Planning of indoor lighting

predavatelj
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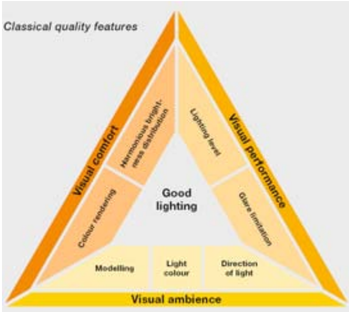
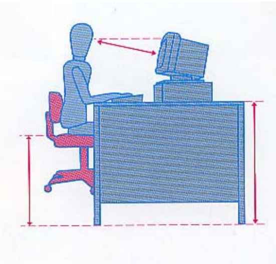
Purpose of indoor lighting



The primary purpose of the lighting is to provide good visual environment in room (on workplace), which will enable optimal use of vision, welfare and working atmosphere.

Purpose of indoor lighting



In the foreground is of course well-being, without that work can not be efficient and productive.

Ergonomics

science that deals with exploring the physical and mental abilities and making appropriate adjustments to the workload.

Purpose of indoor lighting

However, lighting design is not easy. There are always several possible solutions, which are “at first sight” equally good. In addition, the designer repeatedly encounters problems without optimal solutions which can not be solved only mathematically or technically as they require a “different approach”.

Purpose of indoor lighting

Therefore, when designing the lighting we should always taken into account

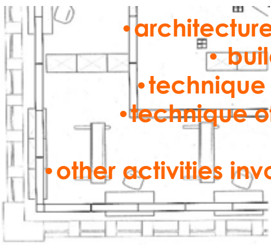
humans

and their needs

and not to consider lighting design only from technical and economical point of view.

Good beginning is important

Lighting is part of the room,so we should consider also:



- architecture and design of the room;
- building structure technique;
- technique of electrical installations;
- technique of heating and ventilation;
- acoustics;
- other activities involved in the room design.

Good beginning is important

Therefore, the lighting designer should start to cooperate with architects and designers of other elements even before he/she starts working on lighting design.

He/she should consider optical, physiological, psychological and economic requirements, but should also not neglect the requirements of architecture and other activities involved.

Good beginning is important

It is important:

- to start as soon as possible;
- to collect all needed information;
- to cooperate with architect and other design engineers.

Needed information

The purpose of the room (space):

- activities and the direction of view;
- ergonomic and functional components;
- allocation of machines, furniture, windows, ...;
- specific activities (industry);
- transport routes.

Needed information

Position of light sources:

Light sources in a room (the facility), as well as ones in the vicinity should be considered:

- daylight (and obstacles in front of windows);
- structure of the building;
- outdoor lighting (can also influence the situation in the interior).

Needed information

Local and climatic conditions:

affect mainly daylight and need to regulate the luminous flux:

- daylight (specific conditions);
- sunshine duration;
- orientation of windows (geographically);
- average cloudiness;
- climatic conditions (temperature, precipitation);
- size of windows.

Needed information

Features of the room:

- blueprint of room (plan, sections), scale 1: 100 or 1:50;
- windows (position, size, structure, blinds);
- reflectance and the quality of the surfaces (walls, ceiling, floor, ...);
- building construction (especially the ceiling – hanging of lamps);
- the type and execution of installation, regulation, ...;
- barriers in the area of the reflecting surface, ...;
- dustiness, humidity, temperature, ...

Needed information

Personal references (desire):
sufficient level of illumination;
- direction of light, shadows, ...;
- glare, reflecting surface, ...;
- appropriate color of light, and Ra;
- color design of room;
- needed security lighting;
- possibilities for maintenance of lighting.

Needed information

Light sources:
- type of light source (tungsten halogen lamps, fluorescent lamps, high intensity discharge lamps, LEDs);
- operating characteristics (efficiency, switch on transients, prescribed position, ambient temperature, maintenance, service life);
- properties of light (colour of light, colour rendering index, non visible light UV or IR).

Impact of errors in design

- Late start of work or lack of coordination between designers of different elements (installations).
- Lack of information about working conditions, work technology and personal statements about the room.
- Inadequate glare protection.
- Failure to comply with specific conditions in the area (eg. moist environment).
- Failure to take into account characteristics of power supply network (voltage fluctuation, interruptions, poor quality).

General lighting guidlines

Illuminance levels

Illuminance at on working area (room) must comply with standards and recommendations (SIST EN 12464).

outdoor orientation:	30 lx
movement, orientation, occasional stay	100 lx
occasional work	150 lx
tasks with small visual requirements	300 lx
tasks with average visual requirements	500 lx
tasks with higher visual requirements	750 lx
tasks with very high visual requirements	1000 lx
tasks with special visual requirements	1500 lx
highly accurate visual tasks	> 2000 lx

General lighting guidlines

Illuminance levels

Activities and the situation in the area should be considered (like reflectance of surface): for optimal visual conditions the luminance of surface should be around 100 cd/m². With the white paper reflectance of 0.7, the needed illuminance for this luminance is:

$$E = \frac{L \cdot \pi}{\rho} = \frac{100 \cdot \pi}{0,7} = 450\ lx$$

But with reflectance of 0,1 needed illuminance is 3140 lx

General lighting guidlines

Uniformity of illuminance

Beside illuminance also its uniformity is important:

$$U_1 = \frac{E_{\min}}{E_{sr}}$$

$$U_2 = \frac{E_{\min}}{E_{\max}}$$

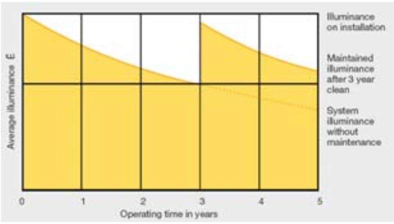
Standard SIST EN 12464 recommends uniformity U_1:

0,4 - 0,7 for working areas,
0,4 for immediate surrounding and
0,1 for background.

General lighting guidlines

Planed illuminance

Planed illuminance (illuminance on installation) should be 1,25 to 2,0 –times larger that maintained one.



General lighting guidlines

Contrasts

Large contrast

Middle contrast

Low contrast

If there are low contrasts present in the room or on the workplace the illuminance should be larger to achieve the same visual conditions for workers.

$$K = \frac{L_1}{L_2}$$

General lighting guidlines

Harmonious distribution of brightness

Surfaces in room must have appropriate and different brightness. Typically, the working surface is darker than the observed object and brighter than the surrounding area.

$L_{object} : L_{working\ surface} \leq 3:1$ (do 1:3)

$L_{working\ surface} : L_{surrounding\ area} \leq 10:1$ (do 1:10)

General lighting guidlines

Limitation of direct glare

Level of glare depends on:
- local illuminance level;
- luminance and size of the areas in the field of vision;
- angle between direction of view and direction to the source of glare;
- contrast between source of glare and its surroundings.

$$UGR = 8 \cdot \log_{10}\left(\frac{0{,}25}{L_b}\,\Sigma\,\frac{L^2\omega}{p^2}\right)$$

General lighting guidlines

Direction of light and shadows

The direction of light is also linked to contrasts comparisons index and with 3D perception of surface structures.

Desired shadowness can be achieved by appropriate selection of the light source (point source, a surface source), and its location in space, the orientation ...

General lighting guidlines

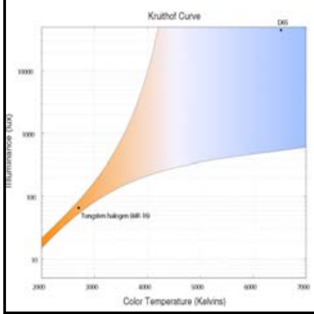
Limitation of reflections

Reflectiones interfere with work, especially on displays. (remember: angle of incidence and angle of reflections are the same).

Reflections can be reduced by:
- proper installation of the luminaires;
- using large area luminaires;
- matt surfaces.

General lighting guidlines

Colour of light

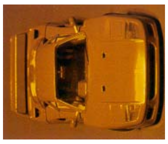


Colour of light is part of the interior and is not important only for aesthetics but also for the entire perception of space.

There is a link between the illuminance and appropriate colour of light (Kruithofov curve).

General lighting guidlines

Colour rendering index



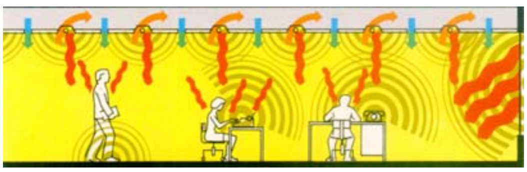
Like the colour of light also colour rendering index affects the perception of space.

Above all, it affects the proper colour perception. Therefore, in the working areas where colours are important, designer must be careful (especially in conjunction with fluorescent lamps).

General lighting guidlines

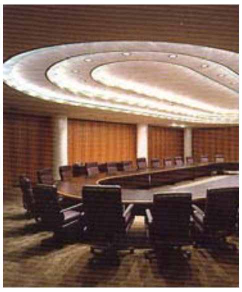
"Climate" in the room

Our perception of space is influenced by: architecture, color, light, temperature, humidity, acoustics, furniture, ... If they match each other, the room is perceived as pleasant.



Lighting concept

How important is concept



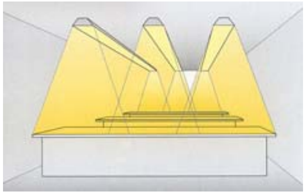
The lighting which is designed only to satisfy the needed maintained illuminance, will sooner or later be criticized.

The meaning of design is not in using known "standard" solution for every room, but to find optimal lighting solutions for each room.

Lighting concept

General lighting

General lighting provides the same visual conditions throughout the area.

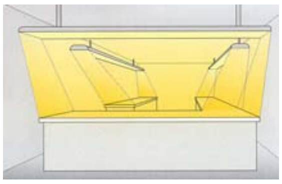


Distribution of working places can be optional. The room acts positive. It is desirable especially in larger spaces.

Lighting concept

Localized (zonal) lighting

Localized lighting is oriented to the (fixed) working areas with higher illuminance than the rest of the space.



It allows different illumination for different working places and reduces electricity consumption, but illuminance is less uniform (up to 1: 3).

Lighting concept

Local lighting

Local lighting illuminates only one (limited) working area.

It is mainly used where we want to achieve specific conditions at one working place like: high brightness, large shadowness, specific direction of light, ...

Lighting modes

Mode of lighting

With the lighting we want to achieve good visual comfort, good contrast and limitation of glare.
We therefore wish the direction of light from above and the corresponding soft transitions of brightness in the room, appropriately bright ceiling is welcome also.
How to achieve this?

Lighting modes

Direct lighting

Can be general or localized lighting.

Light comes from above, shadows are sharp, walls and ceiling are poorly illuminated. It may cause direct or reflective glare.
Illuminance and uniformity are good.
Consumption of electricity is low.
Weaknesses can be corrected by appropriate selection of properties of surrounding areas.

Lighting modes

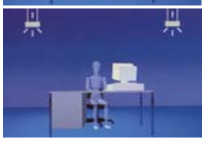
Indirect lighting

Can be general or localized lighting. Luminaires can be standing or suspended.

The light in the room is very diffuse, almost no shadows. The ceiling is very bright - it can look unnatural. Low glare, good illuminance of vertical surfaces, good uniformity of illuminance, simple installation with standing luminaires.

Lighting modes

Direct-indirect lighting

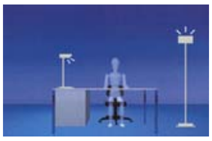


A combination of previous two. Direct-indirect luminaires are used. Luminaires can be standing or suspended.

Indirect part can be used as a general lighting and direct as local or localized lighting. The illuminance is even, the shadows are present, but not too strong, the ceiling is not so bright.

Lighting modes

Two-component lighting



A "weak" general lighting in combination with local lighting of workplaces.
There is possibility of glare (from local lighting), difficult to install at larger workplaces.
Good illuminance on working area, more individual design, optical separation of the workplace and its surroundings, suitable for CAD jobs.

Daylight

Lighting with daylight

Adequate lighting of interior spaces with natural light and visible connection with the exterior has a positive impact on the health, well-being and ability to work. It also helps to save energy.

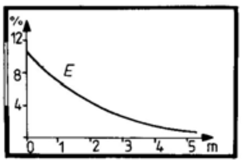
Daylight

Lighting with daylight

The problem lies in the fact that the illuminance (from the window into the room) decreases, so that the space more inside may be insufficiently illuminated. Rooms with depth up to 6 m and up to 3 meters high can be sufficiently illuminated only with windows (only daylight). At least for a certain period of day.

Daylight

Lighting with daylight

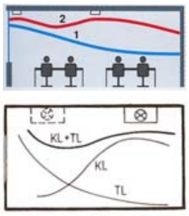


$$FDS = \frac{E_{znotraj}}{E_{zunaj}} \cdot 100\%$$

To determine illuminance caused by daylight, daylight factor (FDS) can be used. FDS represents the ratio of the Illuminance inside and outside. It is a relative number, which is independent of the year and time of day. Illuminance in room can be calculated from known illuminance outside.

Daylight

Complementing the daylight



If space is mainly used during the day and when there is not enough daylight we can use (artificial) lighting to complemented daylight - especially in areas and times when there is not enough daylight. We should do it so, to achieve good uniformity of illuminance.

Lighting design process

1. Collection of information

We begin with colection of:

- technical information
- personal information

Lighting instalation, we need to start to design sufficiently early, when it is still possible to influence the necessary changes in architecture, construction, installation, ...

Lighting design process

1a. Collection of technical information

Among technical information are:

- location of object;
- climate conditions;
- architectural building construction;
- equipment in the room;
- art of installations;
- climate in a room.

Lighting design process

1b. Collection of personal information

We need to know:
- gender, age and vision of users;
- location and duration of the work;
- previous experience with lighting;
- opinions about lighting;
- prejudices about lighting;

Sometimes it is necessary to create a mock-up model or an experimental lighting instalation and check response.

Lighting design process

2. The decision: what we want to achieve with lighting

Lighting significantly impact the appearance and usability of space. Therefore, it is necessary to decide:
- what will be the appearance of the area;
- how will the luminaires be included in the architecture;
- where are positions of workplaces.

Lighting design process

2a. The decision: appearance of the area

Should the place (room) works:
- hot or cold;
- light or dark;
- do we want to emphasize any part of the area or maybe its geometry: height, width…

Lighting design process

2b. The decision: inclusion of luminaires in architecture

How the user perceives luminaires:

- luminaires are obvious part of architecture;
- luminaires are "invisible", we perceive only light;
- with luminaires we want to emphasize the geometry of space.

Lighting design process

2c. The decision: where are workplaces

Workplaces will be distributed:

- fixed or floating;
- individually or in groups;
- they will be divided by partition walls, or will be in cubes (their height is important).

Lighting design process

3. Activities in the room

Activities is the room should be considered while planning the lighting. We should take into consideration:

- zones in the area (entrance, exit, hallways, quiet areas, areas for meetings);
- social structure (individual, group communication);
- activities (basic, specific, permanent, temporary, ...).

Lighting design process

4. Technical parameters

What is the recommended in standards;

- illuminance and its uniformity;
- colour of light;
- colour rendering index;
- unified glare index;

Other: distribution of brightness, shadowness, direction of light, energy consumption…

Lighting design process

5. Choice of concept and mode of lighting

Based on collected information and the guidelines (standards) we decide on the most appropriate:

- lighting concept (general, localized, local lighting, daylight);
- lighting mode (direct, indirect, direct-indirect or two-component lighting).

Lighting design process

6. Calculation of average illuminance

The average illuminance in the room is calculated in several stages:

- calculation of needed luminous flux;
- calculation of number of light sources;
- calculation of number of luminaires;
- determination of the arrangement of luminaires;
- calculation of actual average illuminance.

Lighting design process

6a. Needed luminous flux

Needed luminous flux in the room is calculated from the wanted illuminance using the following equation:

$$\Phi_{celotni} = \frac{E_{sr} \cdot a \cdot b}{\eta \cdot f}$$

Lighting design process

6a. Needed luminous flux

In equation:

a and *b* … room dimensiones

E_{sr} … maintained average illuminance

η … utilization factor

f … maintenance factor

Utilization factor and maintenance factor are determined based on information from manufacturer of luminaires and information about the activities in the room.

Lighting design process

6b. Number of light sources

Calculated luminous flux is used to calculate needed number of light sources:

$$n_{total} = \frac{\Phi_{total}}{\Phi_0}$$

In equation is Φ_{total} needed luminous flux and Φ_0 luminous flux of one light source.

Lighting design process

6c. Number of luminaires

Based on number of needed light sources we can calculated number of needed luminaires:

$$n_{lum} = \frac{n_{total}}{n_i}$$

where n_{total} is number of needed light sources and n_i number of light sources in one luminaire.

Lighting design process

6d. Arrangement of luminaires

Required number of luminaires is evenly distributed over the room. Following should be considered:

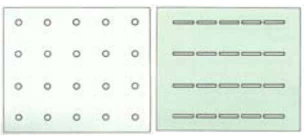
- position of workplaces and equipment;
- orientation of the luminaires in the room (longitudinal or transverse direction);
- possibilities of fixing the luminaires on the ceiling (smooth ceiling, ceiling construction, suspended ceiling).

Lighting design process

6d. Arrangement of luminaires

For general and localized lighting normally following distributions are used:

- individual placement;
- Line placement;
- field layout of luminaires.



Lighting design process

6d. Arrangement of luminaires

If calculated number of luminaires can not be nicely arranged, it is necessary to:

- change the number of luminaires;
- change the number of light sources in one luminaire;
- select another light source or other luminaire.

If we change number of luminaires or light sources it is necessary to check again the utilization and maintenance factors.

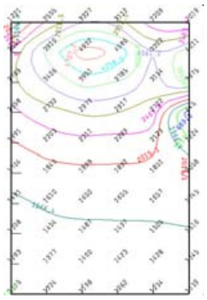
Lighting design process

6e. Calculation of illuminance

At the end, actual average illuminance can be calculated based on selected number of luminaires :

$$E_{average} = \frac{n_i \cdot n_{lum} \cdot \Phi_0 \cdot \eta \cdot f}{a \cdot b}$$

Lighting design process



6e. Calculation of illuminance

It is even easier to calculate average maintained illuminance by verified computer program for lighting calculations.

Lighting design process

7. Control of the uniformity of illuminance

After completion of the calculation of the illuminance, its uniformity should be controled:

- based on information from manufacturer of luminaires and its installation (mounting height, layout, distance between luminaires);
- with the help of computer software.

Lighting design process

8. Control of glare

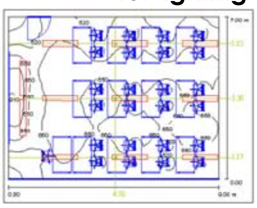
Glare is determined by calculating the unified glare index (UGR):

- based on information from manufacturer of luminaires and its installation (mounting height, layout, distance between luminaires);
- with the help of computer software.

Lighting design process

9. Drawing of blueprints for lighting

Based on selected parameters, blueprints for lighting installation can be drawn:



- ground plan with positions of luminaires;
- section plans.

Lighting design process

9a. Ground plans

- Ground plans (1:20, 1:25, 1:50 ali 1:100) (type of luminaires, type of light sources, installation height of luminaires, mounting method);
- lighting parameters (illuminance, uniformity, UGR);
- electrical parameters (installed power, cos φ);
- maintenance instructions (how to maintain, cleaning period…).

Lighting design process

9b. Section plans

Characteristic section plans must be when:

- luminaires are mounted at different heights;
- luminaires are mounted in different positions;
- when a non-standard fittings for hanging are used (also drawings of accessories for hanging must be provided).

Lighting design process

10. Determination of electrical parameters

Based on the blueprint it is necessary to elaborate electrical installations plan, where following should be provided:

- installed electric power;
- power factor;
- arrangement of luminaires;
- control and switch-on schemes.

Lighting design process

11. Economic parameters

Lighting project should also provide calculation of economic viability, which comprises:

- analysis of investment costs (pro forma invoice);
- analysis of operating costs;
- calculation of investment and operating costs;
- economic analysis.

Lighting design process

11a. Investment costs

Investment costs are directly affected by:

- quality of lighting;
- light sources;
- luminaires;
- ballasts;
- the cost of electrical installations;
- the cost of connection to the grid.

Lighting design process

11b. Operating costs

Operating costs include:

- depreciation expense;
- insurance costs;
- costs for the use of el. network;
- cost of cleaning and maintenance;
- cost of replaced light sources;
- costs of consumed el. energy.

Lighting design process

11c. Economic analysis

Different variants of the lighting can be compared on the basis of:

- investment costs;
- operating costs (annual);
- energy costs;
- productivity increase;
- improvement of product quality;
- manufacturing success.

Lighting design process

12. Selection of variant

During the design process, it is advisable to create several variants so optimal solution can be chosen. Variants should:

- be based on the same qualitative and quantitative factors;
- take into account all relevant costs;
- be chosen based on appropriately evaluated individual criteria.

Lighting design process

13. Measurements

After completion of the project (after the installation of the luminaires in the room), it is advisable to carry out measurements of lighting installation. In this way, we can confirm the correctness of the project and identify possible shortcomings. We should try to remove the shortcomings, and use gained experiences in next projects.

At the end…

- The lighting design should be started early enough.
- Designer should consider both technical as well as personal information.
- It is advisable to process and evaluate several variants.
- At the end control measurements should be performed.

… and if you have any…

Questions?