From Light to Life

The Development of Architectural Design Through The Quantitative and Qualitative Analyses of Light

William Patrick Carr
Bachelor of Architecture Undergraduate Thesis Report Spring, 2002
Department of Architecture Ball State University
Andrea Swartz Design Studio Professor
Robert Koester Thesis Advisor

© Carr 2002
Contents

Acknowledgements 04
Abstract 05
Introduction 06
Lighting Studies 08
Precedent Studies 10
Program 14
Context 16
Conceptual Design 18
The Product 22
Reflections 30
Bibliography 32
Acknowledgements

God

My family

Andrea Swartz, thesis design studio professor

Robert Koester, thesis advisor

Jeffrey Culp, studio consultant

I would like to give a special thanks to everyone in studio. Throughout our time here, you have all made the hard work a little more bearable and the good times into the best. In addition, I would like to thank Sara for the trips for ice cream, Shaun for always making me laugh, and SuLin for the dinner breaks from studio. Lastly, a very special thanks to Josh for just being you.
here are two basic questions with which I began this thesis study. They are:

1) How can architectural design enhance the functionality of space through the manipulation of natural light?
2) How can the poetic nature of space be influenced by the manipulation of natural light?

The first step undertaken in the study of these questions was the creation and photographic documentation of a series of light boxes. Six boxes with varying sizes and types of openings were created to study the way light enters defined space. Several lighting characteristics were defined through this exercise.

Upon the completion of the light box study, several preexisting structures were studied for either their lighting characteristics or building typology. Included in this study were Mount Angel Abbey Library, Philips Exeter Library, the San Francisco and Cleveland Public Libraries, the Kimbell Art Museum, and the Church of the Light. Also at this time I developed my first semester project, an outdoor reading and congregating space adjacent to Bracken Library on the Ball State University campus. This piece also helped to further my understanding of the impact of lighting on space.

Following these studies, I created the program for my thesis, a new branch library for the Allen County Public Library in northeastern Indiana, and began developing conceptual ideas for the project. After progressing through multiple schemes, I completed the design with the creation of "The Product."

Having now completed the thesis study, I am pleased overall with the outcome. There are certain areas of the study that I wish I would have had more time to develop and pieces that may have been stronger, but I feel that the final product was a strong element in answering the questions with which I began the thesis investigation.
Natural light can be manipulated in order to support the functionality and poetry of a space.

In the world in which we live today, most buildings use sunlight in a basic and uninspired way. Allowing natural light into a building typically deals more with pattern-making on the exterior of the building rather than considering the ways in which the natural light can influence both the functionality and poetry of the building. Functionally, light can be utilized to illuminate tasks, as well as create order and aid in user understanding of space. Poetically, light can affect the overall atmosphere of space, as in creating awe or mystery.

**How does light move through space?**

There is a natural progression in the manipulation of light in space. The progression begins with the sun. Light emitted from the sun passes through space, crosses through the earth's atmosphere, and strikes the earth's surface. In order to affect the interior quality of the space, designers create some type of openings in the building envelope to allow the light to penetrate into the space. Many designers stop at this point, only creating openings to allow random light to enter their spaces.

There are two important steps which follow that are necessary if light is to both support the functionality and create a poetic response in the space. Designers must consider both the quantitative and qualitative aspects of the light entering the space. As I have defined it, the quantitative aspects of the light deal with the question *how*. In this area, designers must question how light moves through the space, how materials and their textures affect light, and how the geometry of the space affects light. When looking at qualitative aspects, designers focus on the question *why*. Here designers may ask questions as to why this amount of light enters the space, why this light is appropriate for the space, and why this lighting strategy is better.
for the space than other potential lighting strategies.

Through the consideration of how and why, designers can create a cyclical process that can improve the overall design. First, designers create an opening; next, they question how the light comes in through this opening; finally, they question why this lighting strategy is or is not appropriate for both the function and poetry of the space. After completing this process, designers can then return to the stage of creating an opening to further manipulate the opening to fit the desired effects more appropriately. Again, the analyses of quantitative and qualitative behaviors follow to deem the appropriateness of the new opening.

**How does the designed form affect light?**

While the pattern of natural light produced by the sun has a very specific path that it follows, once the light penetrates into a designed form, that form plays a dramatic part in the specific lighting qualities of the enclosed space. The geometric form of the space has the ability to reflect, bend, or diffuse the light. The material type, texture of the material, and material color affect the ability of the form to reflect, bend, or diffuse the light. In each of these ways, the design of a particular space plays a key role in creating the lighting quality of that space.

**How can light affect the creation of the designed form?**

The natural path of the sun creates a simple logic to the design of space. By focusing on how the sun moves through the sky, a designer can manipulate space to take advantage of the sun. Forms, textures, materials, and colors can be manipulated to take optimal advantage of the changing light from the sun. By creating an opening to further manipulate the opening to fit the desired effects more appropriately. Again, the analyses of quantitative and qualitative behaviors follow to deem the appropriateness of the new opening.
before beginning my first semester project for studio, I felt that it was important to study some basic characteristics of how light enters space. To do so, I began my first lighting experiment. The experiment began with the creation of six light boxes. Each box measured 5"X5"X5" and was constructed from 3/16" white foam core. Each box was open at one end to allow photography of the interior and contained an additional opening or openings to allow light to penetrate into the interior. The total area of additional opening for each box measured 2.5 square inches. Each box was then photographed with artificial light simulating the light penetration of the sun at 9am, noon, and 3pm on June and December 21.
Lighting Studies

Principles regarding three basic opening types were discovered through this experimentation. First, square openings, or other openings where the opening height was very near its width, were best used to provide spot-lighting. When placed in walls, these openings can create a general illumination on the interior. On the other hand, openings that were narrow but the full height of the wall provided a type of ray of light into the interior. When placed at corners, these openings create an effect of illuminating an entire wall. The final openings, those which contained a type of light shelf, allow less direct light into the space, but create a more diffuse lighting condition.
Mount Angel Abbey Library
Alvar Aalto
Mount Angel Abbey, Oregon

The Phillips Exeter Library utilizes two key lighting ideas. The first idea is the use of the windows on the exterior of the building; these windows are juxtaposed with the reading carrels to allow changing lighting conditions to reach the carrels throughout the course of the day. The second idea is the large atrium in the center of the library. The atrium allows both direct and diffused sunlight to enter the core of the library. Since direct sunlight can damage books, the atrium allows space for the light to be diffused before penetrating into the book stacks. This allows natural lighting throughout the library without the damaging effects direct sunlight can cause.

Philips Exeter Library
Louis Khan
Exeter, New Hampshire

The Mount Angel Library uses several lighting strategies. First, northern facing windows allow diffuse light to enter the book stacks. In addition, a specially designed skylight detail allows varying types of light into the book stacks and circulation areas. Private reading studies have both transparent and translucent glass to allow light to penetrate through the studies into interior portions of the building. Circular skylights throughout other portions of the library illuminate offices, corridors, and the entry. In addition, each of these skylights contains a lamp directly above it to allow light to enter the space through the skylights even at night.
San Francisco Public Library
Pei, Cobb, & Freed
San Francisco, California

The San Francisco Public Library possesses two main lighting features. The first is a series of large exterior windows that allow light to penetrate deep into the building’s interior, a necessity given the buildings 200’ by 300’ footprint. The second major lighting component is a large, central atrium. The atrium, a circle with a 60’ diameter, spans five floors and allows light to penetrate into the core of the building. A reading room on the fifth floor projects into the atrium; however, rather than blocking a portion of the light, the room actually allows even more light into the interior of the building - the room is completely enclosed in glass and extends above the rest of the library to draw in more light.

Cleveland Public Library
Hardy Holzman Pfeiffer Associates
Cleveland, Ohio

The Cleveland Public Library offers an interesting view on lighting. While its lighting strategy may not be quite as developed as other precedent studies, it does offer one key lighting idea that is not expressed with such vigor in any of the other precedent studies. The Cleveland Public Library acts as a beacon at night with nearly the entire Stokes wing aglow. While the other precedent studies carefully examine the way light enters the building during the day, the Cleveland Public Library looks much more closely at how light can emanate from the building at night. In addition, the glass facade contains a series of convex and concave portions that respond differently to accommodate the lighting needs of the users within the space.
Kimbell Art Museum
Louis Khan
Fort Worth, Texas

The Kimbell Art Museum is an example of a powerful unification of form and lighting. Each barrel vault has an arch-shaped window just below the vault to allow light to penetrate into the space. The resulting effect is the illumination of the wall at the end of each vault, making the space seem more open and expansive. In addition, a specially designed reflector travels the length of each vault to allow natural light to penetrate into the space below. The reflector bounces a diffused light into the space while also blocking the users from a direct view of the skylight above. In addition, the barrel vault helps to reflect the light from the reflector into the center of the space below.

Church of the Light
Tadao Ando
Osaka Prefecture, Japan

The Church of the Light unites lighting into both a very functional and very poetic experience. The cross-shaped aperture allows light to enter the church in a way that emphasizes the function of the space. In addition, this aperture also creates a feeling of spirituality and self-reflection. Other apertures in the structure allow beams or walls of light to grace the interior of the church. The overall effect fully supports the function of the church. This is an example of a lighting strategy based solely on utilizing the power of light.
Bracken Library Reading Space
Ball State University
Muncie, Indiana

The reading space I created for my first semester project was used to explore how lighting could be utilized in the definition of space. The project was divided into two main portions. The first portion was a large gathering space for classes to meet or other large groups to gather; the second piece was a smaller area meant for an individual or small groups.

The larger space contained openings to filter light on the eastern and western walls, as well as a wooden trellis filtering southern light. This space was intended to receive a greater amount of direct sunlight than the smaller space.

The smaller space, contained in a cylindrical form, used its shape as the basis for its lighting effects. The brick form starts at a lower height on the southern side and steps up to its highest point on the northern side. This element creates an ever-evolving light pattern on the northern wall. A square opening on the eastern side of the cylinder creates a spotlighting effect on the interior in the morning hours. In addition, horizontal openings on the southern wall allow direct light to penetrate into the form during the winter while bouncing light into the form during the summer.
The entry space is primarily intended for circulation. It is meant to invite visitors into the building and provide direction to different portions of the library. The circulation desk is located within the entry space to provide ease of material check-out and return, as well as for security reasons.

The general library stacks contain the general reading and studying materials of the library, including books, periodicals, reference texts, maps, and atlases. Users of this portion of the library will use computer work stations to seek library materials, find the materials in the various stacks and cabinets, and browse through these materials at the tables, study carrels, or other furniture. In addition, users may choose to bring study materials into the library to use in these same locations.

The alternative media stacks will include audio and video media, as well as computer software. All of these media will be accessible through the use of computer stations in the alternative media stacks. In addition, hard copies of many of these items will be available for check-out. PC work stations will be provided for users wishing to use library computers, as well as work stations available for connecting lap top computers to library databases.

The computer labs will consist of two main functions: first, they will provide free computer access and internet access to the public; second, they will be used to provide computer classes and workshops for the public. During regular use, individual users will be using the lab for their own purposes. During classes or workshops, the lab will not only be used for computer work, but will also be used for instruction.

The private reading rooms will be used for one or two individuals to study or work in a private, quiet space. A computer will be provided in each private reading room for computer use, as well as a port to connect a lap top to the internet.

The classrooms will be used for general instruction. Specific items being taught have not been identified, so the classrooms may be rearranged to meet the specific needs of instructors and classes. Instruction may include lectures, slide presentations, and audio and video presentations.

The small conference rooms will be used for small group meetings of up to twelve people. Activities in these spaces include meetings, graphic presentations, and slide presentations.

The large conference room will be used for group meetings of up to twenty people. Activities in these spaces include meetings and graphic and slide presentations.

This space is for the use of the director of the library. Uses will include the individual work of the director, meetings with individuals from the public, and small group meetings.

This space is for the use of the assistant director of the library. Uses will include the individual work of the assistant director and meetings with individuals from the public.

The library media storage will be used to house texts, periodicals, audio and video media, and computer software that is not being displayed in the public stacks of the building. Activities of this portion of the library will include the retrieval and replacement of media being checked out by the public.
<table>
<thead>
<tr>
<th>Item</th>
<th>Qty</th>
<th>Square Footage</th>
<th>Net Square Footage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entry/Circulation Desk</td>
<td>1</td>
<td>X 400</td>
<td>400</td>
</tr>
<tr>
<td>General Library Stacks</td>
<td>1</td>
<td>X 4000</td>
<td>4000</td>
</tr>
<tr>
<td>Alternative Media Stacks</td>
<td>1</td>
<td>X 1000</td>
<td>1000</td>
</tr>
<tr>
<td>Computer Lab</td>
<td>2</td>
<td>X 600</td>
<td>1200</td>
</tr>
<tr>
<td>Private Reading Room</td>
<td>8</td>
<td>X 50</td>
<td>400</td>
</tr>
<tr>
<td>Classroom</td>
<td>2</td>
<td>X 600</td>
<td>1200</td>
</tr>
<tr>
<td>Small Conference Room</td>
<td>2</td>
<td>X 200</td>
<td>400</td>
</tr>
<tr>
<td>Large Conference Room</td>
<td>1</td>
<td>X 400</td>
<td>400</td>
</tr>
<tr>
<td>Director’s Office</td>
<td>1</td>
<td>X 150</td>
<td>150</td>
</tr>
<tr>
<td>Assistant Director’s Office</td>
<td>1</td>
<td>X 120</td>
<td>120</td>
</tr>
<tr>
<td>Library Media Storage</td>
<td>1</td>
<td>X 2500</td>
<td>2500</td>
</tr>
</tbody>
</table>

Net Square Footage = 11,770

Gross Square Footage* = 11,770s.f. / 0.65 = 18,108

<table>
<thead>
<tr>
<th>Item</th>
<th>Item Calculation</th>
<th>Sub-Total</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building Cost</td>
<td>[18,108 gsf x $70 / sf]</td>
<td>$1,267,490</td>
<td>$1,267,490</td>
</tr>
<tr>
<td>Fixed Equipment</td>
<td>[8% of Building Cost]</td>
<td>$101,399</td>
<td></td>
</tr>
<tr>
<td>Site Development</td>
<td>[12% of Building Cost]</td>
<td>$152,099</td>
<td></td>
</tr>
<tr>
<td>Total Construction Cost</td>
<td>[additive total of above]</td>
<td>$1,520,988</td>
<td>$1,520,988</td>
</tr>
<tr>
<td>Site Acquisition/Demolition</td>
<td>[not available]</td>
<td>$--------</td>
<td></td>
</tr>
<tr>
<td>Movable Equipment</td>
<td>[15% of Building Cost]</td>
<td>$190,124</td>
<td></td>
</tr>
<tr>
<td>Professional Fees</td>
<td></td>
<td>$22,814</td>
<td></td>
</tr>
<tr>
<td>Programming</td>
<td>[1.5% of Construction Cost]</td>
<td>$22,814</td>
<td></td>
</tr>
<tr>
<td>Architecture</td>
<td>[7% of Construction Cost]</td>
<td>$106,469</td>
<td></td>
</tr>
<tr>
<td>Interiors</td>
<td>[2% of Construction Cost]</td>
<td>$30,419</td>
<td></td>
</tr>
<tr>
<td>Contingencies</td>
<td>[10% of Construction Cost]</td>
<td>$152,099</td>
<td></td>
</tr>
<tr>
<td>Administration Costs</td>
<td>[2% of Construction Cost]</td>
<td>$30,419</td>
<td></td>
</tr>
</tbody>
</table>

Total Budget** [additive total of above] = $2,053,332

* Assumes a 65/35% efficiency ratio

**Estimated Cost is in December 2001 Dollars
The site chosen for this project is on the north-east side of Fort Wayne near the junction of State Road 37 and Interstate 469; this location allows for easy vehicular access from all parts of the city, although it would most likely be used primarily by local residents. The site is located in a commercial district that includes a Meijer department store and a Menards, as well as restaurant and bank. In addition, there are plans to expand the commercial area to include another grocery store and a Kohl's department store on the opposite side of State Road 37. This commercial district is surrounded on all sides by residential land. Nearby are two elementary schools and a middle school.
his portion of Fort Wayne is quickly growing, but does not have close access to a branch library of the Allen County Public Library. The population of the district ranges from lower-middle to upper-middle class citizens. Portions of the area have been annexed into the city of Fort Wayne recently, and additional portions are expected to be annexed in the coming years.
The early conceptual design for this project began with the creation of two models. The first model represented the idea of creating a very organized building facade with no concern for resulting lighting conditions. The second model represented total concern for interior lighting conditions with no regard for building facade, organization, or functionality. The creation of the building was meant to fall somewhere between these two extreme conditions. Upon completing this modeling exercise, sectional studies of specific portions of the library, shown at right, were creating as a way of studying the possible ways that building skin could be used to affect the ways in which lighting would be brought into the library. From these sectional studies, as well as the creation of the first scheme, the list below of methods for allowing light to enter the library was created. Eventually, the conceptual idea of utilizing rotated geometries as a basis for the introduction of several of these lighting methods was incorporated.

Methods for allowing light to enter the building:

1) Thickening/Thinning of Wall
2) Absence/Extension of Wall
3) Baffling/Diffusing of Light
4) Reflection/Bouncing of Light
5) Spotlighting
6) Wall Washing
7) Light Wells
Conceptual Design

Lighting opportunities of rotated geometries:
1) Rotation aligns with opaque vs. transparent walls.
2) One geometry aligns with spaces needing light, the other aligns with spaces requiring less light.
3) Crossing of geometries creates space to use for light wells.

scheme One uses a semicircular form for the main library functions. Half levels in this space allow for expansive views from each portion of the library. Computer labs adjacent to the western side of the computer lab act to buffer light entering into the lower levels of the library, while the roof of this portion acts as a light shelf to bounce light into the upper portions of the library. Conference functions and the alternative media and children's sections of the library are housed in the northern portion of the building where they receive less direct sunlight.
Scheme Two uses the earlier idea of an element of the building to buffer the general stacks, but this piece is now a reading space for the library. Conference rooms, classrooms, and computer labs have moved to a cube in the northwest portion of the building. The alternative media stacks and children's section of the library remain in the northeastern portion of the library. A light-filled atrium connects all portions of the library.
scheme Three condenses the library into two main volumes. The semicircular form is retained to house the general library stacks, but now also includes the alternative media stacks and children's sections of the library. The conference wing has moved to a cubic in the northeastern portion of the building. The overlapping semicircles remain in the stacks area to filter light. Overlapping forms have been introduced in the conference portion of the library as a conceptual way of filtering the amount of light that enters the functions housed in this portion of the library. In this scheme, the circulation desk moved to the center of the library to allow optimal views of library stacks and patrons.
hen beginning this project last fall, I was concerned that I wouldn't be able to find the right project that would be able to keep my attention and interest for the entire year. Now that the year is complete, I find myself wishing that I had another six months to develop the project further. Whether that means that I found the right project or that I'm crazy, I'm not sure, but it was definitely a fun journey.

verall, I'm quite pleased with the places I have gone with this project. The process was an ever-evolving game that started with a plethora of random ideas floating around in my head and ended with a well-organized structure following very simple principles. While the final product may not meet all of the expectations I had for it, I believe that the process through which I traveled on the way to the final product was far more important than the final product itself. That journey certainly went beyond any expectations I may have had for it.

ooking back now, there are a few elements I wish I would have developed further. I would have liked to develop the light wells in the rotated cube to a further degree. I also would have liked to have further developed the hanging panels in the general library space. Moreover, development of the entry courtyard and site could have made this structure a much stronger element in its suburban context. Nonetheless, the lessons I have learned along the way are far greater than any drawing or model could ever show.


Aalto's Second American Building: An Abbey Library For A Hillside In Oregon.


Controversy in Cleveland. Inland Architect: September-October, 1989, 9, 12, 16.


