ENERGY EFFICIENT OFFICE LIGHTING
EFICIENȚA ENERGETICĂ A ILUMINATULUI DIN BIROURI

Florin POP, Dorin BEU

Modern office lighting has to face two challenges: to be very flexible, with an emphasis on lighting quality, and to be energy efficient, with a high performance/cost ratio. The lighting design software packages generally neglect the room content and cost aspects.

The paper deals with the trends in office lighting based on a couple of European studies related to the evolution of office work pattern and furniture, based on the greater use of information technology.

Lighting systems design for offices has to take into account more and more furniture and office equipment (especially the low partition case of 1.2-1.6 m). Therefore it is proposed a correction of the Lumen Method by using an obstruction factor. This factor is a function of the luminaire class and the ratio of vertical surface of obstruction and room area. Despite highly energy-efficient lighting equipment, office buildings don't take full advantage from these possibilities. The paper explains some of the reasons: inappropriate design methods and economical and human response to lighting control.

Introduction

Starting from the new trend in office working patterns it became clear that new lighting systems has to face two problems: first, lighting design has to take into account the increasing number of furniture and equipment (obstructions) and, second, the lighting has to be flexible in order to face frequent changes. The search for new design methods, which take into account obstructions, has started ten years ago and has lead to an CIE Technical Committee TC 3-31 'Electric lighting for real interiors'. This committee was started in 1995, and it is chaired by Dr. David Carter, and includes members from all over the world (including Dorin Beu) and based on surveys and computer simulation it was proposed a modified lumen method by using an obstruction factor. This obstruction factor it is a function of luminaire class and the ratio of vertical surface of obstruction and room area.

Lighting represents about 38% from the total electric energy consumption of an office building, so energy efficiency measures focus more and more in this particular area. One of the simplest solutions was the use of free daylight, but despite lighting designer's solutions, end-users continue to neglect it. The authors have continued the researches in this direction, as there is no data available on this subject despite the fact that day+electric light is common situation in an office. First results based on computer simulation showed daylight illuminance level reduction (light losses) till 40% in the case of dense furniture office, and also the importance of window orientations and other factors. From this simulations it can be observed an increase of light losses with obstructions density. In this conditions the biggest losses can be reach in the case of large obstructions with an average of 34.22 %. The paper also presents some graphs with simulations results expressed as illuminance values or as reduction ratio of illuminance level.

Trends in office layout

The first step was based on a 1996 BRE report: "New Environments for Working"[7]. Large-scale use of information technology has lead to new way of organising office workspaces. Offices have become spaces were people work seldom and at unregular hours, so buildings are used during a long period of the day. In some companies people are working at home most of the time and make reservation through telephone for a workplace, when they intend to come to office.

The researchers where interested in which way the new layouts will affect in the next ten years the office organisation and which building types existent in UK will be suitable for this new trends. It was identified four distinctive working patterns, which were named: hive, den, cell and club. The small companies will use one or two of these types, but big companies will use all four. In hive case, work is routine and repetitive, and work places are occupied all the time. In open offices and there is little interaction with other peoples. Work shifts can be introduced for an intensive use of space. Work in den offices is the 'interactive projects' kind or group work and peoples have different backgrounds. Furniture have some simple layouts, as discussion tables and different workplaces. The club layout combine demands of those who work independent, as in cell case, with interactive teams, as in den case. Work process is in continuous change, depending on individual demands or team necessities. The furniture is easy to move and this characteristic is very important for these spaces. Different persons can share workplaces. Mainly creative peoples who work independent use cell type offices. Space is divided in small offices, or workstations are divided partitions (1.2m or 1.6m mobile walls). Space occupancies are unregular as peoples go often to meetings.

The main trend is that cell and den to move toward club layout. This will facilitate an intensive use of space by sharing the same workplace by several persons; each worker will have a mobile cupboard, which can be move in the room depending on the place that will be occupied. Internet and mobile phone have changed the image of the office and the working pattern has become more creative, interactive and based on group/project teams. The occupation of an office has changed from '9 to 5' style, with own working desk, to an 'continuously' shared workplace with location assignment on basis of tasks and not of status.

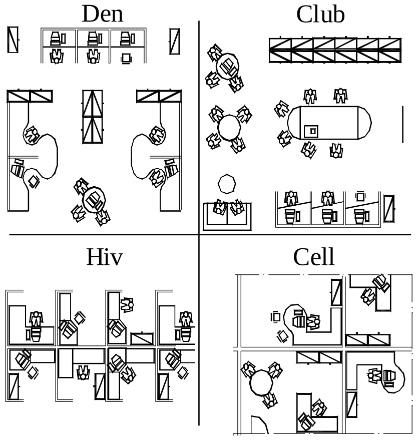


Figure 1. Office layout types

Wouters & Bommel study. It was published in 1998 in Internationa e title 'The many faces of the office', authors Marius Wouters and Wout van Bommel. Starting form the preceding study the authors had set five-office function: hive, cell, meet, club and lobby. This time the classification is according with room function and not the layout; however three types are almost identical: hive, cell and club. The two new functions are presented like this:

Meet function: almost all companies have at least one room for meetings. In these spaces, communication between the members of a team is essential. . Work is characterised as unique, the time and the numbers of meeting participants are variable, and the infrastructure is communication oriented. The meet type is not limited to meeting room, but include also videoconference halls, reception desks, and the conference table in a smaller room is also part of meet function.

Lobby function: it is present in all office buildings. In the lobby case the communication importance it is not essential and the space is used all users share a liaison between different rooms and departments and it. In some cases the function is also representative. Corridor, staircase, entrance hall, library and canteen are part of lobby function in an office building.

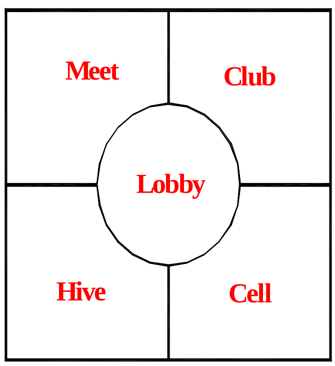


Figure 2. Office spaces concept model

Table 1. Comparison between traditional and modern way of working [8]

	Traditional	Modern
Working pattern	Routine Individual assignement Isolated	Creative Group/project teams Interactive
Workplace	One type	Different types for different tasks
Occupation	8 hours (9.00 – 17.00) Own working desk/room	'Continuously' shared workplaces
Location assignement	On basis of status	On basis of tasks

Implications of working pattern of modern offices on lighting systems. The new concept of working pattern enhanced the interest for researches in lighting obstructed spaces for some reasons:
Intensive use of spaces which means an increased number of furniture and equipment
The increase of illuminance level and starting from here the problem of estimation of illuminance reduction due to the presence of obstructions.
Interior design becomes more and more flexible, so initial lighting system design is no longer based on initial furniture arrangements.
In the same time, lighting system become more flexible too, in order to adapt it to new office trends. This demand will impose the use of intelligent control systems for a continuous adaptation of the system which can related to some 'smart card' where are recorded personal preferences regarding lighting
It becomes necessary to introduce the 'standard obstruction' concept which will lead to a lighting design which is independent on initial furniture arrangements and future evolution of space
Lighting company software should assess illuminance reduction, probably based on standard obstructions.
Extensive use of localised light make necessary the luminous ambient analysis, to determine if quality conditions are not affected
Lighting systems must be more flexible, according to people demands at a certain moment.

Researches in real offices lighting
AUTHORS HAVE STARTED ABOUT TEN YEARS AGO RESEARCHES ON OBSTRUCTION IMPACT ON LIGHTING SYSTEM IN ORDER TO FIND GUIDE METHODS ABOUT ILLUMINANCE REDUCTION IN REAL INTERIORS.
Electric lighting design method for obstructed spaces. Based on a survey campaign in real interiors with standard obstructions and computer simulations TC 3-31 has proposed a lighting design method based on Lumen Method. The modified Lumen Method involves an Obstruction Factor, OF, which is a multiplier of the utilisation factor. The room content is quantified by Vertical to Floor Ratio – *VFR*, that is the ratio between vertical surface area above work-plane and floor area. Researches have shown that *OL/VFR* graph (where *OL* is Obstruction Losses expressed as percentage of illuminance level) is a line with the slope *m*. Average value of the slope *m*, from the equation $m = OL/VFR$, depends on luminaire class and room index *k* (table 2). The luminaires classification is made according with 'CIBSE Code for interior lighting 1994'. The value of the Obstruction Factor is calculated with the relation $OF = 1 - VFR \cdot m/100$.

Table 2. File containing the value of **m**, depending on luminare class and room index [9]

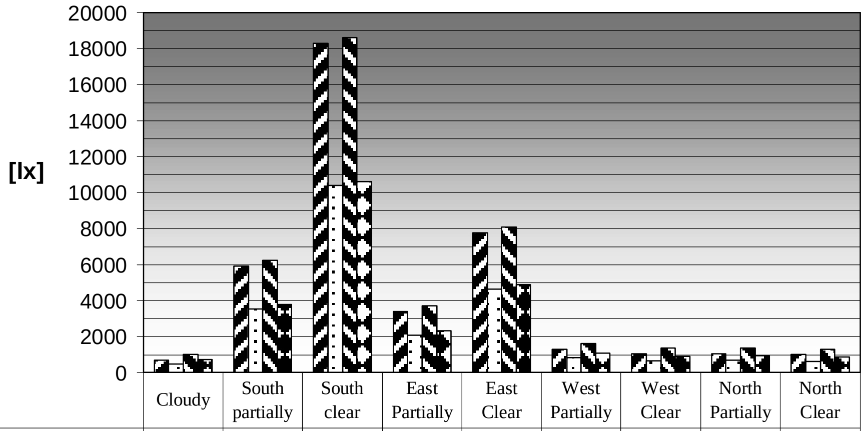
Room index	Luminaire class														
	1	2	3	4	5	6	7	8A	8B	8C	9	10	12	15	16
k = 1,00	34.4	33,4	33,2	33,9	33,7	25,6	32,1	28,8	28,9	32,3	28,9	31,7	33,5	29,7	33,9
k = 1,25	35,8	34,4	34,3	34,6	34,0	25,0	33,1	28,9	29,8	33,9	26,6	31,7	34,7	28,0	35,2
k = 1,50	39,6	38,0	35,9	36,3	34,6	26,3	37,0	30,5	31,4	36,4	27,8	33,8	38,4	30,1	39,1
k = 2,00	40,0	40,0	35,7	35,6	39,1	21,9	36,6	27,3	31,7	35,5	26,7	32,7	40,1	26,9	38,6
k = 3,00	43,2	42,1	39,5	37,0	36,8	22,6	39,9	28,2	31,3	38,2	28,5	36,8	39,0	28,5	41,7
k = 4,00	42,3	42,4	39,8	36,9	35,4	21,5	39,3	28,2	31,9	36,5	26,0	32,6	40,5	26,5	39,5
k = 5,00	45,2	45,8	41,1	37,8	35,3	22,8	40,6	27,0	33,0	38,4	26,5	36,8	42,2	26,5	42,4

Daylight offices. The problem of lighting quality in offices it's a subject of debate for specialists, and when it came to practical aspects like daylight illuminance level or impact of obstruction on daylight quality there is lot to say yet. The aim of our research is to perform computer simulations with different parameters, to create a database from where design recommendations can be drawn.

In the last 20 years office daylight was influenced by two important factors: energy efficiency and large-scale use of computer screens. This factors has lead to a reduction of illuminance level in offices and the used of lighting control equipment. Recent research of Begemann, Tenner and van den Beld [1] has shown that people wanted to add on average 800 lux artificial lighting on their workplace, which result in an average total illuminance (daylight + artificial lighting) of 1900 lux. They also shown that the average minimum accepted illuminance lies above 900 lux when daylight is present, ranging from 1000 to 1700 lux (additional artificial lighting ranging between 100 and 1000 lux). The average preferred illuminance lie around 1700 lux (900 lux additional artificial illuminance).

The Begemann study proves to be interesting in conjunction with the obstruction influence on illuminance level. What was anticipated before, based on experience or intuition, that people tend to let in use the electric lighting even if daylight illuminance level is above 300 lux, is confirmed by this study, plus it gives values for minimum accepted and preferred illuminance level.

Starting from Begemann study, the authors have continued the research in the area of obstructions, this time in the area of daylight and mixed day and electric light to obtain data about illuminance reduction ration (light losses) and on window orientation impact. Due to complexity of on-site daylight measurements it has been found more appropriate to use lighting computer software Lumen Micro, which has been checked in electric lighting obstructed spaces by Raitelli&Carter [6]. The use of this software become easy with new PC's but still it takes about twenty minutes to perform a c single complex simulation. There were analysed four situations: for North, South, East and West window orientation for an office with the dimensions 9m x 6m x 3.3m (considered to be an average Romanian office) with a layout of six workplaces. For each window orientation there were taken into consideration three types of sky (clear, partially clouded and clouded) and three types of standard obstructions (small, medium and large) [3].



	Cloudy	South partially	South clear	East Partially	East Clear	West Partially	West Clear	North Partially	North Clear
Enat empty room	709	5930	18300	3410	7760	1320	1050	1070	1010
Enat large obst.	476	3530	10400	2100	4650	845	653	686	627
Enat+el empty room	1020	6240	18600	3720	8070	1630	1360	1380	1320
Enat+el large obst.	723	3780	10600	2350	4900	1090	899	932	872

Figure 3. Average illuminance for empty room and for large obstruction, January 15th, time 10am

Simulations have been done for daylight and electric+daylight for 8am, 10am, 12am, 4pm for the 15th of January, April, July and October. Electric lighting was provided through six luminaires, with louver and lamellae, surface mounted for a maintenance factor of 0.8. Each luminaire have two fluorescent lamps of 36W and have batwing photometry curve. There are three windows on the same side of the room. From the set of simulation data it can be seen a rise in light losses with obstruction density. In this conditions the highest light losses occurs in the case of large obstructions, with an average of 34.22%. The results are presented as illuminance values or as illuminance reduction ratios (light losses) – figures 3 and 4.

Comparing the results depending on month and obstruction type show that for cloudy sky, light losses are independent on month or orientation with an average of 32.81% for large obstructions, 27.37% for medium obstructions and 12.3% for small obstructions. At 10am for North or West window orientation, in the case of clear or partially cloudy sky there is no important monthly influence (a possible explanation is there is no direct sunlight in the morning for this orientation). Major differences for light losses at 10am appear in the case of South and East orientation, with a maximum in the winter.

From the results it can be seen that due to obstruction presence the average illuminance in the room is in some cases under the minimum accepted illuminance of 900 lux, indicated by Begemann, and this is a possible explanation why electric lighting is in use most of the day. From figure 3 results that on January 15th at 10am, for large obstructions and with North or West orientation, illuminance level is under 1000 lux, so it can be concluded that in real situation electric lighting is still in use.

Researches will be continued by enlarging the database, by measurements on-site in order to make a statistic approach, with the aim of supplying recommendations to lighting designers. It will be also interesting to make some studies on the impact of Flat Bed Computer Screens.

Conclusions. Study on obstruction impact on lighting systems has lead to an over-sizing of luminaires required, which will increase installed power. In order to reduce electricity consumption it's important to use lighting controls. Regarding daylight, researches has shown dramatically reductions of average illuminance, depending on sky conditions and window orientation, and this is an explanation of the reasons why electric lighting remain on use most of the day.

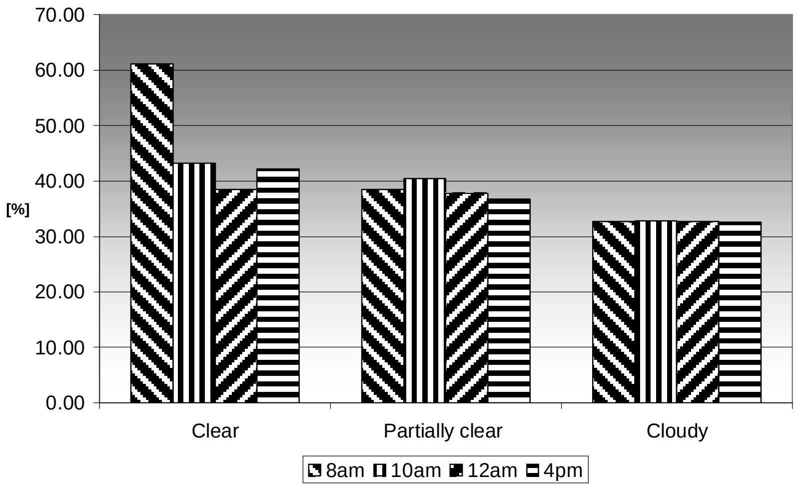


Figure 4. Daylight illuminance reduction on January 15th, for South windows, depending on time.

Trends in lighting equipment

Regarding the offices the news are the 16 mm fluorescent lamp, high power CFLs and small dimensions metal halide lamps. All this lamps are characterised by reduced dimensions and higher efficacy, comparing with previous models. The new luminaires especially design for these new types of lamps and the trend is toward direct-indirect luminaire with one or two lamps/luminaire with individual dimming (which imply the use of electronic ballast).

Another trend is the light-sensing device, which is integrated into the luminaire and has a regulating function. The state-of-the-art in lighting controls is the multi-sense, which combine daylight control, presence detector and remote-control functions. The remote-control may be part of the Building Technical Management, which has pre-set lighting programs and in some cases can individually command each luminaire from the building.

Recent studies on workplace occupation showed that effective occupation is about 5% of the time in 1995 comparing with 18% in 1960. This is another reason for use of lighting control, in order to balance the increase in lighting quality (which in some cases can lead to higher energy consumption).

Energy-efficiency barriers

First problem is the continuously decreasing of electricity prices and the fact that cost of electric energy bill for lighting is less than one percent of total annual costs for a typical office. Despite the fact that in some buildings lighting represents till 38% of total energy consumption, the interest of the company who runs the offices is low for this problem. Sometimes even lighting company advertise that for the price of two cups of coffee a day, lighting conditions in an office can be improved as to result in improved productivity.

Another problem is the price of lighting control equipment; having in mind that in many cases it is used in conjunction with the electronic ballast this will lead to high investment costs. The payback time is more than one year and in the case of bus systems can be around ten years. Even if these control systems are installed, it is the human factor that is normally neglected by designers. Sometimes, peoples are irritated by extensive switching or by often malfunctions of control systems. Also the widely use of venetian blinds will reduce the efficiency of the control systems. All control systems will have to be correctly installed (i.e. delay time of movement detector has to be set according to designer recommendations) in order to avoid sabotage. Unfortunately in the area of systems sabotage it looks that people who work in offices have a lot of imagination, starting with a simple chewing-gum on light-sensor and finishing with paper stripes on table-fan in order to confuse the movement detector.

In many cases the company is not the owner of the office spaces, so it has little interest on any technical improvement, which involves investments. The building owner is neither interested. As it is not him who pays the electricity bills, so the owner has little interest on energy efficiency.

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Dr. Florin POP, Professor, Electrical Installations and Lighting, Department of Building Services
Dorin BEU, Senior lecturer, Department of Building Services
UTCN – Technical University of Cluj-Napoca
15, C. Daicoviciu Str., RO-3400 Cluj-Napoca, ROMANIA
Fax.: +40.64.192055; Telephone: +40.64.187514
E-mail: Florin.Pop@insta.utcluj.ro
E-mail: dorin_beu@mail.dntcj.ro