POLITECNICO DI TORINO
SECOND SCHOOL OF ARCHITECTURE
Master of Science in Architecture
Honors theses

Daylighting and energy savings: calculation methods and design criteria

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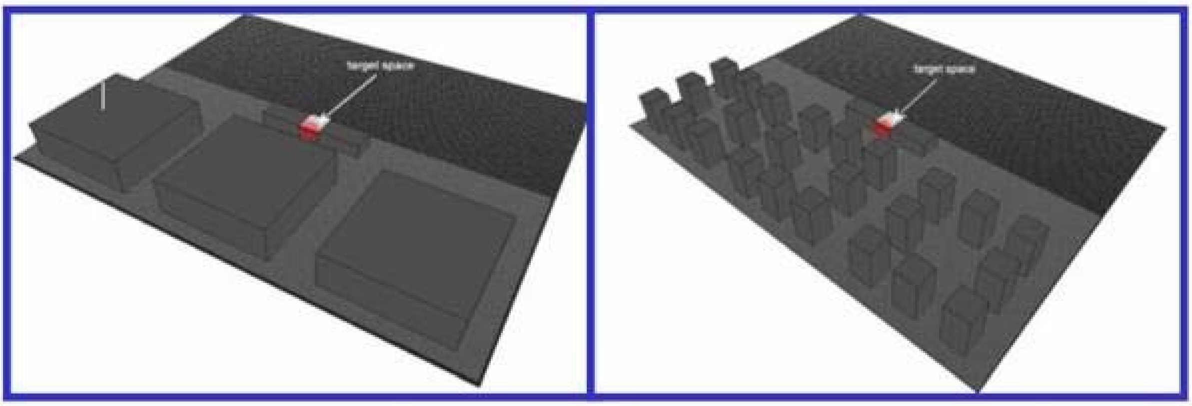
This work of thesis is focused on a critical analysis of existing standards relative to energy savings concerned with a rational use of daylight. This analysis is aimed at verifying potentials and limits concerned with different calculation methods which are proposed and at providing designers with criteria for a correct application of proposed methods during the design stage.
The theme of using daylight for energy saving purposes is scarcely addressed by recent European and Italian norms relative to building energy certification. On the other hand, prescriptions can be found in laws, standards and technical recommendations which have been published both in international, American (according to LEED – September 2006) and European (according to UNI EN 15193/2008), and in national contexts, regional and local, that is to say some Building Regulations and Energetic-Environment enclosures, such as the one with "Building regulation for the town of Turin".
Basically, the daylighting design approach is based on the obsolete concept of mean daylight factor in a room (DF_m). Several formulations have been provided in standards or in international scientific publications (such as Lynes' formula).
For above reasons, the work of thesis is aimed at comparing through analytical calculations DF_m values which are obtained from different formulae and at validating the reliability and consistency of each formula through numerical simulations. In particular, the formula provided by Italian standards was compared to Lynes' formula and to the formula proposed by the European standard UNI EN 15193/2008. For this purpose, the software Radiance was used, this being acknowledged as the most accurate to simulate daylight and sunlight within the international scientific community (as stated by the CIE – Commission Internationale de l'Eclairage).

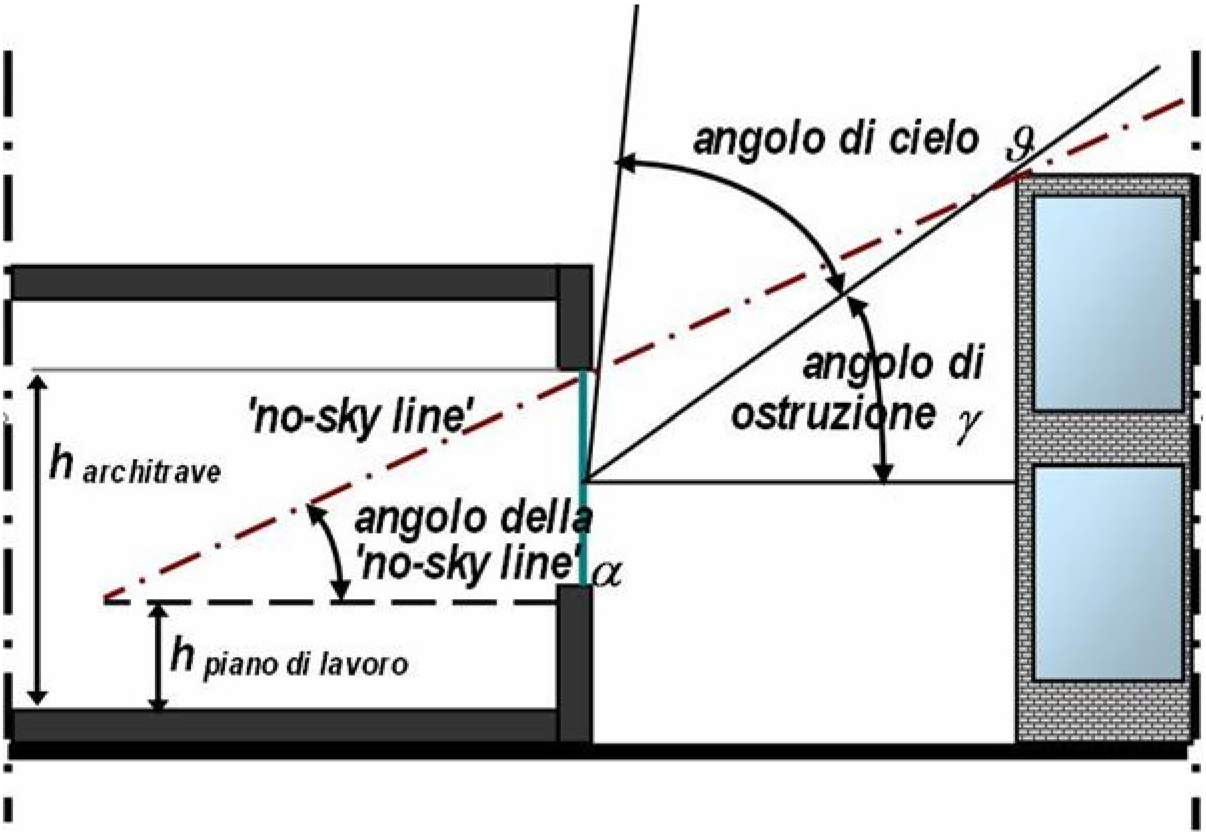
As many as 768 case-studies were simulated, different for room sizes, glazing sizes, glazing visible transmittance properties, obstruction angles and external obstruction geometries, shading typologies and geometries (overhang and vertical fins) and albedo reflectance properties.



Parametri variabili	Valori		#
Fattore di trasmissione luminosa, TL [%]	35	75	2
Larghezza finestra [-]	Larghezza dell'intera facciata	50% dell'intera facciata, centrata	2
Larghezza ambiente [-]	1.0*Altezza ambiente	3.6*Altezza ambiente	2
Angolo di cielo [°]	90 75 60	45 30 15	6
Aggetto [-]	Si	No	2
Mensola verticale [-]	Si	No	2
Ostruzioni prospicienti [-]	Continue	Discontinue	2
Fattore di riflessione luminosa delle ostruzioni e del terreno [%]	10	30	2
			Tot. 768

Representation of urban contexts which were modelled: “continuous” obstructions (to the left) and “discontinuous” obstructions (to the right). A table summarizing all variables used to create the 768 case-studies is also shown

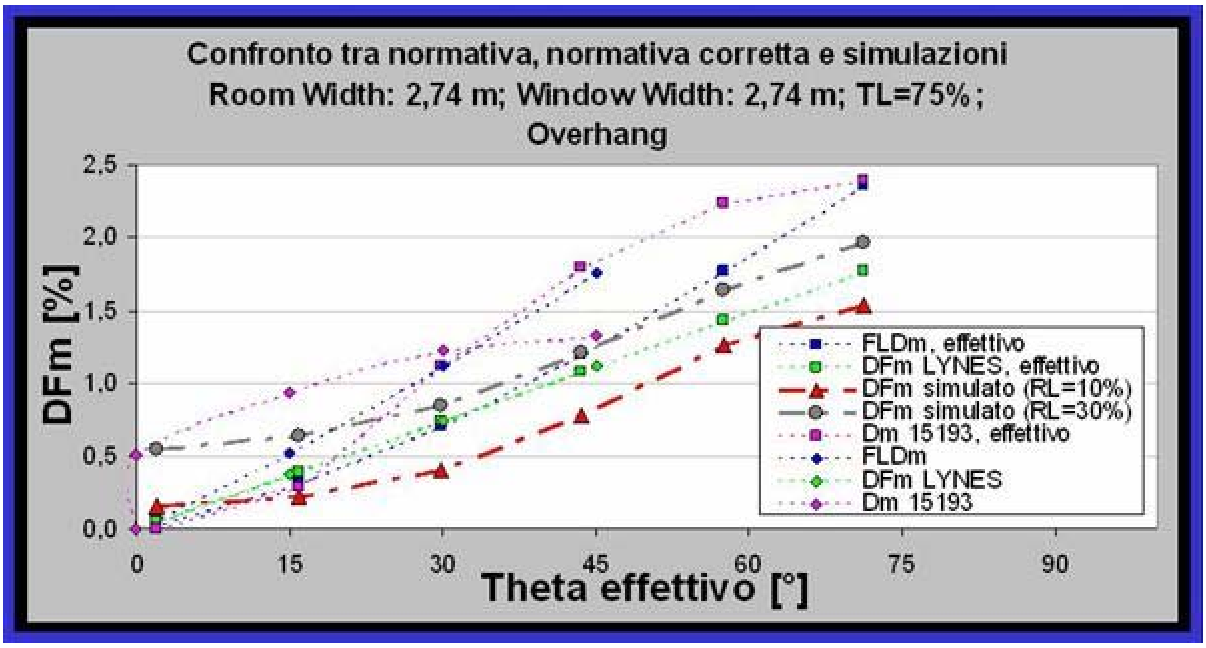
Based on the analyzed standards, a limit concerned with modelling of external obstruction is observed: these are actually characterized through a single “obstruction angle γ” (or through its complimentary “sky angle ϑ” – see figure 2): this corresponds to an endless continuous obstruction with constant height, without accounting for discontinuous building with different height, which represent the most common urban contexts.



Visualization of the "obstruction angle γ" and of the "sky angle ϑ" for a sample room

Furthermore, many standards do not allow accounting for the simultaneous presence of facing buildings and shading systems, especially when vertical fins are present. For this reason, an alternative calculation method was defined to accurately model external obstructions, based on the use of Waldram diagrams. The proposed method allows determining an "effective sky angle" for facing buildings, overhangs and vertical fins individually or simultaneously present. The method was validated as part of the 768 case-studies.

The simulation results showed which one of the three DF_m formulations which were analyzed is the most consistent to model situations in presence of only facing obstructions or overhangs or vertical fins or of different combinations of them (figure 3).



Comparison of DF_m values as calculated for rooms with an overhang through the formulae proposed by Italian standard, European standard and Lynes' formula. The results which were obtained through the same formulae but by using the "effective sky angle" are also shown

As main conclusion, this work showed that analytical formulations proposed in standards to predict the mean daylight factor within a room, are on average validated by Radiance simulations, though they are simplified methods. The consistency is even better when the new proposed "effective sky angle" method is used to account for obstructions. As a result, above formulae are a consistent design approach to be used during the early design stage.

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