
25.

Natural Light and the Urban Environment

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The urban environment is a combination of many man-made and natural elements. Of the latter, natural light is one of the most important amenities to insure a vital, dynamic, and inhabitable city. High-rise building has increased the need to protect natural light to the street and to consider carefully the design of building bulk; in response, regulatory protections have taken many forms, the most common of which is the Floor Area Ratio (FAR). Unfortunately, FAR is an ineffectual device for environmental and aesthetic considerations and, in particular, for determining quantities of light, air, and wind. In fact, a building's blockage of light to the street is a function of the placement of building bulk in relation to the street, not of its FAR.

This chapter follows the historic development of building regulation for natural lighting concerns. It examines the differences between various regulatory methods that have been recently studied and implemented in New York City, San Francisco, and Boston. Finally, suggestions are made for the development of site-specific regulation, which will provide an overall qualitative analysis of the building's effect on the street environment. The qualitative approach proposed here may provide greater design flexibility as well as stimulate the designer toward a more environmentally pleasing aesthetic.

URBAN LIFE AND HIGH-RISE BUILDINGS

An urban street that is bright yet not heavily shadowed offers a pleasant experience to pedestrians. Imagine a city scene, a vibrant commercial area with a variety of storefronts that create a pastiche of architectural attitudes and historic eras. Some people hurry on their way to work, while others shop and

stroll; perhaps a few indulge in a favorite pastime of many, watching other people.

This image is a positive view of the city, a sparkling street where light plays across the facades of buildings and highlights their architectural detail. The street is not windy or dusty, but crisp and alive. The brilliant natural illumination intensifies the faces of the passersby to make them recognizable and congenial. Many of these strangers are pleasantly enjoying the day as, for a few moments, they escape their office for some fresh air and natural light.

The assumption in this picture is environmental. Light and air are vital to the pedestrian's enjoyment. They not only influence the quality of street life, but reflect the ambience and livability of the city as a whole. Natural light enhances the usefulness of open spaces as well by increasing the enjoyment of squares, sitting areas, and parks. Even in cold weather, people may find the urban park a pleasant place to pause or to eat lunch, if it is warmed by the sun and sheltered from the wind.

Although architects and planners cannot control atmospheric conditions, they can do much to maximize and protect the natural resources of light and air, which highlight existing architecture as well as enhance the value of urban spaces.

Yet that valuable urban amenity, natural light, has been severely overlooked in the past thirty years, when increased density and high-rise development should have required especially careful study and planning. In comparison with the millions of dollars spent to create urban spaces for office and commercial facilities, very few resources have been expended for understanding natural light and protecting it. We have forgotten that the street represents a large portion of expensive urban land, of unbuilt public territory. This oversight has come to bear on the livability

of the American city, where dark, shadowed, canyon-like streets have become the expectation, not the exception.

Natural light also increases the value of buildings. Real estate developers know that perimeter windowed spaces rent more easily and for more money than windowless spaces. Similarly, the value of a building cast in shadow is less than that of one highlighted by sun and sky. Imagine, for example, I. M. Pei's John Hancock Building in Boston crowded by buildings on all sides. The dramatic nature of that structure, its reflection of clouds, sunlight and, in particular, the sunset, which throws a shaft of color onto its bevelled facade, would be lost were the structure shadowed by neighboring buildings.

NATURAL LIGHT: SUNLIGHT VERSUS DAYLIGHT

With greater emphasis on the livability of cities in the 1980s, zoning guidelines and design review have become increasingly important. Yet these planning methods do not necessarily include considerations of natural light. As was stated, the Floor Area Ratio is an inadequate approach for guaranteeing natural light. Placement of building bulk on the site, setbacks, notching of corners, and reflectivity of the building facade all affect the amount of natural light that will reach the street.

Several steps are suggested to develop effective zoning guidelines or regulations for a particular urban environment. First, the type of natural light desired must be clearly defined. The methodology for assessing the impact of proposed development on specific urban streets and open spaces will differ based on whether the long-term goal is to obtain daylight, which emanates from the sky dome, or sunlight, which comes directly from the sun. Second, the existing context must be fully analyzed for current lighting levels and conditions. Third, based on the contextual study, realistic goals must be set for the type of light desired in various sections of the city. Flexible design guidelines may result that not only provide a positive urban environment for the pedestrian, but also offer architectural options for the designer.

Sunlight comes from sun rays, which follow a daily path; the angle of the rays varies depending on the season. In the summer the angle of the sun path to the earth is higher in the sky, while in the winter the sun is much lower. This difference affects the lengths of the shadows that are cast as well as the availability of sunlight during various seasons. Daylight, on the other hand, is diffused from the entire sky dome and

can emanate from either an overcast or a clear sky. For this reason orientation is not as important a consideration as it is for sunlight.

While regulation for daylight can offer a wide range of loose parameters, regulation for sunlight, particularly in dense urban areas, typically must become specific and restrictive. The distinction between regulation for the two types of natural light is evident in the comparison of current proposals in New York City that regulate for daylight with those in San Francisco that propose to regulate for solar access.

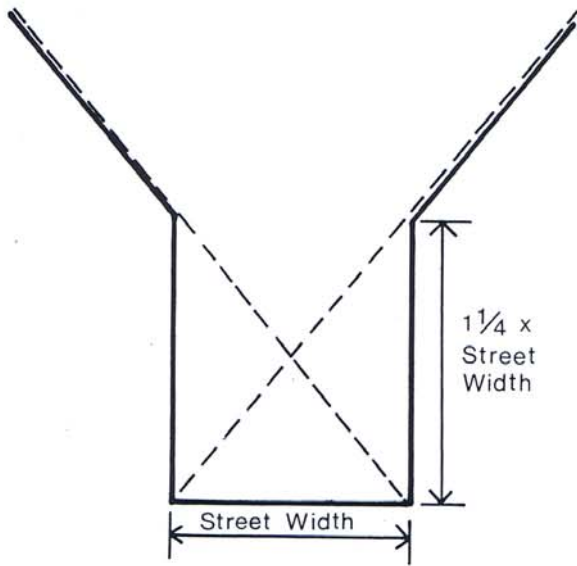
HISTORICAL OVERVIEW OF NATURAL LIGHT REGULATION

Although the need for regulating urban development for daylight may be more pronounced today, public regulation of daylight and sunlight is not a modern invention. A long history of urban planning exists from which references can be drawn for contemporary planning.

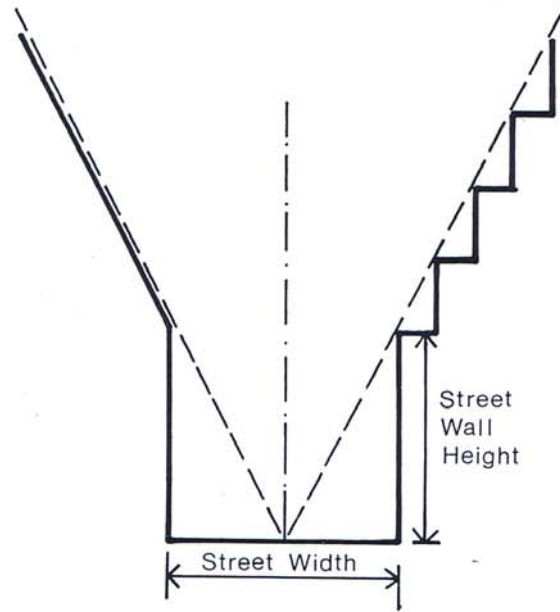
The Ancient Greeks and Romans both mandated minimum lighting standards for their cities (Rodger 1972). The British Law of Ancient Lights, which dates back to 1189, was embodied into statute law in the Prescription Act of 1832. Under that act, buildings that had windows and had enjoyed uninterrupted access to natural light for at least a twenty-year period were protected from a new adjacent building encroaching upon that right.

In the United States, it was not until the turn of the century that daylight and sunlight problems in cities began to attract attention. In 1912, a Boston architect named William Atkinson developed a technique for quantifying how changes in orientation, shape, and building height affected natural light to the street (Atkinson 1912). This research helped him advocate the need for legislative control of building bulk and placement on urban sites. Boston's previous zoning law, dating from 1892, limited the height of buildings to two-and-one-half times the width of the street, with a maximum limit of 125 feet. In contrast, Atkinson's proposal used a sky exposure approach: a line was drawn from the opposite side of the street continuing through the edge of the street wall, which was one-and-one-quarter times the street width, forming the allowable envelope within which a proposed building had to be constructed (fig. 25-1).

Atkinson's work was influential in the development of modern zoning standards, which began to be drafted shortly after the publication of his work. In 1915, the New York Heights of Building Commission, established to study legislative controls in other cities,



25-1. Atkinson's proposal for limiting building height.



25-2. New York's 1916 street-wall and sky-exposure concept.

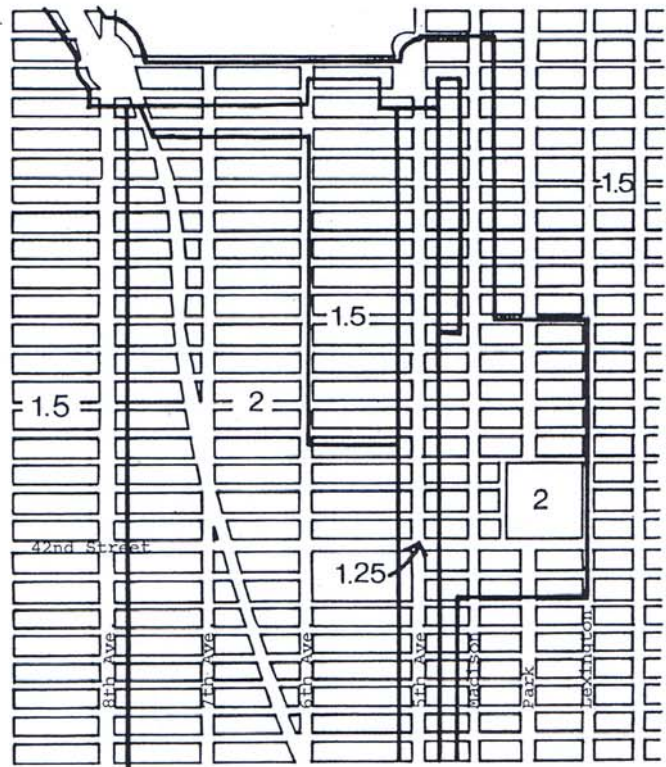
recommended that New York City be zoned on the German system, which divided cities into existing uses and building types and specified maximum building heights for each district (New York Heights of Building Commission 1915). Most of these recommendations were incorporated into the 1916 Zoning Ordinance for New York City (New York City Planning Commission 1945).

As the first comprehensive municipal attempt in the United States to guide and control physical form and function legally, the New York City 1916 Zoning Ordinance guaranteed minimum street-level standards of natural light and air. It incorporated Atkinson's two innovative approaches, the street wall and the sky-exposure plane (fig. 25-2). The street-wall approach related building-wall height to street width, based on five "height districts" related to perceived utility, neighborhood character, and the need for pedestrian amenity (fig. 25-3). For example, Fifth Avenue with its low-scale buildings and carriage-trade retail was designated a lower height district than surrounding streets and avenues.

The other approach, the sky-exposure plane, defined the amount of sky that could be seen from the center of the street, based again on street width and street-wall height. A lower height district yielded greater sky exposure, and thus, more light reached the street.

These regulations had major architectural and planning ramifications, limiting the allowable bulk of building bases as well as the total building bulk. The resulting buildings rose from the street to their allowable street-wall height, and then began a series of set-

25-3. New York's 1916 height district map.



backs to remain within the sky-exposure plane. When the floor area reached 25 percent of the site, a tower of unlimited height was allowed. The characteristic "ziggurat" or "wedding cake" buildings that later resulted from this ordinance may be attributed to the

limitations of the design and development community rather than to the ordinance itself. Although often criticized for being too restrictive, the 1916 ordinance includes such diverse building designs as the Empire State, RCA, and Seagram buildings. In fact, architects such as Raymond Hood, chief designer of Rockefeller Center, found considerable inspiration in the 1916 ordinance. The numerous setbacks of the RCA tower were not required by the ordinance; rather, they celebrated the setback concept itself, much in the same manner as Hugh Ferriss did in his expressive drawings of an "imaginary metropolis" (1929).

For more than forty years, the 1916 ordinance remained the model zoning standard for many American cities. Even New York City did not substantially change it until 1961. Yet further work was being done, especially in England and Scandinavia, to refine methods of measuring daylight to the street and the effect of buildings on street daylight. George Ford, New York's regional planning director, in his posthumous book *Building Height, Bulk and Form*, added an economic analysis of daylight to his extensive review of planning attitudes and studies on this subject. He stated that, "Indeed, there is an almost universal feeling that light is one of the most important factors affecting the profitableness and permanence of larger bulk buildings" (1931: 7). The idea of linking profit to daylight, although based on common sense, has not been exploited expressly as a planning argument since then. Yet, of course, the real estate and development industry is fully aware of the relative value of buildings located on daylit streets, as compared with those that are shadowed throughout the day.

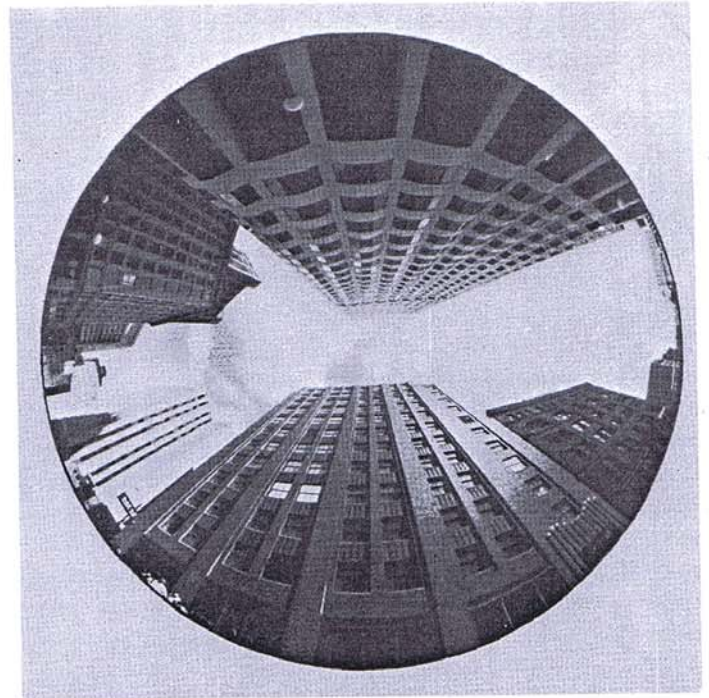
In the 1960s, most cities either had or were in the process of adopting a new type of zoning, usually based on the Floor Area Ratio. FAR is a convenient quantitative measure: it regulates the number of times the overall lot area can be multiplied, resulting in the total allowable floor area of a building. Yet FAR has not proved to be an effective method of controlling the *placement of building bulk on a site*. Its shortcomings were especially evident in the 1960s, when municipalities began to use FARs to encourage the inclusion of public amenities into proposed building projects. For example, an increase in building height or FAR was permitted only if plazas, lobbies, and retail spaces were included in the building design. This process, often based on discretionary review, frequently disregarded the traditional role of zoning to provide natural light and air to the street. It yielded buildings that rose sheer from the street or property line, creating the all-too-common "canyon effect" mentioned earlier.

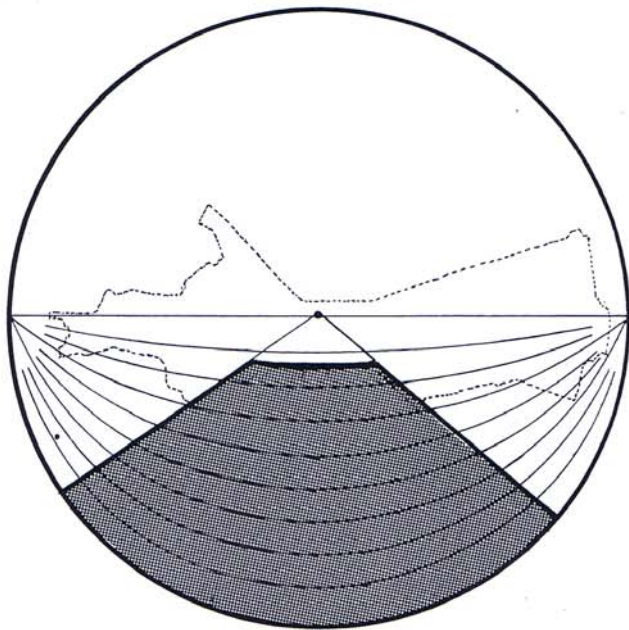
ADVANCES IN DAYLIGHT ASSESSMENT

An alternative method of assessment to the FAR approach was used in the preliminary studies of existing conditions for Boston in 1984. It was adapted from a research methodology developed by the Swedish architect Gunnar Pleijel (1954), who designed a technique for measuring the percentage of unobstructed sky at any urban location. With this technique, existing conditions can be analyzed and the impact of proposed buildings in an existing context can be projected.

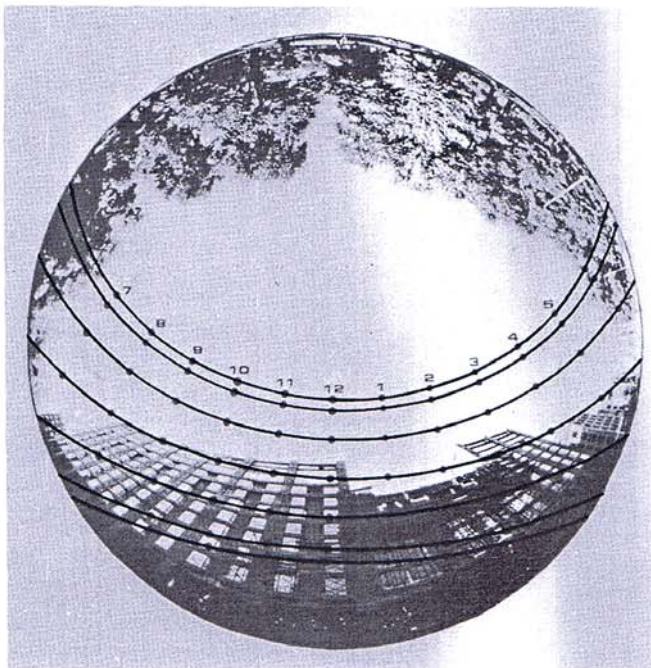
Pleijel used his invention, the globoscope (a device that was the forerunner of today's fish-eye lens), to photograph the sky dome. These photographs can document daylight at any desired location by recording a distorted, yet proportional, impression of the surrounding buildings on both sides of the street (fig. 25-4). Light to the street is measured by the amount of the sky dome that is obstructed by a building in the fish-eye photographs. The daylight cutoff angle created by the building's roof edge can easily be found and masked with a transparent overlay sized to the diameter of the fish-eye image. The overlay helps to measure the building's angle of elevation (the angle between the horizon and the roof edge). From the overlay, one can easily determine the amount of light to the street by extending the vertical edges of the street side property lines to the zenith and by subtracting the obstruction mask from the resulting pie-shaped form (fig. 25-5).

25-4. Typical fish-eye-lens photograph.





25-5. Obstructing mask subtracted from pie-shaped property envelope.



25-6. Sunpath overlay for block adjacent to the Boston Commons.

One can also use the fish-eye projection to determine the amount and duration of sunlight striking urban open spaces. This is done by using a sun-path transparency as an overlay on the fish-eye photograph taken from the open space (fig. 25-6). The number of hours per day of sunlight at any reference location

and at any particular time of the year can be easily gauged with sun-path overlay transparencies. This technique can be used to develop guidelines to guarantee solar access to open spaces during a specified portion of the day.

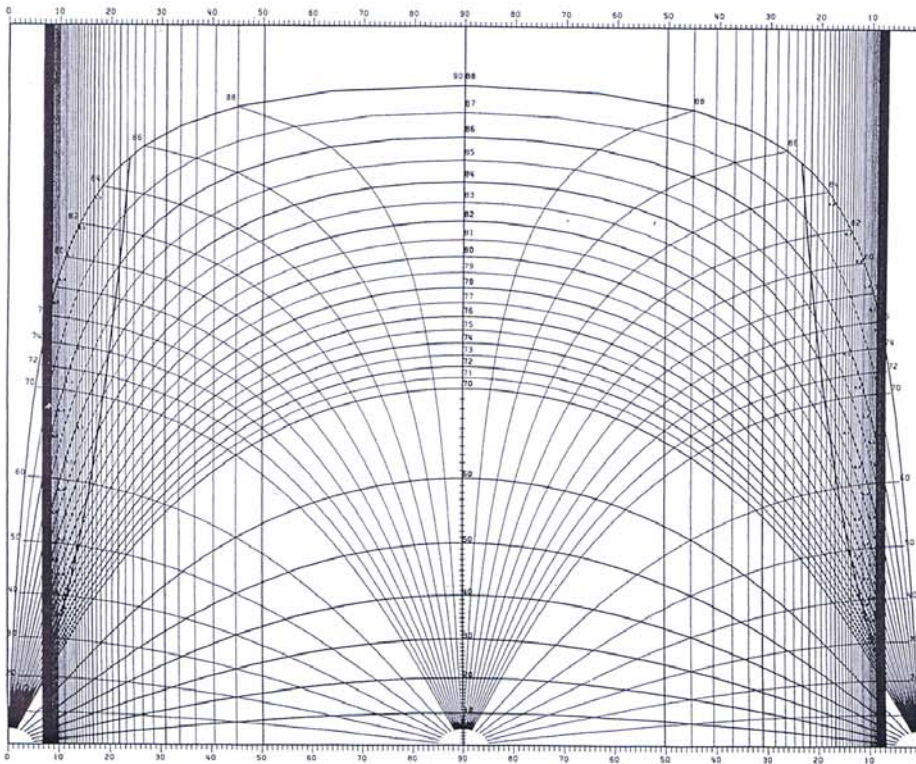
CONTEMPORARY PERSPECTIVE

Cities throughout the United States are placing greater emphasis on the livability of the urban environment by requiring downtown development to meet urban design criteria. Although the mistakes of the 1960s and 1970s cannot be reversed, cities can begin to look toward buildings that preserve the openness of streets and that protect the right of pedestrians to daylight. New York City initiated a zoning study for midtown Manhattan in 1980 (New York Department of City Planning 1980), San Francisco soon followed with a sun and light study for downtown in 1983 (Bosselmann et al. 1983, and see chap. 15), and Boston undertook a daylight study of Boylston Street and its financial district in 1984 (Bryan and Stuebing 1984). These studies find their roots in the early work of Atkinson and Pleijel and look toward more sensitive zoning methods.

Midtown Manhattan's New Ordinance

In midtown Manhattan's revised zoning ordinance, the placement of building bulk on the site and the admission of light to the street become, once again, key concerns. The design of new buildings must maintain the context of their surroundings based on pedestrian perception from the street, building mass, street-wall height and length, and the placement of building bulk on the site. These elements also predict the effective light to the street.

The performance approach of this ordinance involves a four-part test that evaluates a proposed building by a point system. The building must score 55 points out of a possible 100. The crucial test is for daylighting, which must be evaluated at a minimum 40 points and can represent as much as 60 percent of a proposed building's overall score. A modified version of a sky-vault diagram, called the Waldram Diagram, is used to measure the amount of daylight to the street for a given building (fig. 25-7). The chart is a grid that quantifies the daylight reaching the street from the top and around the sides of a building. As the proposed building is masked onto this grid, the grid's unobstructed blocks are multiplied by weighted values and then totalled, resulting in a daylight equivalency score. This score is obtained in each direction for



25-7. New York's daylight evaluation chart for a 60-foot street.

each street on which a proposed building borders, evaluating the presence of the proposed structure as perceived from a point 250 feet away.

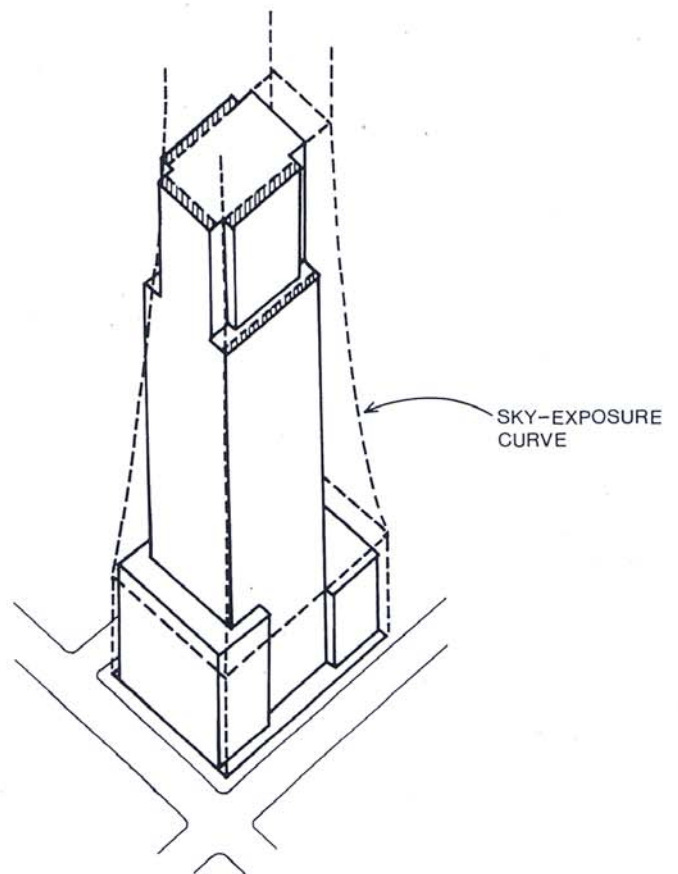
Although an important step to protect daylight, this approach has proven too complex to become an effective urban design tool. The New York City Planning Commission thus countered with an alternative prescriptive approach that was simpler yet architecturally more restrictive (New York Department of City Planning 1982). In theory, this prescriptive approach is similar to the sky-exposure planes of the 1916 ordinance. "Sky-exposure curves" are used, which define the allowable shape and bulk of proposed buildings (fig. 25-8).

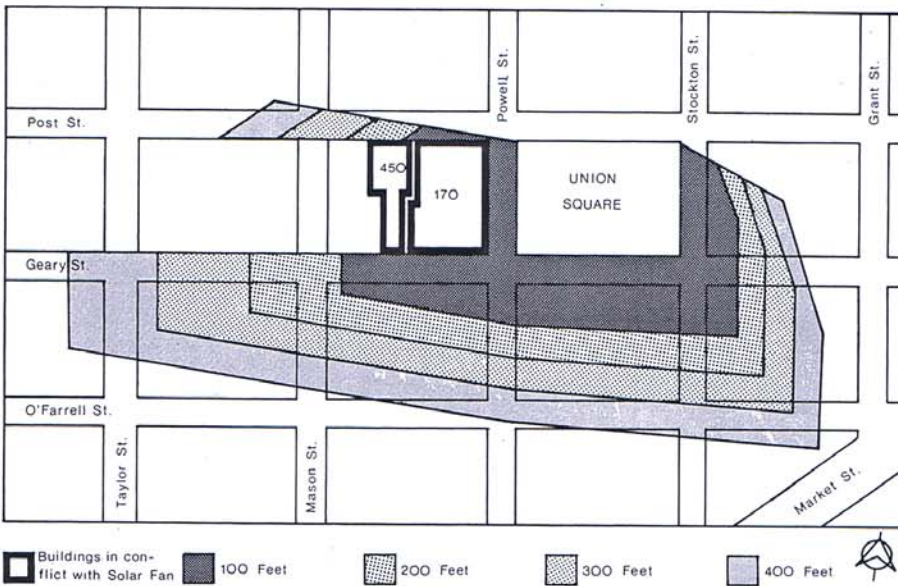
San Francisco's New Ordinance

In 1983 the City of San Francisco commissioned a study to explore the effect of high-rise buildings on the quality of its urban environment. Although the evaluation of light to the street was similar to that of New York City, the resulting guidelines, based on the work of Ralph Knowles (1981) and the concept of a solar envelope, were more restrictive in an urban environment with existing high-rise buildings.

The study investigated a number of public open spaces and city streets for sun and light access during critical times of the day (from about 10:00 AM to 2:00 PM). Sunlight (as opposed to daylight) access during those hours was deemed necessary to ensure active

25-8. New York's alternative to the daylight evaluation chart: the sky-exposure curve.



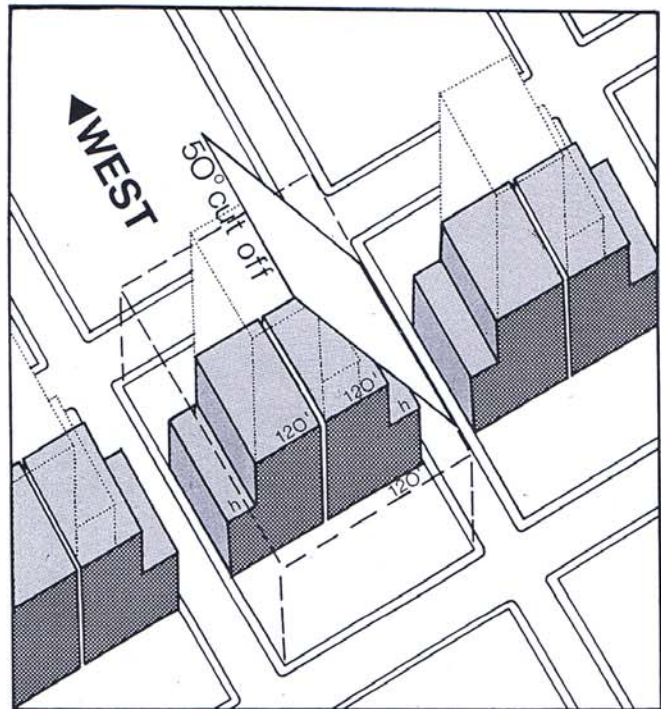


25-9. San Francisco's proposed height envelope around Union Square.

use, especially for outdoor lunch-hour activities. For each open space studied, solar access criteria were established and a sun profile plane was generated to shape the height envelope within which a new building would be required to conform. Thus, the envelope, as defined by the sun profile plane, set parameters of the shape and height of the largest possible building on a given site that would not shadow an adjacent open space (fig. 25-9).

Solar access criteria for San Francisco streets were developed in a similar manner as those for open spaces. Downtown San Francisco has four basic street orientations (north-south, east-west north of Market Street, northeast-southwest, and southeast-northwest south of Market Street). Along east-west streets north of Market Street, for example, solar access was allowed from March to September during the majority of the day. A sun profile plane was generated from the north sidewalk to establish an envelope within which proposed buildings on the south side of the street would have to be sited (fig. 25-10).

San Francisco's approach provides for selective solar access to public streets and open spaces (Bosselmann et al. 1983). Interestingly, however, it creates uneven allowable envelopes along downtown streets. For example, the heights of buildings along the south side of an east-west street will be less than those along the street's north side. Because much of San Francisco's existing downtown does not meet the proposed guidelines, widespread conformance to this approach may be difficult to achieve. However, San Francisco's use of solar access criteria to control development adjacent to public open space is a unique and useful model, although care must be taken to prevent such criteria from becoming overly restrictive.



25-10. San Francisco's proposed zoning envelope for east-west streets north of Market Street.

The Boston Study

Both the New York and San Francisco studies laid the groundwork for the Boston study (Bryan and Stuebing 1984), whose goal was to develop daylighting guidelines that designers could easily address. Intended to predict the most positive attributes of proposed projects, the guidelines could not be overly prescriptive.

Unlike the gridirons of New York or San Francisco, Boston's historic narrow and curving streets have

been continued by contemporary downtown development. As a result, however, these oddly sized streets and irregular patterns require more detailed analysis than was necessary in either New York or San Francisco.

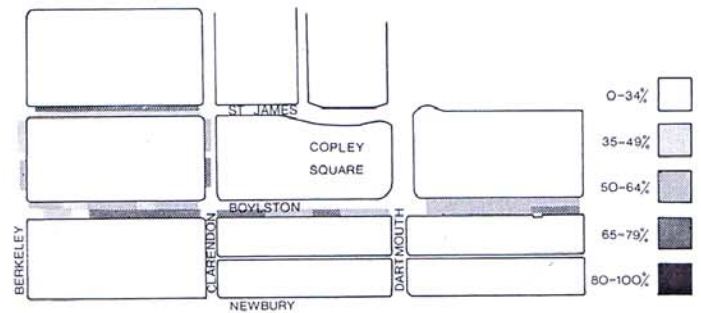
Two areas were investigated: Boylston Street and the financial district. Assessments of fish-eye photographs resulted in values assigned to buildings based on the amount of daylight that was able to reach the street. The assigned numerical values accounted for site, design, setback, and notching of the building, which allow light to reach the street from the building's sides. Often, towers with high cutoff angles monopolized only part of the site and had lower values (because more light was reaching the street) than smaller buildings built to their property lines.

Boylston Street is a major entryway to Boston's downtown. Foresighted planning of the Back Bay area resulted in low cutoff angles and a general commonality in street-wall height. The low and consistent street wall, coupled with Boylston's generous width, offers a unique boulevard quality (fig. 25-11). For most of the length of the street, the cutoff angle remained below 65 percent, owing to both low building heights (maximum 70 feet) and the existence of setbacks at street level. However, several new structures violated the old established street wall, destroying vistas and creating shadowed pockets along the street. The need for sensitive regulation is demonstrated by such development, which, if continued, could threaten the openness of Boylston Street.

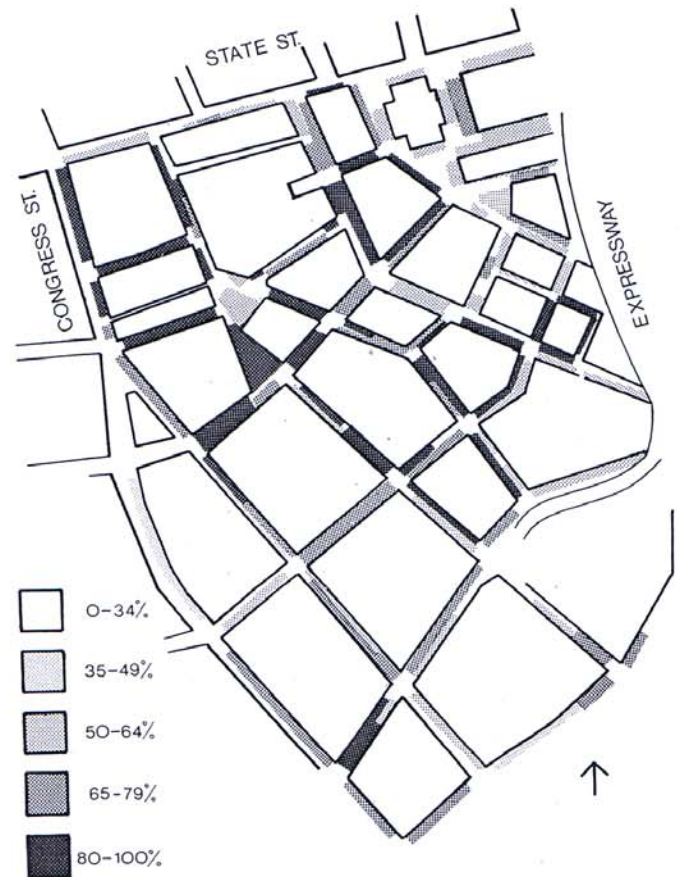
The level of daylight in the financial district is consistently lower than on Boylston Street (fig. 25-12). The majority of the streets there, particularly in the center of the district, have little light (above 80 percent cutoff) due primarily to the irregular street patterns, narrow street widths, and lack of setbacks. In addition, new office building construction during the last few years reaches building heights of up to 500 feet. A few nineteenth-century blocks are the only areas in this district that offer relief from the dark and shadowed street environment.

STATE-OF-THE-ART DAYLIGHT ASSESSMENT

Although high FARs often coincide with the loss of daylight to immediate surroundings, the Floor-to-Area Ratio is not the only factor to be considered. Buildings with similar FARs can result in very different amounts of light to the street, and buildings with low FARs can significantly reduce daylight, depending on the placement of bulk on the site.



25-11. Daylight map of Boston's Boylston Street: percentage of sky obstructed.

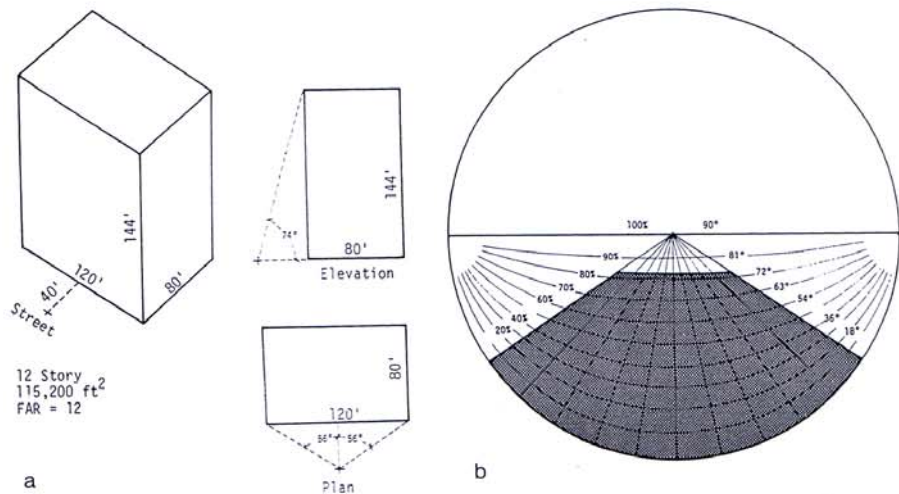


25-12. Daylight map of Boston's financial district: percentage of sky obstructed.

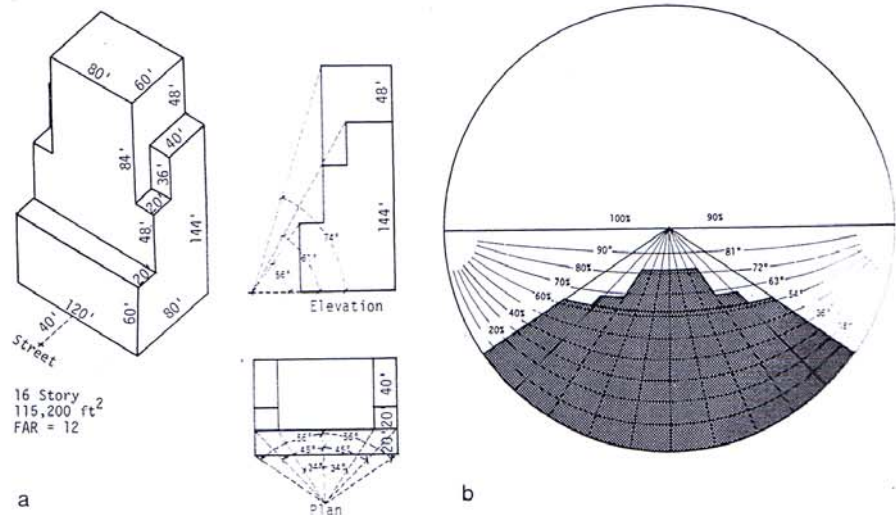
The following example illustrates the impact of a daylight analysis of a proposed building. Let us assume that two buildings that are to be constructed on the same site have identical FARs. Assume also that the buildings differ only in their design: the first (fig. 25-13a) is a large rectangular solid, while the second (fig. 25-14a) has several of its upper stories set back and its corners notched. One can compare the daylight impact of the buildings by constructing a projection that is identical to the fish-eye projection. The plan and the elevation of the buildings are drawn, with corners defining the shape of the building located in reference to the center of the street. Under the hypothetical conditions proposed, these corners are 40 feet from the buildings because the street is given to be 80 feet wide, with no initial setback from the property line in either case. By drawing lines to connect the center of the street to the critical corners

of the buildings, one can determine a series of angles and use them in conjunction with the angle of elevation overlay to mask the buildings onto the fish-eye projection (fig. 25-13b, and 25-14b). The percentage of light to the street is then calculated by dividing the pie-shaped property envelope into 100 units. This is accomplished by multiplying the ten equal angular increments that are on the angle of elevation overlay (which consists of ten fixed arcs of 9° each) by the ten equal angular increments (which vary depending on property and street dimensions) that have to be drawn within the angle of azimuth—the angle in plan that is formed between the reference point in the center of the street and the edges of the two streetside property lines. With the pie-shaped property envelope so divided, the number of units of unobstructed sky can then be subtracted from 100, resulting in the percentage of light to the street that is obstructed.

25-13. Proposed building designed as a rectangular solid: a. building bulk and relationship to the street; b. diagram showing 82 percent of the sky obstructed.



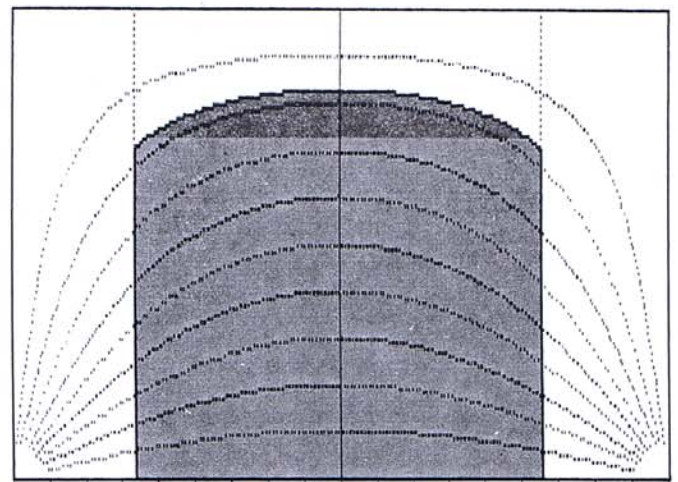
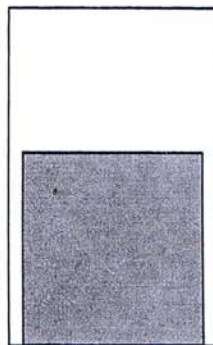
25-14. Proposed building designed to set back on the site: a. building bulk and relationship to the street; b. diagram showing 75 percent of the sky obstructed.



This hypothetical projection illustrates that although the FARs for both buildings are identical, the design of the second building accounts for 7 percent more daylight to the street. The placement of bulk to the back of the site, the street-wall (200-foot setback at 60 feet), and the notched corners are features that make the second building more sensitive to daylight, even though it is given to be 48 feet taller than the building illustrated in fig. 25-13.

Although the fish-eye projection is extremely useful for determining sky obstruction, the tediousness involved in its construction detracts from its use as a zoning evaluation tool. Through microcomputers, however, one can easily automate and graphically display the technique outlined in this chapter. In fact, a microcomputer program called BRADA was developed at the Massachusetts Institute of Technology for this purpose. BRADA will automatically construct a

25-15. Output from the BRADA program: a. daylight obstruction diagram for building shown in figure 25-13; b. same diagram for building in figure 25-14. Note the same results.

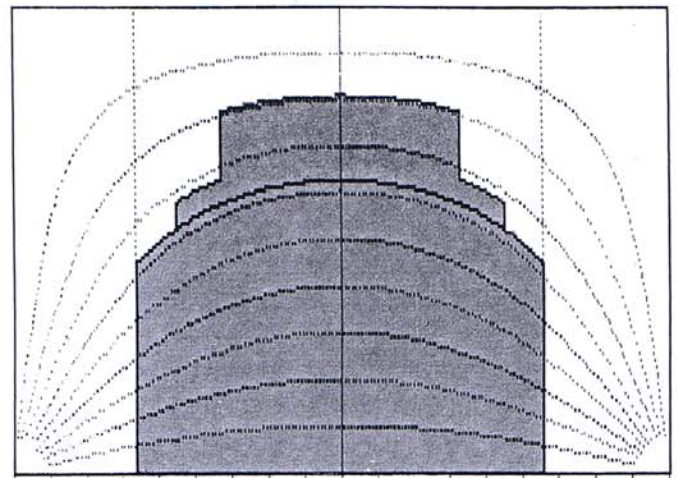
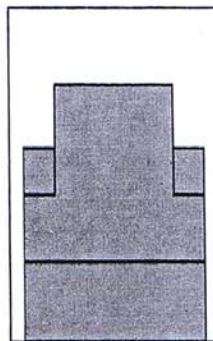


Boston Redevelopment Authority Daylighting Analysis

90 80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80 90

Daylight obstruction 82.7%

a.



Boston Redevelopment Authority Daylighting Analysis

90 80 70 60 50 40 30 20 10 0 10 20 30 40 50 60 70 80 90

Daylight obstruction 74.5%

b.

rectangular projection of half the sky dome, plot the obstructing building, and compute the percentage of obstruction in approximately two minutes. The program also has a parametric run option, which allows the designer to quickly compare a new building configuration with previous analyses. Figure 25-15 presents BRADA output for the two previously discussed buildings (notice the same results as those generated in figures 25-13 and 25-14).

CONCLUSION

The designer need not be overly restricted by efforts to ensure the presence of daylight in the street environment. In this chapter, we have presented an alternative method to evaluate the design of buildings that involves a quantitative measure of a qualitative effect. It should be perceived as an example of methodology for considering daylight. Other methods may be developed that adapt this approach or that consider the same aspects from a different perspective and for particular circumstances.

In this methodology the following concerns are critical: (1) existing context, (2) building height to width of the street or street wall, (3) placement of building bulk, (4) type of light desired, specifically, sunlight or daylight, and (5) type of urban space, specifically, open space or park area. Additional considerations may include the type of material used on the building facade: light-reflective material may be considered as having a more positive effect on urban space than a dark absorptive material, such as dark tinted glass.

Each building must be considered individually. However, by standardizing the evaluation within the urban context, one can more easily establish a comparative basis between proposed and existing buildings. The method of evaluation need not be overly restrictive, even if it governs the design of the bulk of the building. For appropriate zoning, priority may be given to certain considerations, depending on the local context. For instance, if the street-wall relationship is considered the most important feature, it should not be altered for the purpose of daylighting without careful study.

Failure to ensure the presence of light and other environmental amenities threatens the livability of

the urban environment. Clearly, the cost of increased density of development may be far greater than is measurable in economic terms. An urban environment may be compromised in such a way that a vital street can become dreary, dark, windy, and lifeless. Similarly, historic and renowned areas may be ruined if cast in the shadow of dense high-rise buildings that are erected without consideration of the context. The daylight assessment methodology presented in this chapter offers an approach that can both stimulate better design of buildings and protect urban environments.

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