1 diagram of design prototype schema
(Gero, 1990)

The design prototype also stores designer's knowledge and context knowledge between function, structure, expected and actual behavior. "It brings together all the requisite knowledge appropriate to a specific design situation. Although the contents of a design prototype are developed by individual designers, like-minded designers will tend to agree on its general contents."(Gero, 2003)

2. CASE STUDY1: HERMAN MILLER MARKETPLACE

The Marketplace grew from the need to reduce the size of functional areas and to move employees into one building. Before working together in the MARKETPLACE, employees worked in four different buildings, each with its own lease. Rather than renew each lease, Herman Miller, the owner, decided to reserve resources and construct one high-performing, centrally located building to house those employees.

2.1 Client and User

Herman Miller, Inc. is a leading global provider of office furniture and services for the workplace. In business since 1936, the firm has a longstanding commitment to green building design, being one of the original sponsors of the U.S. Green Building Council (USGBC). [2]

Many of the firm's buildings have been designed and built to meet high building environmental goals, and when plans were made for a new facility, the Herman Miller organization asked that it should be designed and built to the newest Green Building standards. The minimum goal was to achieve the LEED Silver standard as set by the Green Building Council.

2.2 Designer

The principal architect for the Marketplace building was Integrated Architecture of Grand Rapids. Integrated Architecture President, Paul Dickinson, explained his approach to sustainability as doing more with less. "Our approach to green design features simple, sustainable materials within an environmentally sensitive envelope. Each project design is carefully crafted for maximum human comfort, which results in tangible benefits of increased productivity and worker satisfaction." The Integrated Architecture group has produced several LEED rated projects like Forest Hills Fine Arts, Northpointe Bank, and Keystone Church.

2.3 Design Process

2.3.1 Analysis

In Herman Miller Market place each of the design team, including user, owner, developer and designers, has committed to the environment. That resulted into specifying certain goals to be obtained:

- Create a prototype office environment that showcases practical applications of Herman Miller products and systems, while also serving as a working office for 450 Herman Miller employees during a 40 hour work week.
- This project, a speculative office building, was designed and developed to achieve at least a LEED Silver rating.

2.3.2 Synthesis

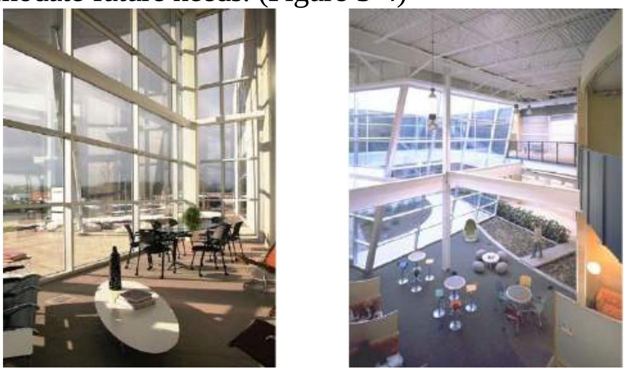
Project is located in a commercial development next to a McDonald's restaurant. The sub-urban location required a large parking lot. The green space and tree-filled parking lot offer a pleasant

[2] The U.S. Green Building Council (USGBC) , founded in 1993, is a non-profit trade organization that promotes sustainability in how buildings are designed, built and operated. The USGBC is best known for the development of the Leadership in Energy and Environmental Design (LEED) rating system and Green build, a green building conference that promotes the green building industry, including environmentally responsible materials, sustainable architecture techniques and public policy

alternative to traditional commercial development (Figure 2). A bicycle rack is located adjacent to the main entry and four showers with lockers are available within the building for cyclists' use. In order to reduce the size of the parking lot, the built capacity is less than the township ordinance for parking capacity. Signage was designed and installed to identify 22 parking stalls specifically designated for vanpooling[3] and carpooling. To promote alternative transportation, these signs were placed at the closest locations to the main entry. Additionally, alternative refueling stations provide receptacles to recharge electric-vehicle batteries.

Fig.2 Marketplace site plan (eere, 2003)

The building design encompasses 100,000 square feet of floor space, with a very open, two-story interior design. Over 65% of the wall area is glazing, providing day lighting for much of the office area through the day (Figure 3-a). The building design features exposed cabling and ductwork. HVAC[4] equipment is located in metal towers at the building's perimeter, creating a wide expanse of flexible floor space. This was done to facilitate rapid changes in building systems to accommodate future needs. (Figure 3-4)



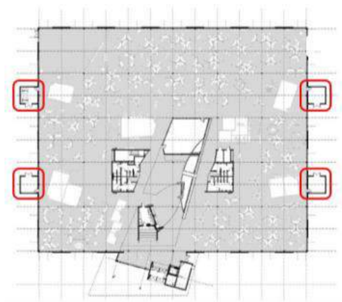


Fig.3-a the glass-enclosed multi-purpose interior patio and the flexible meeting space overlooking it (eere,2003)

Fig.3-b roof floor plan (eere, 2003).

A variety of green strategies, as outlined by the U.S. Green Building Council, were built into the specifications, drawn into the construction documents, executed through construction, and confirmed through commissioning exercises. The goal of the project was to achieve the highest possible LEED rating. (Table.1)

3 Carpooling (also known as car-sharing, ride-sharing, lift-sharing), is the shared use of a car by the driver and one or more passengers, usually for commuting. Carpooling arrangements and schemes involve varying degrees of formality and regularity. Formal carpool projects have been around in a structured form since the mid-1970s

4 Heating, Ventilating, and Air Conditioning

Table.1 Green Strategies and Solutions

Green Strategies	Green Solutions
Use materials that contain minimum 20% by weight post-consumer recycled content or 40% by weight post-industrial recycled content:	Site work included 100% post-consumer recycled crushed concrete.
	Structural steel was 90% post-consumer recycled.
	Metal joists, floor deck, and roof deck were all 95% recycled.
Use a minimum 50% of wood-based materials certified.	Use non-wood forms made of recycled materials.
	Use wood forms from certified sources.
	Use locally produced materials.
Green Products Used	Natural Linoleum Flooring
	Recycled-Content Acoustical Ceiling Panels
	Recycled-Content Carpet Tile
Design for Materials Use Reduction	Group or stack bathrooms and other water-using spaces
	Minimize space devoted exclusively to circulation
	Consider exposing structural materials as finished surfaces.
Greenhouse Gas Emissions from Manufacture	Use concrete masonry units with flyash [5] replacing a portion of the cement
Improve interior environment:	Entry of Pollutants by Design entry to facilitate removal of dirt before entering building and by avoiding carpet and other hard-to-clean floor surfaces near entry.
	Use large exterior windows and high ceilings to increase delighting
	Design open floor plans to allow exterior daylight to penetrate to the interior
	Provide occupants with control of light and temperature in their area
	Specify acoustically absorbent materials to lower reflected noise levels
	Use moving water to create a pleasant acoustic environment
	Provide sufficient sensors and control logic
Achieve at least a 40% reduction in energy use over ASHRAE 6 Standard.	Zone the building for modular HVAC control
	Create zones that unite spaces with similar thermal requirements
	Use Energy Star computer equipment [7]
	Design roof system with consistent thermal integrity
	Use different task and ambient lighting
	Use high-efficacy lamps
	High-performance Windows and Doors
	Provide showers and changing areas for bicycle and pedestrian commuters
	Provide storage area for bicycles
Reduce pollution and land development impacts from automobile use.	Provide vehicle access to support car and vanpooling
	Provide for electric vehicle charging
Day lighting for	Use atrium for day lighting
	Use large exterior windows and high ceilings to increase day lighting
	Design an open floor plan to allow exterior day lighting to penetrate the interior

5 Fly ash is one of the residues generated in the combustion of coal. Fly ash is generally captured from the chimneys of coal-fired power plants, whereas bottom ash is removed from the bottom of the furnace. It is used as an additive to concrete to improve its specifications.

[6] 6 ASHRAE the American Society of Heating, Refrigerating and Air-Conditioning Engineers: advances technology to serve humanity and promote a sustainable world. Membership is open to any person associated with the field.

7 Energy Star power management features place computers (CPU, hard drive, etc.) into a low-power “sleep mode” after a designated period of inactivity.

2.3.3 Commissioning :

Building commissioning is a systematic process of ensuring that a building performs in accordance with the design intent, contract documents, and the owner's operational needs. Commissioning is critical for ensuring that the design developed through the whole-building design process is successfully constructed and operated.

The PECI commission guide specification was used during the construction stage as a template to satisfy all LEED requirements:

Part I. Commissioning Requirements - Design Phase
Part II. Model Commissioning Plan - Design Phase
Part III. Commissioning Guide Specifications
Part IV. Model Commissioning Plan - Construction Phase

3. CASE STUDY2: HERMAN MILLER MARKETPLACE

When David and Jan Blittersdorf decided in 1999 to build a new headquarters for their company, which had grown to become the world leader in wind measure equipments, they immediately began thinking “beyond the box”. “We wanted a building that reflected our values,” says David Blittersdorf. “Our previous building was a tin box ... not very energy-efficient, not a good environment for our people.”Another primary concern was the price of energy. “As a business decision, we wanted to protect ourselves. We could see where the price of oil would be going. We knew we wanted a building that was extremely energy-efficient. We also knew that if we put our money into using renewable energy, we would have lower operating costs over the life of the structure.”

These concerns about environmental and people health aspects were the main aspects that lead to the design of the world fourth green industrial facilities, The NRG Manufacturing Facility

3.1 Client and user

NRG Systems has been in the wind energy industry for more than 25 years. Its wind measurement systems can be found in 130 countries, serving electric utilities, wind farm developers, research institutes, government agencies, and universities. When NRG Systems was founded in 1982, the wind energy industry was starting. The technology was new and wind as an energy source was viewed as an alternative. Today, more than 25 years later, NRG Systems is experiencing tremendous growth as the demand for clean wind energy is dramatically increasing around the world, powering more than 4.5 million homes in the U.S. alone. The great concerns towards environment are clearly showed in the company’s core values “Our business expresses a commitment of over 20 years to a safe, healthy, renewable energy future for our children and for the planet. We have built our facilities to incorporate state of the art energy conservation, and we work to minimize and continually reduce our environmental impacts from manufacturing, transportation, and other business activities.” NRG planned their new office and manufacturing facility to embody its core mission: "furthering the use of renewable energy and providing a healthy, productive, and beautiful workplace for its employees."

3.2 Designer

First NRG chose the architect, William Maclay Architects and Planners, and design team based on their past experience and proposal to address the project environmental goals. The mission of William Maclay Architects and Planners is: “to enhance the world we inhabit through making places for people and nature to live and to flourish with dignity, spirit, and beauty." William Maclay Architects and Planners design buildings and communities that are models for healthy, inspired living, advancing to a carbon neutral and ecologically sustainable future. The firm's current workload is divided equally among residential, multifamily and commercial projects, all connected with "Green Architecture".

For William Maclay the challenge of designing the new home for NRG Systems was also tremendously exciting. NRG is certainly an example of how a building can be built, how it should be built," says Maclay. "If you figure out the true long-range costs, building a green building is actually cheaper. And then when you consider the health and production of employees and the earth's ecosystems, green buildings are the only prudent long-term investment."

3.3 Design Process

3.3.1 Analysis:

The design was based on using sustainable design as the core organizing principle for the project. The owner, architect, and entire design team, including energy, lighting, and sustainability consultants, shared this commitment.

The environmental design and performance process, which led to the success of the project, was established during the pre-design analysis stage. The design team worked with NRG for over a year to find and select a site that was appropriate for NRG's mission and goals. An initial budget was then developed. Detailed programming, site selection, and budgeting had been completed and the environmental goals had been outlined before the design process began. The design team generated model environmental goals and implementation measures to establish the mission goals as the following:

- Design a model workplace combining social and environmental goals.
- Design a headquarter that embodies clients values, mission and core business.
- Accommodate company's expected growth (30% per year).
- Develop a model workplace: healthy, functional, beautiful, and productive.
- Demonstrate a high performance building that uses primarily renewable energy.

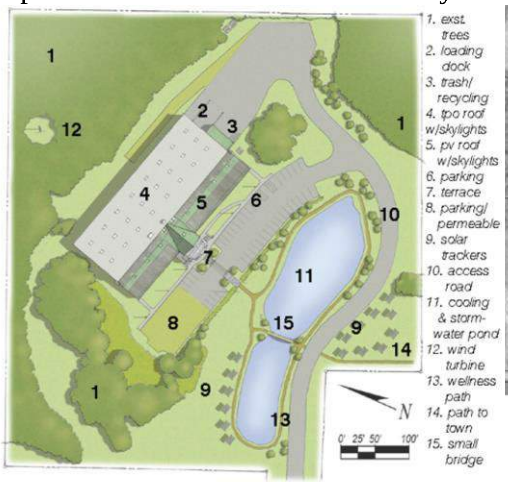
3.3.2 Synthesis

NRG conducted search and assessment process before selecting the site for its new facility. The company's commitment to the economy and culture of this small town (Hinesburg, Vermont) led to selecting and master-planning a site to encourage sustainable growth of the existing village center. The company owners wanted to remain near their employee base and maintain their positive impact on the local economy.

The master plan for the overall property located the facility on about 10 acres of the 56-acre property to allow for agriculture, forestry, recreation, land conservation, and, possibly, future housing, while allowing public access for recreation. The facility is built in the area of the site that had the least impact on the surrounding land. It is located at the bottom of a hill and set back from the road to minimize visual impact and site disturbance. (Figure 4)

The building sits at the border between a hayed field and a wooded hillside, minimizing impacts on the two ecosystems. The facility Location facing south hillside maximizes solar exposure, minimizes heat loss, minimizes exposure to northwest winter winds, maximizes exposure to southwest summer cooling breezes, and maintains farmland, forestland, and wildlife habitat. The landscape design preserves the existing ecosystems and vegetation and integrates new native vegetation in areas where the site is altered. Existing trees are retained to shade the building, reduce winter wind, provide views from inside the building, and reduce offsite visibility. Existing open fields to the south are retained for agriculture and solar access. Native fruit trees, shrubs, and other vegetation are planted to soften offsite views, screen parking, provide limited food production, and provide wildlife habitat.

Another part of the site preparation was creation of an 11 -foot-deep pond that has benefits like enhancing the view for NRG employees, a circumferential walking path for warm weather recreation, and hockey and skating in the winter. The pond also serves as catchments for parking lot runoff and a source of cold water, which is piped throughout the building's floor system to provide summertime cooling, and a discharge point for the warmed water. The project includes a pedestrian path that connects the NRG facility directly to the village.



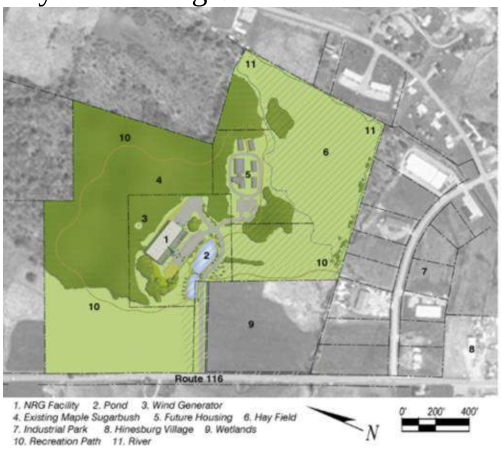


Fig.4-b the project's site plan (eere,2003) **Fig.4-a the building and the surrounding area. (eere,2003)**

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The building is located in the hillside using the benefits of the sloped site. (Figure 5). The north side of the whole first floor is fully underground, and the second floor half-underground. The hillside location reduces heal loss and conserves energy. It also leaves exposed areas to the south for solar collection and wind generation. The open floor plan and three-story vertical openings at the building's center enhance ventilation and cooling. The exterior skin of this steel building is carefully detailed to eliminate all major thermal breaks while allowing penetrations for solar gain, day lighting, and ventilation. A wood-pellet boiler provides radiant heat. The radiant slab also delivers cooling, with heat rejection to the combined storm water, cooling, and recreation pond. Renewable energy is provided onsite by photovoltaic panels, solar thermal collectors, and a wind turbine.

8 Hybrid vehicle is a vehicle that uses two or more distinct power sources to move the vehicle. The term most commonly refers to hybrid electric vehicles (HEVs), which combine an internal combustion engine and one or more electric motors.

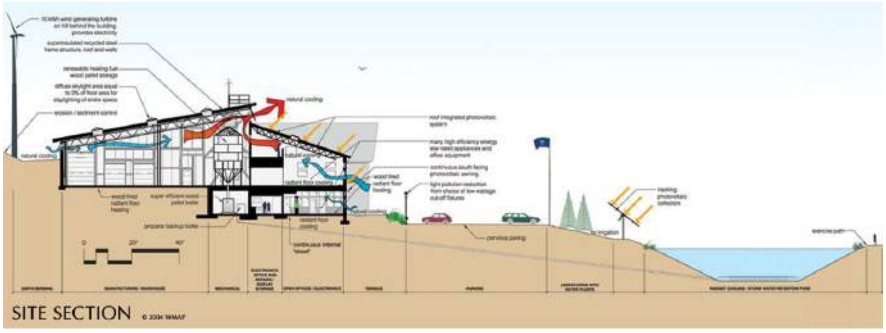

Fig.5 The Project's Site Section. .(William Maclay Architects & Planners, 2008)

The building is elongated on the east-west axis to maximize solar gain in winter and to capture daylight all year. The majority of the glazing is located on the south façade, where it is easy to capture desirable winter sun while limiting undesirable summer sun except for day lighting use. The south-facing roof is used for photovoltaic[9], skylights, and domestic hot water heating (Figure 2). The north-facing roof is white to reflect solar heat gain. The south-facing clerestory windows are used to bring direct sunlight into the warehouse space as well as for nighttime cooling of the building. Trees to the east and west of the building provide summer shading to reduce cooling loads.

The shape and color of the building were selected to be reminiscent of regional warehouses. Local stone and wooden beams and interior finishes were used to provide warmth and relate to regional building methods and techniques. An artist designed the floor to represent the history of wind energy (Figure 6).

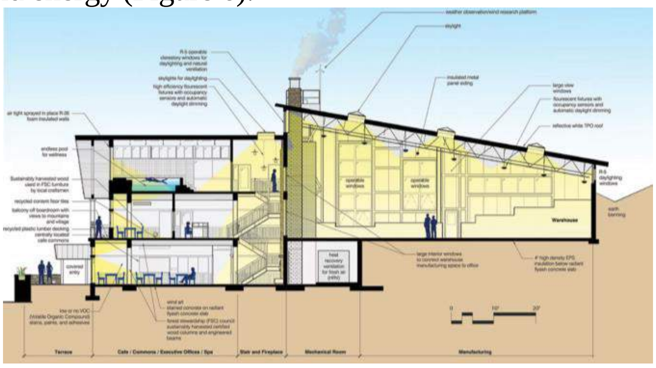

Fig.6 Building Cross Section Showing Skylights. (William Maclay Architects & Planners, 2008).

Fig.6 flooring and interior (William Maclay Architects & Planners, 2008).

An integrated design approach was used, and active and passive environmental strategies were incorporated into the project to accomplish NRG's ambitious human and environmental goals to build a model workplace and to achieve a LEED Gold rating.(Table 2)

3.3.3 Commissioning :

Building commissioning was accomplished using techniques defined in the ASHRAE "Guideline For Building Systems Commissioning," discussed in the LEED guidelines. A dedicated construction LEED team was formed to focus on environmental goals; LEED requirements, opportunities and solutions; and client service. The team included an environmental specialist and LEED manager, the project manager, the superintendent, and the estimator. A strategic plan and process for achieving LEED requirements was developed. Elements of this process included:

9 Is the field of technology and research related to the application of solar cells for energy by converting sunlight directly into electricity.

Table.2 Green Strategies and Solutions

Green Strategies	Green Solutions
Responsible Planning	Ensure that development fits within a responsible local and regional planning framework.
	Site buildings so as to help occupants celebrate the natural beauty
	Provide for solar access
Support for Appropriate Transportation	Provide safe access for bicyclers and pedestrians.
	Provide showers and changing areas for bicycle and pedestrian commuters.
	Provide storage area for bicycles.
	Provide vehicle access to support car and vanpooling.
	Provide for electric vehicle charging.
Reduce waste water	Plumbing fixtures were all chosen for water conservation.
	Runoff Reduction by Considering porous turf-paving systems on low-traffic parking and driveway areas and using surface infiltration basins in landscapes.
Primary Peak-Reduction10 strategies include:	primarily south-facing windows with a low solar heat-gain coefficient, which reduces summer heat gain
	efficient water-to-water heat pumps
	energy-recovery ventilation
	reduced plug and motor loads
	radiant cooling (with no fans)11
	Variable-frequency drives and carbon-dioxide sensors on ventilation air.
	effective daylight use and control.
	High-performance openings: optimize energy performance of glazing systems
	Extensive daylight-dimming and occupancy control of lighting.
Day lighting for Energy Efficiency	Use south-facing windows for day lighting
	Orient the floor plan on an east-west axis for best use of day lighting
Using Other Energy Sources	use a wind turbine system to generate electricity
	Use a photovoltaic (PV) system to generate electricity on-site
	Arrange for sale of excess electricity into the grid
Design for Materials Use Reduction and longevity	Consider exposing structural materials as finished surfaces
	Minimize dependence on sealants by good detailing of building skin
	Select durable window assemblies
	provide a drainage plane in exterior walls to prevent bulk water (rain) penetration
Ventilation and Filtration Systems	Design for optimum cross-ventilation through
	Specify ventilation rates that meet or exceed ASHRAE Standard 62-1999
	Design ventilation system to exchange both heat and humidity between incoming and outgoing air
	Use solar water heaters

- Assembling a LEED team.
- Developing specific subcontract requirements, policies, procedures, and measures for the construction team and subcontractors to ensure compliance with all project goals.
- Conducting regular onsite training and performance reviews throughout the duration of the construction process.
- Continuously tracking environmental metrics to allow for proactive performance evaluation.

[10] Peak-Reduction Represents the load that can be reduced either by the direct control of the utility system operator or by the consumer in response to a utility request to curtail load.

[11] Radiant systems use existing surfaces and structures to deliver heating and cooling to a space and reduce the amount of air movement required for occupant comfort. Radiant floors use tubing or wiring system beneath the floor surface to provide frequent heat or cooling instead of conventional thermostats and air conditioning.

4. CONCLUSION

4.1 Green Design Main Attributes

The Third part of this research paper discusses the relationship between the general design prototype schema proposed by Gero (Gero, 2003) and the two case studies presented previously in order to find a design prototype for green buildings design. Starting by the general design prototype the main attributes for the general model are:

1- Context and knowledge
2- Functional properties and required behavior.
3- Structural properties and actual behavior.
4- Evaluation processes

4.1.1 Context and knowledge:

Design contexts forms the basis for the general design prototype schema , see figure1. it is where required and structural knowledge are generated from. Context includes natural elements such as location, climate, vegetation, row resources,.. etc. In the first case study , Herman Miller Market place, the sub-urban location was a vital factor that affects decision making in more advanced design stages. On the other hand, in the second case study, finding a proper location was a design decision that resulted from deep understanding to design goals and client vision. Climate, orientation and natural resources, as presented in both case studies, played vital role in deciding building setting out, building form, space organization and even the selection of interior finishing materials and furnishing.

Herman factor should not be ignored when talking about design context. Human candidates include client, users and design and construction team. In both case studies, the green building design story starts with a client who has environmental concerns and real responsible towards community and human well being. In the first case, the client was one of the United States Green Building Council (USGBC) with a strong belief in economic, social and environmental benefits of building a green building. Client in the second example has been working the renewable energy field for more than 25 years, that lead to a true commitment towards environment.

A client with high environmental value chose an architect who has the required background and experience, this is how it went in the two selected projects. The designers for the two selected buildings have strong background and precedent knowledge dealing with the design and construction of green and sustainable facilities . They have their own vision and towards more sustainable built environment.

In short, in the pre-design stages, a database of design knowledge is created by the interaction between context natural and human candidates. This knowledge data base forms a basic background in the proposed prototype for green building design . (Figure 1)

4.1.2 Functional properties and required behavior.

As shown previously, design knowledge is gained by the interaction between human and natural factors of design context. According to Gero's model, Design knowledge is divided into functional knowledge, or required behavior, and structural knowledge, or actual behavior. In both case studies a design goal was set up according to available design knowledge. Design goals represent required behavior in green building design. In the first example, the design goal was to create a prototype office environment that reflects client vision for the ideal working place in addition to achieving at least a LEED silver rating. in the second example social, financial , beauty, and well being factors were set up as a design goal beside using renewable energy resources and accommodating company's expected growth.

Design goals are the main criteria in the judging evaluation processes from the early stages of design.

4.1.3 Structural properties and actual behavior.

As shown in the two case studies, synthesis process started by laying down design strategies. These strategies are set up in order to guide synthesis processes to meet design goals. Design strategies were represent what Gero's defined as structural properties or actual behavior. Design strategies represent a frame work or a design guidelines to be followed throughout synthesis processes to insure meeting all design goals.

4.1.4 Evaluation Processes

Evaluation is a continuous process starts with the design phase and continues to construction and post occupant phases. As shown in the case studies special commissioning and evaluation techniques were used such as computer software measurement equipments and commissioning guides. The evaluation process is presented in Gero's model by a reciprocal relationship between required behavior or design goals and functional properties. The evaluation processes leads design to achieve goals by following design strategies.

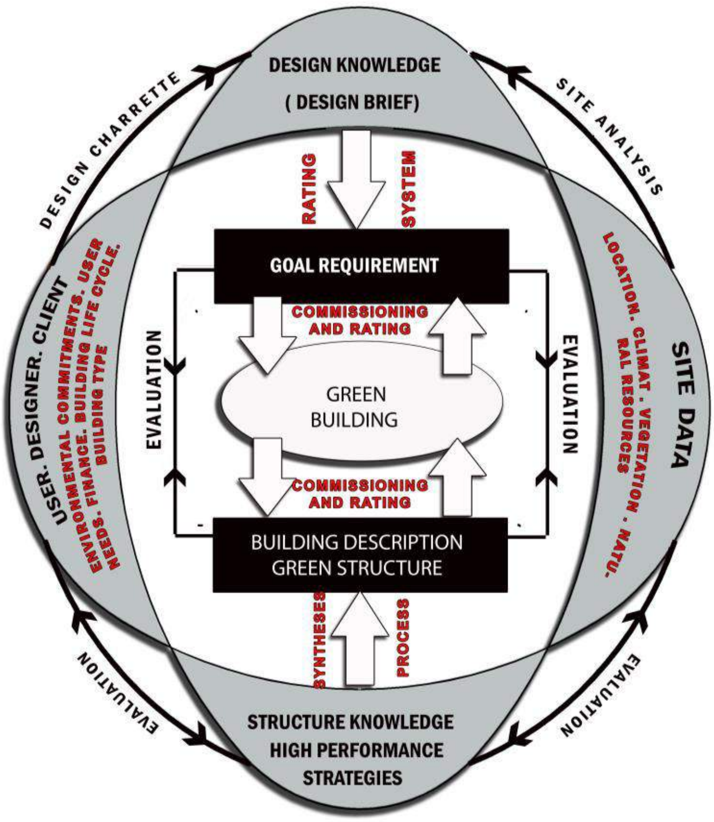

Fig. 7 Green Building Prototype Schema (Author)

In conclusion, the story of designing a green building starts early before the design process begins. In The pre-design stages, a database of design knowledge is created by the interaction between clients, users and designers and site data. The integrated design team defined design goals which are the required behavior for the green building. These goals are characterized according to building context, the vision of the design team, users and client. The synthesis process starts by setting out design strategies which describe the structural properties of the building. Green building design strategies are defined by analyzing design goals, referring to design knowledge database. Evaluation is a very important during synthesis and pre-synthesis process. The evaluation process is applied from the very pre-design and early design stages and up to the construction, operation and post-occupancy stages. It is applied by using special techniques that helps to satisfy design goals during the progressing of the design process.

A simple diagram summarized the above findings, a green building design prototype, and can be used as a design framework for green buildings design. (Figure 7)

4.2 Recommendations

1- Client's vision is a start point in any design process. So it's important to enhance green and sustainable concepts into our culture to improve the green design process.

2- Design process is no more a "one man show", and architect is not the main and only player in the design process anymore. There must be an emphasizing on the concept of integrated design team in both educational and professional fields.

3- There is an increasing need for green and sustainable rating systems to help in the commissioning and evaluation process during design, construction and post occupancy processes of green buildings.

4- The use and development of design prototypes and design models are becoming major subject in green and sustainable design practices because of the diversity and complexity that characterize processes and constrains involved in it.

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