Daylighting as Determinate of Architectural Form

Studio 002
Studio Professor: Robert Fisher
Faculty Advisor: Robert Koester
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Acknowledgements

Daylighting as Determinate of Architectural Form

Thanks to Bob Fisher for your advice, encouragement, and the beer at BW3’s.

Thanks to Bob Koester for helping to push the design further than I thought I could take it.

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Thanks to everyone in Studio 002 for your suggestions and the fantastic year.
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A Louisville-based developer, JKL Properties, Inc. wishes to construct a mid-rise residential, office, and retail building on the corner of Pearl Street and Riverside Drive in downtown Jeffersonville, Indiana. The building will accommodate (18) two bedroom condominium units; (1) community recreation area; (1) community entrance area; (1) office for an environmental research organization that specializes in gathering land-use statistics, energy consumption statistics, and conducting environmental impact studies for lawmakers, policymakers, industrial organizations, and special interest groups; (1) café with outdoor seating, specializing in coffee, sandwiches, and pastries; and (6) tenant build-out retail units.

The tenant build-out retail units will be located on the first floor of the building in order to maintain an essential connection to the street. The tenant build-out retail units will also be located as closely as possible to the streets and feature large expanses of glazing in order to attract passing pedestrians on the street and greenway. The office and café areas will occupy the second floor since they required less connection to the street and because the improved views are an important amenity. They are to also maintain a strong relationship to the Ohio River in order to increase the desirability of the units. The condominium units will be located on the upper floors of the building and feature a number of amenities that are intended to attract an upper-middle class clientele. To this end, the condominium units will have a strong relationship to the Ohio River and contain many features normally associated with suburban homes such as a generous allotment of well organized indoor and outdoor space.
Introduction

The sun has been Man's primary source of illumination for millennia. It reliably provided an abundance of light for a yearly average of 12 hours per day. The other 12 hours were marked by darkness, which could merely be displaced by fire, Man's other source of illumination. As fire could not provide enough illumination to perform visually intensive tasks, Man, being a visually oriented creature, was forced to conduct the majority of his activities when daylight was present. Therefore, Man learned to adapt his built environment to effectively utilize daylight.

During the late nineteenth century, Man discovered that running an electrical current through media such as tungsten or mercury could produce light. As he gradually improved this new form of artificial illumination, he began to celebrate his dominance over darkness as he had with other forces of nature. With an abundance of artificial illumination at his control, Man began to disregard the daylighting strategies employed by his predecessors.

Eventually, Man realized that there were shortcomings to relying too heavily on artificial illumination. First, it consumed large amounts of energy. This became increasingly important as he realized that the resources on his planet were finite and that he damaged nature every time he worked to become independant from its forces. Not only did his lamps consume energy as they produced light, but they also produced roughly twice the heat per footcandle than daylight. Man also realized that, despite his efforts, electrically illuminated spaces were not as comfortable as those illuminated with daylight. Daylighting rendered colors better, creating lively, vibrant spaces. It also varied throughout the day, due to the sun's movement and atmospheric conditions. This caused the mood of spaces to change with the passing of time and the ever changing weather, keeping man in tune with the outside world. Electrically lit spaces were sterile and uncomfortable in comparison.
# Programme

## A. Two Bedroom Condominium Unit (18 total)

1. Living Room w/ balcony and fireplace  240 S.F.
2. Entry
   a. Vestibule  100 S.F.
   b. Coat Closet  90 S.F.
   c. 10 S.F.
3. Kitchen
   a. Kitchen w/ range, oven, dishwasher, microwave, pantry, bar, and casework  100 S.F.
4. Dining  100 S.F.
5. Half-Bathroom  80 S.F.
6. Office  120 S.F.
7. Restroom  80 S.F.
8. Bedroom w/ 6 linear feet of closet space  120 S.F.

### Master Suite
- Master Bedroom  260 S.F.
- Walk-In Closet  140 S.F.
- Master Bathroom w/ (2) sinks, toilet, and bathtub  80 S.F.

### Utility Closet w/ water heater, water softener, furnace, washer, dryer, and storage  90 S.F.

### Net Square Footage  1290 S.F.

### Grossage (30% Net Square Footage)
- Includes circulation, structure, interior partitions, and mechanicals  390 S.F.

### Gross Square Footage  1680 S.F.

## B. Community Recreation

1. Rooftop Garden w/ landscaping  N/A
2. Community Room w/ pool tables, dining tables, fireplace, and basic food preparation equipment  2000 S.F.
3. Restroom
   a. Men's Restroom  250 S.F.
   b. Women's Restroom  100 S.F.

### Net Square Footage  2250 S.F.

### Grossage (20% Net Square Footage)
- Includes circulation, structure, interior partitions, and mechanicals  450 S.F.

### Gross Square Footage  2700 S.F.

## C. Community Entrance

1. Entry Vestibule  60 S.F.
2. Vertical Circulation Core
   a. (2) Elevators @ 120 S.F. each  240 S.F.
   b. Elevator Vestibule  120 S.F.
3. Mailroom w/ (18) postal lockboxes  50 S.F.
4. Community Storage Room w/ (18) 20 S.F. closets and equipment to secure bicycles  700 S.F.
5. Janitor's Closet, Telephone, and Water Fountain  40 S.F.
6. Restrooms
   a. Men's Restroom  250 S.F.
   b. Women's Restroom  100 S.F.

### Net Square Footage  1680 S.F.

### Grossage (50% Net Square Footage)
- Includes circulation, structure, interior partitions, and mechanicals  840 S.F.

### Gross Square Footage  2520 S.F.

## D. Cafe

1. Outdoor Dining  N/A
2. Indoor Dining for 40 patrons  850 S.F.
4. Food Preparation  100 S.F.
5. Serving Counter w/ bar seating  100 S.F.
6. Utility Closet  40 S.F.
7. Restroom
   a. Men's Restroom  80 S.F.
   b. Women's Restroom  40 S.F.

### Net Square Footage  1170 S.F.

### Grossage (30% Net Square Footage)
- Includes circulation, structure, interior partitions, and mechanicals  400 S.F.

### Gross Square Footage  1570 S.F.
Programme

E. Environmental Research Organization

1. Vestibule / Reception w/ 8 linear ft coat closet  120 S.F.
2. General Office for (3) secretaries and supplies storage  170 S.F.
3. Manager's Office  180 S.F.
4. Conference Room for (8) individuals w/ video conferencing system  300 S.F.
5. Open Office Area for (10) researchers, (2) marketing specialists, and (1) IT specialist  1200 S.F.
6. Break Room w/ kitchenette and table seating for (8) individuals  200 S.F.
7. File Storage  100 S.F.
8. Utility Closet w/ water heater, water softener, and storage  40 S.F.
9. Restrooms
   a. Men's Restroom  100 S.F.
   b. Women's Restroom  150 S.F.

Net Square Footage  2560 S.F.

Grossage (50% Net Square Footage) Includes circulation, structure, interior partitions, and mechanicals  1280 S.F.

Gross Square Footage  3840 S.F.

F. Office / Café Access

1. Lobby  1500 S.F.
2. (2) Elevators @ 120 S.F. each  240 S.F.
3. Janitor's Closet, Telephone, and Water Fountain  40 S.F.

Net Square Footage  1780 S.F.

Grossage (20% Net Square Footage) Includes circulation, structure, interior partitions, and mechanicals  360 S.F.

Gross Square Footage  2140 S.F.

G. Tenant Build-out Retail Units

1. Tenant Build-out Unit (6) @ 1500 S.F. each  12000 S.F.

H. Mechanicals

1. Mechanical Room @ 6% gross square footage for environmental research office, café, office / café entrance, and retail units  1200 S.F.
2. Mechanical Room @ 6% gross square footage for community entrance, circulation, and community recreation area  770 S.F.

Total Gross Square Footage  64540 S.F.
The site for the proposed mid-rise residential, office, and retail building is located on the corner of Pearl Street and Riverside Drive in downtown Jeffersonville, Indiana. The site measures approximately 280' x 220' with an area of 61,600 square feet. The site for the proposed multi-use building has a rich and varied context. It is located on the north bank of Ohio River and features an excellent view of downtown Louisville to the south. An amphitheatre has been recently constructed on the southeast side of the site. It will serve as a terminus for a greenway project linking Jeffersonville, Clarksville, New Albany, and Louisville. To the east is a popular local bar / grill and Spring Street, the main street through Jeffersonville's downtown area. To the north is the floodwall, a Corps of Engineers pumping station, and a seven-story retirement complex. On the west side of the site are a number of single and multi-family residences. Many of the structures in the vicinity date to the late 1800's.

Jeffersonville has been in the process of revitalizing its downtown and riverfront for the last decade. Much of the effort has been directed toward attracting upscale businesses and upper-middle class residents to the area. A considerable amount of effort has also been directed toward preserving the character and architectural heritage of Jeffersonville's downtown. Several buildings have been preserved at great price, and many of the buildings that have been constructed in the last two to five years were designed using historical precedents.
Aerial Composite Photograph of the Site and Context. The greenways and parks are in green, commercial corridors in brown, the proposed location of a new 30 story commercial/residential building in yellow, and the site in red.
There were two primary objectives that drove this project, one qualitative, one quantitative.

The first, qualitative, objective was to utilize daylighting as a tool for the creation of pleasant living and working environments. Companies such as Herman Miller and Lockheed Martin have found that illuminating their facilities with sunlight has had a positive impact on their employee morale. Le Corbusier claimed that the house is "a receptacle for light" and to "teach your children that a house is only habitable when it is full of light and air." To Le Corbusier, there was a direct relationship between the quality of natural light present in a space and its habitability.

The second, quantitative, objective was to utilize daylight as the building's primary source of illumination, thus lowering energy consumption. Electrical illumination alone accounts for approximately 5% of the total energy consumption in the United States. This figure could be dramatically reduced with the effective use of daylight. Daylight contributes half the thermal load per footcandle of electrical illumination. This means that less energy is required to cool a building that is illuminated with judiciously utilized daylight than one that is illuminated with electrical lighting.
Mechanics

There are two components to daylight, beam light and skyvault light.

Beam light is a result of the sun’s rays on a clear day. It can illuminate perpendicular surfaces with an intensity of 6,000 fc - 10,000 fc. This is much too bright for task illumination and it releases heat on the first surface it comes in contact with, so some measures must be taken to moderate it.

Skyvault light is a result of reflection and refraction of the sun’s rays as they pass through the atmosphere. Skyvault light from either a clear or overcast day can illuminate surfaces with 500 fc - 2,000 fc. It is soft and diffuse, and it contributes almost nothing to a building’s thermal loads. Skyvault illumination on a clear day is at its highest levels at the periphery of the sun and at its lowest levels 90° from the sun with a 10:1 ratio between the brightest and the darkest portions of the sky. On an overcast day, skyvault illumination is at its highest levels at the zenith and at its lowest levels at the horizon, with a 3:1 ratio between the brightest and the darkest portions of the sky.

Generally, light from the north and south is desirable because it is relatively glare free. The sun is closest to the horizon in the east and west, meaning that it can become a source of glare in the morning and evening.
Alvar Aalto, Baker Dormitory, Massachusetts Institute of Technology
Baker Dormitory's diagonal axis and curvilinear form juxtaposes against MIT's orthogonal campus grid. It uses a single loaded corridor so that all rooms receive southern light, and so that diagonal views of the nearby River are maximized.

Le Corbusier, Unite d'Habitation, Marseilles
Unite d'Habitation was a double loaded corridor design, with units penetrating through the entire width of the building. Because it was double loaded, it was elongated on the north-south axis so each unit had equal access to daylight. Though the units were deep, they are well illuminated because large expanses of glazing were incorporated, and the units had access to light from both sides.

Louis I. Kahn, Exeter Library, Phillips Exeter Academy
At the heart of the Exeter Library was a top lit atrium, surrounded by and inner ring of stacks and then an outer ring of reading carousels. Double height glazing with sills at chest height insured that light penetrated deep into the inner ring of stacks. Just below the double height glazing were the reading carousels with small apertures for view. To Kahn, it was natural that a person with a book goes to the light to read.
Strategies

There are a few simple strategies that can be employed to maximize the benefits of natural illumination while minimizing its negative impacts.

Elongating a building on the east-west axis maximizes access to glare-free south and north light while minimizing low angle east and west light. Many indigenous cultures such as the ancient Greeks and Pueblo Indians followed this pattern for development.

Lightshelves function by reflecting light through the upper portions of an aperture while shading the lower portion. This lowers the level of illumination towards the front of a room while maintaining the level of illumination towards the back of a room, resulting in uniform distribution. This uniform distribution creates the perception of increased levels of illumination.

Vertical louvers can be utilized to shade apertures against low-angle east and west light. Vertical louvers were used by many late modern architects.

Separation of apertures into portions for illumination and portions for view results in a good distribution of light, while limiting visual access where privacy is a concern.
In order to study daylighting strategies in detail, a number of model studies were conducted. Studies A, B, and C were conducted on the heliodon to judge the effectiveness of different methods of reducing glare from low angle east and west beam light. Studies D and E examined a traditional method of integrating fenestration versus approaching the fenestration as being separated into components for illumination and view. In both studies, the head height and area of the aperture were constant, only the configuration varied. They were conducted in the mirror box and outdoors to determine the effectiveness of the different methods.

Study A examined the effectiveness of vertical louvers to block low angle east-west beam light. It was found that the louvers needed to be 4 units deep for every 9 units in between louvers in order to function adequately, due to orientation. For the results of the study, see Appendix A.

Study B examined the effectiveness of rotating the fenestration to face south to block low angle east-west beam light. For results of the Study, see Appendix B.

Study C examined the effectiveness of angled overhangs to block low angle east-west beam light. It was found that the overhangs performed well, but they drastically reduced the amount of glazing available and they precluded the use of lightshelves. For results of the study, see Appendix C.
Studies

Study D examined the effectiveness of a traditional method of integrating fenestration. For results of the study, see Appendices D and E.

Study E examined the effectiveness of separating the fenestration into separate components for illumination and view. It was found that this method resulted in higher levels of illumination throughout the space. For results of the study, see Appendices D and F.
Throughout the project, several models were built in order to study the relationships of programmatic elements. These studies were key in the development of the project and serve as benchmarks in its evolution.

The first study was a massing exploration. The primary method of providing shading from east-west beam light in this study was the incorporation of vertical louvers.

The second study was also a massing exploration. However, the primary method of providing shading from east-west light beam light in this study was a combination of incorporating vertical louvers in the retail component and rotating the residential and office components to face south. It was found that this solution greatly enhanced views of the river.

The third study was a massing exploration in which all components of the building were rotated to face south. While glare from east-west beam light would have been reduced, the retail component was at odds with the geometry of the street.

The fourth study was a massing exploration in which the residential component was oriented to face south and the office and retail components were oriented with the street grid. This was judged to be a more optimal solution to the problem, as it simultaneously addressed views, glare from east-west beam light, and the geometry of...
the street. The office and retail components were subdivided in order to fit the context.

The fifth study was a more detailed exploration of the fourth study.

The sixth study was a massing exploration in which the residential component was subdivided further and the rotation of surfaces to face south was explored on the office component. This concept addressed the juxtaposition between the residential component and the retail and office components.
Solution

The mid-rise residential, office, and commercial building could be likened to stand of trees on a fractured limestone river bluff. Such geological formations are found periodically along the banks of the Ohio River and often serve as the backdrop for local history and legend. The office and retail component of the building are clad in brick. The vertical mortar are joints dyed to match the brick and the naturally colored horizontal mortar joints are raked to produce shadows in order to emphasize the weight of the component. The fenestration is rotated from the street grid give the office and retail "base" a sense of being fractured. The "base" is also scaled to the surrounding 1-3 story buildings. The residential component is clad in red cedar clapboard and stained a dark color. A faceted facade with deep balconies, along with the pilotis causes the residential component to serve as a reference to trees. The dichotomy of the vertical and horizontal components, along with the dark color helps to push the residential component into the background. Aluminum paneling serves to link the commercial and retail component to the residential component and to tie the aluminum light shelves to their respective facades. The use of trellises with vines and green roofing on the southern side of the building helps to link it to the greenway.

Several methods of distributing daylight were chosen for the building. First, the beam component is dealt with by incorporating deep lightshelves into the fenestration on the south side of the building. This helps to distribute light while simultaneously reducing solar heat gain. The skyvault component is dealt with by incorporating high aperture head heights and a narrow building section on the north-south axis. These two factors helped to create a large attenuated angle. In other words, any point inside of the building would “see” a large portion of the sky vault. Shallow light shelves are incorporated into the north side of the facade in order to facilitate the distribution of skyvault light. Low angle east or west beam light is moderated by rotating the largest glazed surfaces to face south or by incorporating screens.

Electrical Illumination is integrated into the lightshelves in the form of semi-indirect flourescent luminaries. Architects such as Bill Lamb and Alvar Aalto favored integrating daylighting sources and electrical luminaries because it helps to insure consistency in how daylighting and electrical illumination is distributed.

The building’s fenestration is treated as having separate components for view and illumination. This simultaneously permits even distribution of light while accomodating varying needs for privacy. Transoms and glazed interior partitions were incorporated to aid penetration of natural illumination.
Solution

Anything within the building envelope that obstructs daylight is generally placed perpendicular to the glazing. In the residential zone, storage areas, bathrooms, and the utility closet are aligned along the west wall in a linear arrangement. This maximizes the area of fenestration in the residential units. In the retail and office units, cubicle partitions and shelving are placed perpendicular to the fenestration to aid the penetration of light.

The retail and office component of the building features a mixture of elements that are rotated to face south and elements that respect the street grid. On the first floor retail units, rotated elements are used to define entries, while elements that respect the street grid feature large storefront windows. All the fenestration on the south side of the office and café is rotated in order to transition from the street grid to the residential component.

Each unit of the residential component is rotated to face south to minimize exposure to east and west low angle beam light for the largest expanses of glazing. This is because east and west low angle beam light is problematic early in the morning and late in the afternoon, when occupants are most likely to be home. Rotating the residential units to face south also creates desirable diagonal views of the river and gives views of the high-rise building in downtown Louisville. A trellis with vines is provided on the east side of this balcony in order to shade apertures on its west side, in the master bedroom and dining room. This allows a view of the balcony from these spaces while while addressing the problem glare from low angle beam light. Deciduous trees can block up to 60% of light without leaves, so vines could probably offer similar shading performance. In addition, the west facing apertures are deliberately kept relatively small so that blinds could be effectively utilized to reduce glare.
Perspective of the project from the Ohio River

Perspective of the project Riverside Drive
Interior perspective of a residential unit
Models

South Facade

South Facade
Models

South Facade

North Facade
Models

View of Project From Ohio River

Aerial View of Project
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Daylighting As Determinate of Architectural Form
Daylighting as Determinate of Architectural Form
Enlarged Resilientlighting Section
Sections
Overall, the project could have been gauged as being successful. It was discovered that not only could daylighting enrich as a space and offer energy savings by elongating a building on its east-west axis, incorporating lightshelves, incorporating vertical louvers, and separating apertures into portions for illumination and view, but that the application of these measures could enliven the physical form of the building, giving it expression. The building was also well organized and the spaces were inviting and livable. Despite its size, the building fit its context relatively well. The subdividision of the facade and the use of wood and brick as cladding materials pushed the building into the background.

There were problems with the building, however. The looser organization residential facade and the more formal organization of the office and retail facade did not communicate well. Perhaps, the fenestration could have been modified, the level of physical interaction between the sections could have been increased, or the number of materials could have been reduced. The trees on the rooftop garden may have also presented problems. They should have been placed in planters instead of being placed in mounded soil matrix on top of the roof sheathing.

There were also a few deficiencies in the studies. In the mirror box studies, measurements should have been taken closer to the work plane at the 30" level instead of the 48" level. Light studies involving detailed models of the final spaces should have been conducted in order to assess the intricacies and nuances of their illumination quality. Light studies involving the building massing in its context should have also been conducted in order to assess shadows cast on neighboring buildings.
Appendix A

Heliodon Study A

June, 9:00 am       June, 12:00 pm       June, 3:00 pm

May / July, 9:00 am May / July, 12:00 pm May / July, 3:00 pm

April / August, 9:00 am April / August, 12:00 pm April / August, 3:00 pm

March / September, 9:00 am March / September, 12:00 pm March / September, 3:00 pm
Appendix A
Appendix C

Heliodon Study C

June, 9:00 am
June, 12:00 pm
June, 3:00 pm

May / July, 9:00 am
May / July, 12:00 pm
May / July, 3:00 pm

April / August, 9:00 am
April / August, 12:00 pm
April / August, 3:00 pm

March / September, 9:00 am
March / September, 12:00 pm
March / September, 3:00 pm
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Appendix D

Diagram of mirror Box (image: Moore, Fuller. Environmental Control Systems)

Multisensor Photometers (image: Moore, Fuller. Environmental Control Systems)

Mirrobox Study D

Mirrobox Study E

Plan of the Study D Bedroom study with location of Multisensor Photometer

Plan of the Study E Bedroom study with location of Multisensor Photometer

Section of the Study D Bedroom study with location of Multisensor Photometer

Plan of the Study E Bedroom study with location of Multisensor Photometer
Appendix D

Plan of the Study D Kitchen and Dining Room study with location of Multisensor Photometers

Section of the Study D Kitchen and Dining Room study with location of Multisensor Photometers

Plan of the Study E Kitchen and Dining Room study with location of Multisensor Photometers

Section of the Study E Kitchen and Dining Room study with location of Multisensor Photometers
Appendix E

Daylighting Study D

Bedroom, June, 9:00 am  Bedroom, June, 12:00 pm  Bedroom, June, 3:00 pm

Bedroom, March / September, 9:00 am  Bedroom, March / September, 12:00 pm  Bedroom, March / September, 3:00 pm

Bedroom, December, 9:00 am  Bedroom, December, 12:00 pm  Bedroom, December, 3:00 pm
Appendix F

Daylighting Study E

Bedroom, June, 9:00 am
Bedroom, June, 12:00 pm
Bedroom, June, 3:00 pm

Bedroom, March / September, 9:00 am
Bedroom, March / September, 12:00 pm
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