ECONOMIC ASSESSMENT OF DAYLIGHT AVAILABILITY CHANGES CAUSED BY NEW CONSTRUCTIONS

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ABSTRACT

This paper presents a case study demonstrating new techniques to assess the financial impact caused by changes in daylight availability due to the construction of a high rise building in a city downtown. The entire site surrounding the building has been modelled with a Computer Assisted Design tool. A powerful daylight simulation tool was then used to compute Daylight Factors on all building facades, taking into account multiple reflexions of light in the streets. Local data on luminous climate were used to determine the variations in daylight availability in the buildings in hours per year. Finally, the financial impact related to the modification of daylight availability has been assessed, for the additional lighting consumption as well as the reduction of office rental values. The total losses for the surrounding buildings was found to be 130,000 $/year for a 50 meter high building and 200,000 $/year for a 100 meter high building.

1. INTRODUCTION

It seems evident that the construction of a high rise building reduces the availability of daylight for the neighboring buildings. But it is extremely difficult to provide a financial assessment of the total impact of the construction of a building on its environment. There are many thermal effects: reduction of solar access, modifiction of heat exchanges by convection (modified wind velocity) and radiation (modification of the radiation shape factors). But there are also visual effects, mainly reduction of the view to the outside, and reduction in the amounts of daylight penetrating the buildings. These two phenomena appear to be correlated: blocking the view tends to reduce the availability of daylight, except for specific conditions when sunlight is reflected from a facade.

We thought that it would be useful to estimate the financial aspect of the visual consequences of the construction of a high rise building in a city downtown.

A site has been selected in downtown Albany, N.Y. where a 50 meter high building has just been constructed (KeyCorp Tower building). The principle of our study is to compare the financial impact, related to luminous effects, on the neighboring buidings in three types of situations:

A) No building is built
B) Construction of a 50 meter high building
C) Construction of a 100 meter high buiding

2. DESCRIPTION OF THE METHOD

2.1. Site data collections

The first step was to select all the buildings of the site which might be affected, on a daylighting aspect, by the new building. We selected 23 buildings, all located in an area of 250 meters by 300 meters.

The determination of the dimensions and coordinates of all buildings was conducted on the basis of a plan of the site and photographs taken from specific locations.

The pictures were taken with a 35 mm lens camera. The height of the buildings were determined with the following formula:

$$H = tg\,(\,Arctg\,(h_1/l) + Arctg\,(h_2/l)\,) * D$$

where:

H (m) = height of the building

l (mm) = focal length of the camera lens =35mm
D (m)= distance between the camera and the building (it is read on the plan of the site)
h_1 (mm) = distance measured on the negative between the middle of the negative and the base of the building
h_2 (mm) = distance measured on the negative between the middle of the negative and the top of the building

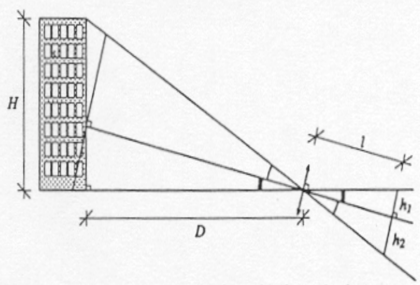


Fig 1. Determination of building heights using a camera equipped with a 35 mm lens.

2.2. Input file creation

Building dimensions were then input using the Super3D CAD software and the color of the facades were defined to allow later on the affectation of adapted luminous reflexion coefficients. This generated the problem description files. Three major files were made to allow the optical simulation of the three cases: A) no building, B) 54 meter building and C) 108 meter building.

The following figure shows a perspective view of the site, as entered by the CAD software.

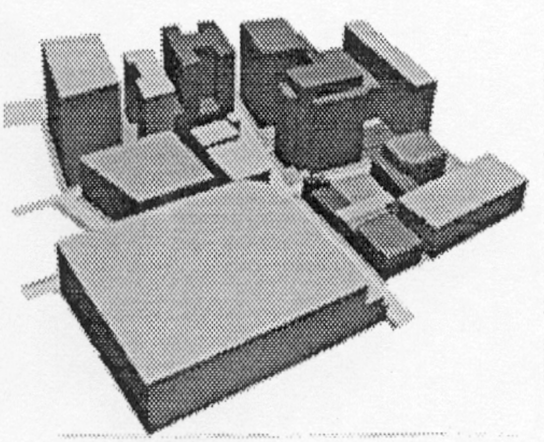


Fig 2. Configuration B: 50 meter building

2.3. Optical simulations

The three files were used as input in the daylighting simulation tool GENELUX developed by ENTPE [1,2]. This powerful tool calculates, with a ray-tracking technique, optical transfer functions between sky patches and any element of the built environment: roofs, facades, streets, as well as indoor surfaces such as floors, partitions and ceiling. These optical transfer functions are directionnal daylight factors [3], expressing the ratio of illuminance (lux) of any small surface to the luminance (cd/m2) of any sky patch.

In affecting appropriate luminance to each sky patch, with a given sky luminance model, it is possible to determine the daylight factors distribution on facades.

2.4. Daylight availability in Albany

Statistics on the daylight climate in Albany have been provided by the Atmopheric Science Research Center. They were given through files containing horizontal diffuse and global illuminances every 5 minutes, as well as other climatic parameters. The files were then processed to compute hourly skies (i.e. luminance distribution), using a sky luminance model validated on the data of Albany [4]. Hourly skies were processed to compute the average sky luminance distribution within office hours. Those were set to be from 8.00 a.m. to 6 p.m.

Daylight availability in buildings can be expressed through the probability to exceed given illuminance levels. The interpretation of daylight factors can lead to this quantity if we know the probability of occurence of horizontal diffuse illuminance outdoor.

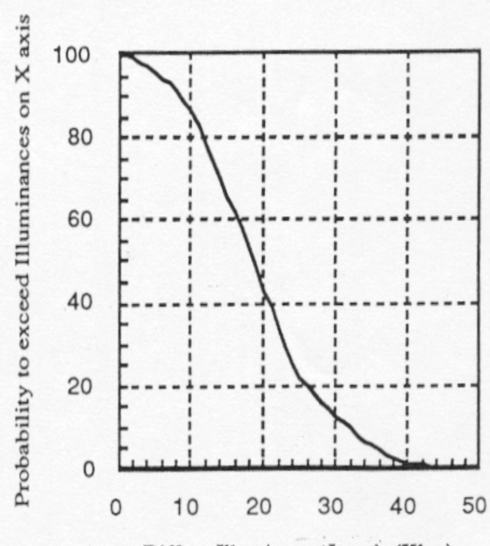


Fig 3: Probability to exceed a given diffuse horizontal illuminance between 8.a.m. and 6 p.m. in Albany, N.Y.

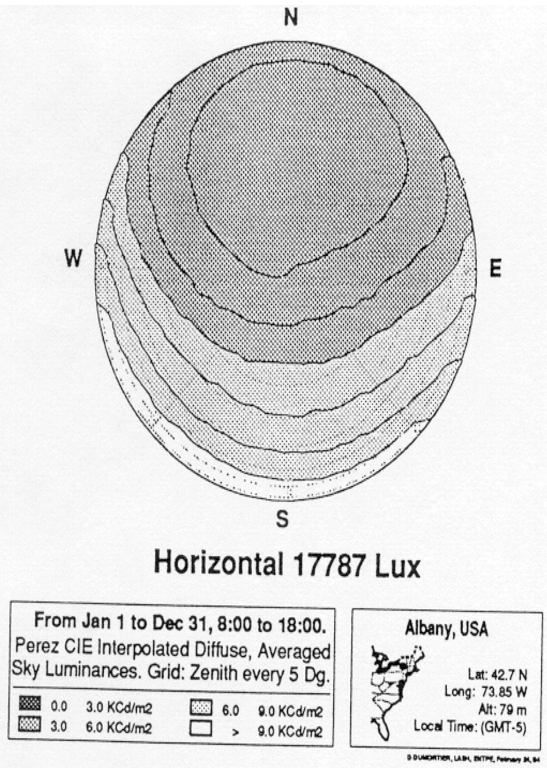


Fig 4. Average luminance distribution of the sky in Albany, N.Y, between 8 am and 6 pm.

3. RESULTS

3.1. Determination of the "impact zone"

The offices for which the reference building height has an impact are those for which the variation of daylight availability is perceptible. This can be directly related to changes of Daylight Factors on facades.

We defined as the "impact zone" the facades of the buildings showing a variation of daylight factors between case A and B, or A and C. In our study we selected only the offices building, taking out the large convention center and the 6 floor parking.

We defined as "concerned floor area" the fraction of the floor area situated within a distance to the window equal to 2.2 times the ceiling height.

We found out that the reference building had a significant impact on:

16,050 m2 of facades of the neighbouring buidings

28,850 m2 of floor area of offices and services

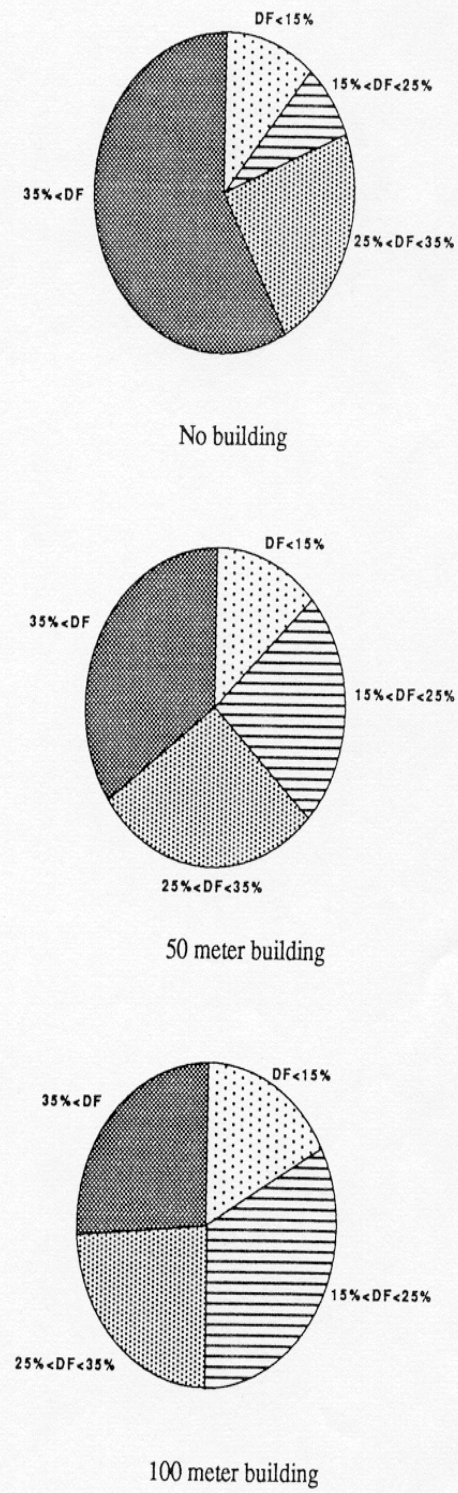


Fig 5. Distribution of Daylight Factors on the facades of the buildings concerned by the construction of the KeyCorp Tower Building

3.2. Indoor daylight availability

We ran optical computations using GENELUX to relate indoor daylight factor values to outdoor daylight factors values on facades. We assumed an average glazed area on facade to be equal to 22 % of the facade area with an average diffuse transmitance of 78 %.

We set the light switching control thresold at 75 lux in the darkest section of the concerned zone (see definition in section 3.1 above).

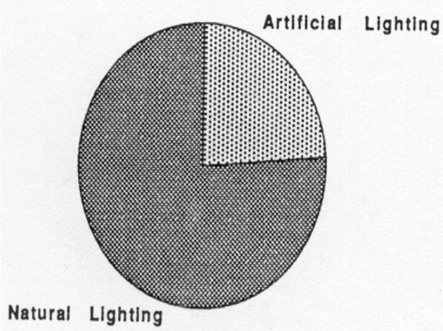
The minimum daylight factor in the concerned zone was found to be equal to 1%. This means that the horizontal diffuse illuminance threshold, in the case of unobstructed site was 7500 lux. This leads to a threshold for vertical illuminance on facades of 3750 lux, the half of the value of the horizontal illuminance (with the hypothesis of a uniform sky). This ratio would need to be adjusted using an average sky adaptated to the Albany climate.

Using the daylight availability chart presented earlier (Fig 3), it is possible to determine, as a function of the daylight factor on facades, the probability to switch lights on or off during the year.

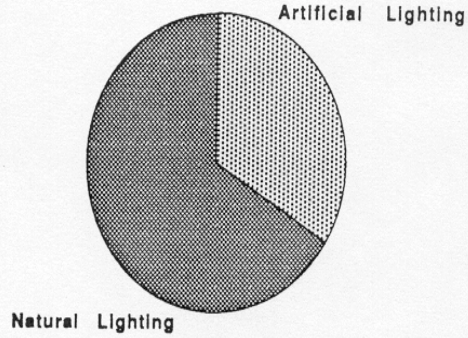
We can deduce the financial impact on lighting electricity consumption, with the following hypothesis:

- lighting power density: 15 W/m2
- lights are switched off when illuminance exceeds 75 lux in the darkest area of the "concerned zones".
- cost of electricity: 0.10 $/KWh (7 cts/KWh plus 10 $/month for power demand).

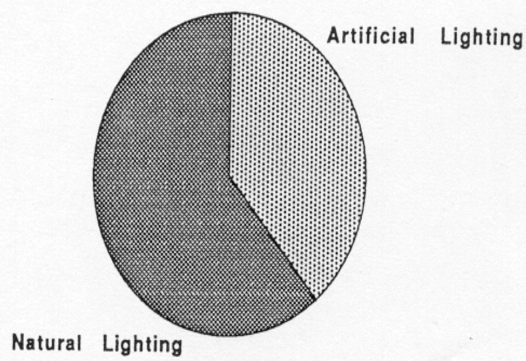
The figure below shows the evolution of the daylight availability inside the concerned zone of the neighboring buildings as a function of the height of the KeyCorp building, and the total financial impact.



No building



50 meter building



100 meter building

Fig 6. Fraction of the working hours, per year, when artificial lighting is needed in the neighboring buildings

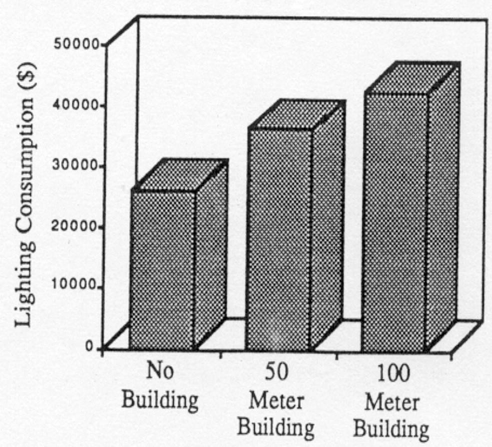


Fig 7. Annual cost of artificial lighting of the concerned office spaces, for the three configurations

3.3. Impact on rental costs

Rental costs for office building appear to be dependant on the number of the floors. For instance, in San Francisco, it was found that on a 30 floor building, rental costs would be 50 % higher on the top floor than on the 3rd one, and that the evolution would be progressive above a given level (when daylight and view start to increase significantly). Preliminary studies in New York City and in Albany show a similar dependance on rental costs.
Since view to the sky and obstruction could be characterized by daylight factors on facades, there should be a degree of correlation between daylight factors on facades and rental costs of office space, at least for the area near the windows (which would be the concerned zone in our case).

The figure below describes a simple model for a such a correspondance in the city of Albany based on local rental rates and some cost sensitivity to height. We tried however to have a conservative approach in assuming a 25 % premium in rental rates on the top of a 15 story building versus the rates on the first office floors.

We also found that when DF is below 15% on façade, the daylighting fraction in the "concerned zone" tends to be close from zero. For this reason, our assumption on rental cost is the following :

DF(façade) < 15% : rental cost = 130 $ / yr / sqm
DF(façade) > 15% : rental cost variation (see figure 8)

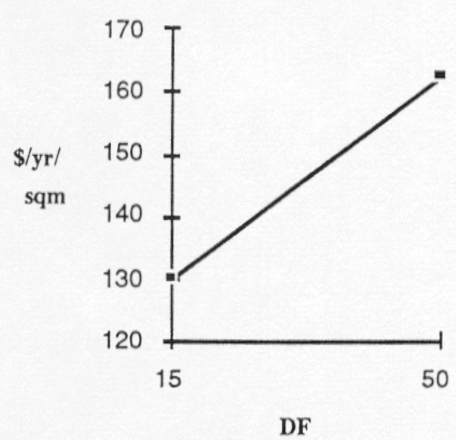


Fig 8. Proposed correspondance between Daylight Factors on facades and rental costs, for offices in downtown Albany.

Using the hypothesis displayed in figure 8, we computed the changes in rental values related to the construction of the building. All buildings are supposed to have the same rental values at the lowest level.

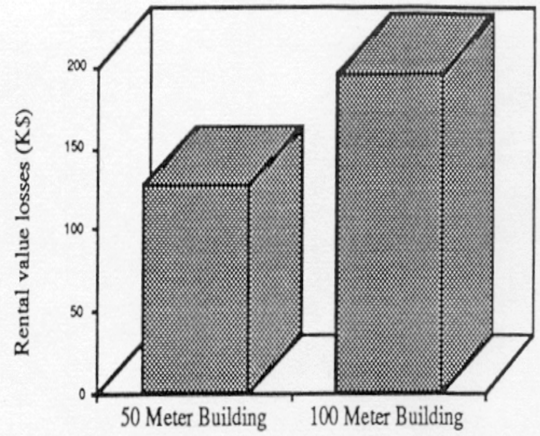


Fig 9: Impact of building height on the rental value of the concerned zone, showing the negative effect of daylight availability reduction

4. CONCLUSION

The general impact of constructing a new building is noticeable. The electricity bills of the surrounding buildings could be increased significantly: more than 10,000 $/yr (+40%) for a 50 m high building and more than 16,000 $/yr (+63%) for a 100 m high one. The estimated losses of income related to decrease in rental values of offices appear more significant: 130,000 $/yr for the 50 m building and 200,000 $/yr for the 100 m building. These values should be seen as particularly high since the office spaces concerned by the new project were exceptionnaly small, and non-office spaces were rejected from our study. It is clear that the hypothesis used in this paper would need more detailed analysis. We also found out the level of detail of the input within the CAD software was probably to high leading to excessive data management. More simple geometry could have been used for the assessment. However, the method seems to have a large potential for future case studies.

5. Acknowledgements

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6. REFERENCES

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