Diffuse daylighting autonomy: Proposal for a more intuitive appraisal of daylighting performance in the European zone

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To quantify buildings daylighting performance, most standards dealing with environmental quality and energy efficiency mainly rely on daylight factor values (DF). Besides the fact that this quantity does not take into account either the location or the orientation of the project, it is far from intuitive. The notion of Diffuse Daylighting Autonomy (percentage of time during which a given illuminance is achieved thanks to diffuse light coming from the sky) makes a link with climatic data and is much easier to understand. However, we found it is necessary to go a step further towards the users so that they can really understand the issues of good daylighting design. This paper proposes a set of tables giving the correspondence between DF values and the number of hours during which it is possible to perform most common visual tasks. These tables focused on the European area and can be used to address questions such as:
“On average, how long could I read the newspapers in my living-room with a 2.5% DF value?"

The notion of diffuse daylight autonomy (DDA)

The concept of diffuse daylight autonomy (DDA) was first developed within the framework of the European Project DIAL-Europe (1999-2002) [1] and described by Paule & al [2], [3].
The principle is to use climatic data of the building location, in order to convert daylight factor values into a new metric aiming to estimate the percentage of time during which the required level of illumination will be achieve thanks to diffuse daylight coming form the sky vault. Diffuse Daylight Autonomy (DDA), excludes the sun contribution and thus, gives a minimum threshold for daylighting availability.

Advantages

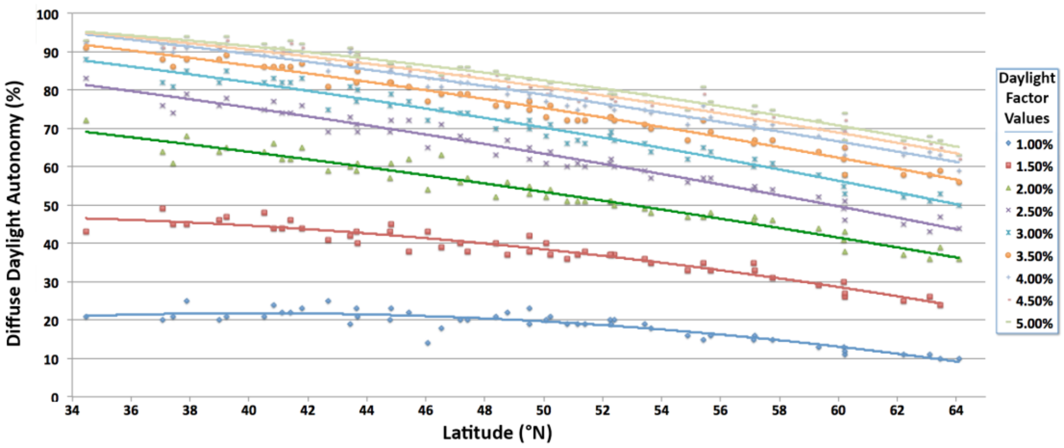
One of the main advantages of this method is its speed (only a few seconds to convert the DF values into DDA values). This is due to the fact that it does not require to run a ray-tracing simulation for each hour. Another benefit is that it allows estimating the annual electricity consumption due to electric lighting. For example, if the installed power for electric lighting is 10 W/m2, then an average DDA value of 60% will let us forecast that the light will be switched-on during 40% of the working hours, that is to say: 10W/m2 x 1850 h x 40% = 7.4 kWh/m2.y

Limits

This metrics does not take into account the sun contribution, which means that there is no maximum threshold. Having said that, analyzing solar penetration implies that one has a clear idea of the management of shading device and user behavior, which is far from being the case under most circumstances.

Geographic area

As mentionned above, the potential for daylight contribution is linked to the building location. One of the main factors of variation is latitude, to the extent that this parameter has a great influence on the day length (the highest the latitude, the shortest the days in winter). We have then selected fifty-one (51) “representative” cities in Europe to construct the tables. For each of the cities, we have then simulated the daylighting autonomy values in a given square room equipped with one horizontal roof aperture in order to get the correspondence between DF values and DDA.
In so far as latitude is not the only parameter that influence the daylight availability, (local climatic conditions may lead to specific variations), we have use the whole data to build polynomial functions that give DDA values as a function of the latitude (for each range of Daylight factor values between 1 – 5%). Cf. Graph 1.



Graph 1. Polynomial functions giving DDA values as a function of the latitude (ranges of DF values between 1 – 5%).

Tables of correspondence

In order to make Diffuse Daylight Autonomy more intuitive, we have then converted the percentage values into the average number of hours per day during which the daylighting contribution will exceed 300 lux. Table 1 shows the correspondences from sunrise to sunset on an annual basis.
According to this table, we can find that, for a given room located in London (lat. ~ 51°N), the average number of hours during which the illuminance will exceed 300 lux with a Daylight factor value of 3% is 8h01. The color scale we have used in the table is centered on 50% autonomy (white color). The above 50% levels are considered "Favorable" to "Very Favorable" and are represented by shades of green. The lower 50% levels are considered "Unfavorable" to "Very Unfavorable" and are represented by a color palette ranging from yellow to red.

300 lux		DAYLIGHT FACTOR VALUES (%)								
		1.0%	1.5%	2.0%	2.5%	3.0%	3.5%	4.0%	4.5%	5.0%
LATITUDE (°N)	64	01h07	02h51	04h21	05h20	06h25	07h19	08h05	08h31	08h50
	63	01h14	02h58	04h29	05h28	06h32	07h25	08h10	08h36	08h54
	62	01h20	03h06	04h36	05h36	06h40	07h32	08h15	08h40	08h59
	61	01h26	03h13	04h43	05h44	06h48	07h38	08h20	08h45	09h03
	60	01h32	03h20	04h50	05h52	06h56	07h45	08h25	08h49	09h07
	59	01h37	03h27	04h58	06h00	07h03	07h51	08h30	08h54	09h12
	58	01h43	03h34	05h05	06h08	07h11	07h57	08h35	08h59	09h16
	57	01h48	03h40	05h12	06h16	07h18	08h04	08h40	09h03	09h21
	56	01h52	03h46	05h18	06h23	07h26	08h10	08h45	09h08	09h25
	55	01h57	03h53	05h25	06h31	07h33	08h16	08h50	09h13	09h30
	54	02h01	03h59	05h32	06h39	07h40	08h22	08h55	09h18	09h34
	53	02h05	04h04	05h39	06h47	07h47	08h29	09h01	09h22	09h38
	52	02h08	04h10	05h45	06h54	07h54	08h35	09h06	09h27	09h43
	51	02h11	04h15	05h52	07h02	08h01	08h41	09h11	09h32	09h47
	50	02h14	04h20	05h59	07h10	08h08	08h47	09h16	09h37	09h52
	49	02h17	04h25	06h05	07h17	08h15	08h53	09h22	09h42	09h56
	48	02h20	04h30	06h12	07h25	08h22	08h59	09h27	09h47	10h01
	47	02h22	04h35	06h18	07h32	08h29	09h05	09h33	09h52	10h05
	46	02h24	04h39	06h24	07h40	08h36	09h11	09h38	09h57	10h10
	45	02h25	04h44	06h31	07h47	08h42	09h17	09h44	10h02	10h14
	44	02h27	04h48	06h37	07h55	08h49	09h22	09h49	10h07	10h19
	43	02h28	04h52	06h43	08h02	08h55	09h28	09h55	10h12	10h23
	42	02h29	04h56	06h49	08h09	09h02	09h34	10h00	10h18	10h28
	41	02h29	04h59	06h55	08h17	09h08	09h40	10h06	10h23	10h33
	40	02h29	05h02	07h01	08h24	09h14	09h46	10h12	10h28	10h37
	39	02h29	05h06	07h07	08h31	09h21	09h51	10h18	10h33	10h42
	38	02h29	05h09	07h13	08h39	09h27	09h57	10h23	10h38	10h46
	37	02h29	05h11	07h18	08h46	09h33	10h03	10h29	10h44	10h51
	36	02h28	05h14	07h24	08h53	09h39	10h08	10h35	10h49	10h55
	35	02h27	05h17	07h30	09h00	09h45	10h14	10h41	10h55	11h00
	34	02h25	05h19	07h35	09h07	09h51	10h19	10h47	11h00	11h05
DDA	<10%	>10%	>20%	>30%	>40%	>50%	>60%	>70%	>80%	>90%

Table 1. Number of hours between sunrise and sunset during which the indoor illuminance will exceed 300 lux on the work plane, as a function of the daylight factor value and the latitude (annual average values for horizontal roof openings).

This table is valid for horizontal openings (e.g. "seeing" the whole sky vault) and the values are averaged over the year between sunrise and sunset. Other tables can be found at the following web address: http://www.estia.ch/#!actualites/c24ol (last visited 08-25-2015).

Tests with Dial + Lighting Software

To go through with this reasoning, we implemented the whole matching process in the DIAL + Lighting simulation software [4]. Fig. 3 shows an example of the results obtained for two variants of a same living room, equipped with different windows sizes. If we focus on the sofa, we can see that in the second variant (right) the number of hours during which it is possible to perform most common visual tasks (>300 lux) is much higher than on the reference case (left). We are convinced that this type of result is able to convince a large audience since the information is understandable by the designer as well as the end user.

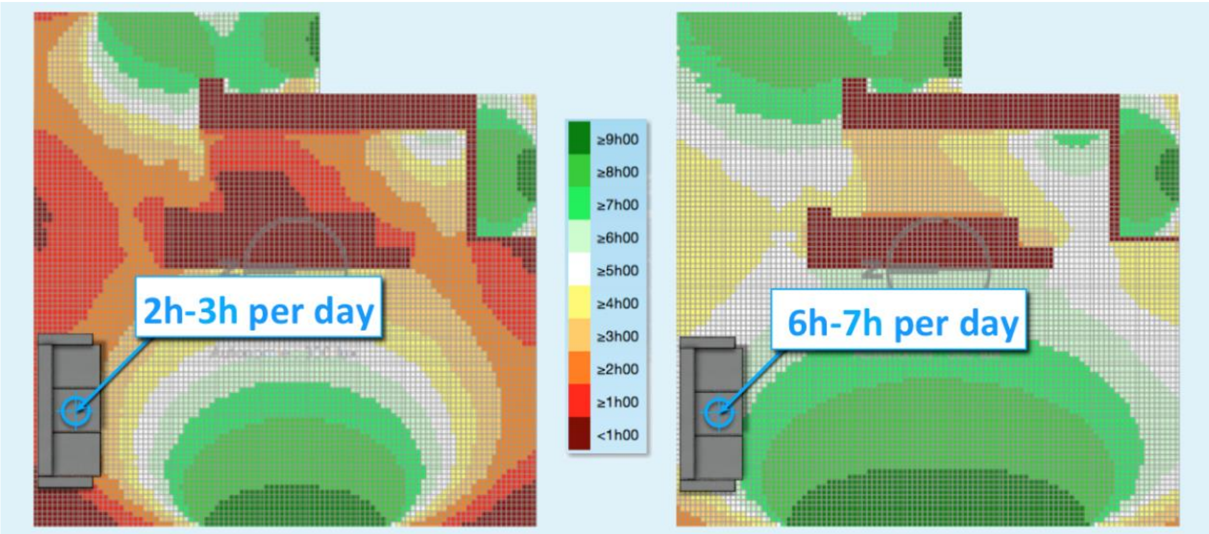


Figure 1. Comparison of two variants of a given living room equipped with different windows sizes (DIAL+*Lighting* [4])

Conclusions

This paper shows an attempt to establish an intuitive link between daylight factor values and the potential coverage of the current lighting needs by daylight. The use of latitude as criterion, allows to set simple goals within the design stage. We believe this information is helpful in the early stages of the building design to compare solutions. This approach should facilitate communication between the different stakeholders in the design process, and therefore, should promote daylighting as a key element of the global building performance.

References

1. Paule B et al: "DIAL-Europe: An European Integrated Daylighting Design Tool", Proceedings of the PLEA -2002 conference, Toulouse, France, 2002.
2. Paule B, Bouvier F, Courret G: "Eclairage naturel", Techniques de l'Ingénieur, CC 3315, 2008.
3. Paule, B & Al, "Diffuse Daylighting Autonomy: Towards new targets", Proceedings of the CISBAT'13 Conference, Lausanne, Switzerland, 2013.
4. www.dialplus.ch: Last visited 08-25-2015