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Building environment design — Indoor environment — Design process for visual environment

Conception de l'environnement des bâtiments — Environnement intérieur — Processus de conception de l'environnement visuel

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 16817 was prepared by Technical Committee ISO/TC 205, *Building environment design*.

Introduction

ISO/TC 205 provides general principles for the design of building indoor environment. These principles are defined in ISO 16813 and help the main participants in the design process to ensure an indoor environment of the quality required for users.

The purpose of this International Standard is to provide design team members with a design process for the indoor visual environment to ensure required visual comfort, physiological effects of light and energy performance and sustainability of buildings. Visual comfort implies more than providing a comfortable lighting environment for executing a task. For example, a window has two functions: to facilitate the entry of daylight and to provide a view.

The design of an indoor visual environment of the required quality for users must take into account human needs that include elements linked to task performance, visual comfort, health, safety and well-being in reference with the work of ISO/TC 159 *Ergonomics*. With respect to illuminating engineering and lighting fixtures, the work requires close consultation with CIE (International Commission on Illumination). The existing standards of CIE and CEN will be used and any new work will be performed in close coordination with CIE and CEN.

This International Standard:

— provides a framework for taking into consideration various parameters and criteria that influence the quality of the indoor visual environment;

— is prepared for design teams (architects and engineers), as well as building clients, contractors, government officials, and academic staff;

— is aimed at assisting these groups in applying an effective design process in the pursuit of an indoor visual environment of the required quality for the users;

— incorporates sustainability considerations;

— is prepared on the basis of the following fundamental ideas:

  i) it addresses the standardization of a design process elaborated through a systemic approach, a system of tasks that are structured together;

  ii) it is a guideline which invites designers to follow an iterative and progressive approach, to make choices and take compromise solutions according to the goals of the client, to the constraints and the opportunities linked to the building site, in relation to the main areas of work covered by ISO/TC 205;

  iii) it allows the performance level or values to be established by the programme and/or applicable regulation.

Building environment design — Indoor environment — Design process for visual environment

1 Scope

This International Standard provides an integrated design process for high-quality indoor visual environment including architectural and engineering aspects of daylighting and artificial lighting for user satisfaction, well-being and productivity as well as the energy performance and sustainability of buildings.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 15686-5:2008, *Buildings and constructed assets — Service-life planning — Part 5: Life-cycle costing*

IEC 60050-845/CIE 017.4:1987, *International Electrotechnical Vocabulary. Lighting*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-845/CIE 017.4 and the following apply.

3.1
aperture
opening that defines the area over which average optical emission is measured

3.2
artificial lighting
lighting that is not provided by sunlight sources

3.3
circadian rhythm
characteristic periodic change in a living organism or life-related process

NOTE 1 A circadian rhythm is an approximate daily periodicity, a roughly 24-hour cycle in the biochemical, physiological or behavioural processes of living beings.

NOTE 2 Circadian rhythms may be influenced by optical radiation.

3.4
clear sky
cloudless sky

NOTE The relative luminance distribution is described in ISO 15469:2004/CIE S 011:2003.

3.5
colour rendering index
measure of the degree to which the psychophysical colour of an object illuminated by the test illuminant conforms to that of the same object illuminated by the reference illuminant, suitable allowance having been made for the state of chromatic adaptation

3.6
colour temperature
K
temperature of a black body (Planckian radiator) whose radiation has the same chromaticity as that of a given stimulus

NOTE Colour temperature is a characteristic of visible light that has important applications in lighting, photography, videography, publishing, and other fields. The colour temperature of a light source is determined by comparing its chromaticity with that of an ideal black-body radiator. The temperature (usually measured in kelvins, K) at which the heated black-body radiator matches the colour of the light source is that source's colour temperature; for a black body source, it is directly related to Planck's law and Wien's displacement law.

3.7
contrast
quantity (in the physical sense) intended to correlate with the perceived brightness contrast, usually defined by one of a number of formulae which involve the luminances of the stimuli considered

EXAMPLE $\Delta L/L$ near the luminance threshold, or L_1/L_2 for much higher luminances.

3.8
daylighting
practice of placing windows, or other openings, and reflective surfaces so that, during the day, natural light provides effective internal illumination

NOTE Particular attention is given to daylighting while designing a building when the aim is to maximize visual comfort or to reduce energy use. Energy savings can be achieved either from the reduced use of artificial lighting, or from passive solar heating or cooling.

3.9
diffuse reflected light
reflection of light from an uneven surface

NOTE The incident ray is reflected at a number of angles.

3.10
directionality
direction of incoming radiation determined by the direct part of it

3.11
disability glare
glare that impairs the vision of objects without necessarily causing discomfort

3.12
discomfort glare
glare that causes discomfort without necessarily impairing the vision of objects

3.13
energy performance
⟨of a building⟩ calculated or measured amount of weighted net delivered energy actually used or estimated to meet different needs associated with a standardized use of a building

NOTE This may include energy used for heating, cooling, ventilation, domestic hot water and lighting.

3.14
illuminance
⟨at a point of a surface⟩ quotient of the luminous flux d Φ_v incident on an element of the surface containing the point, divided by the area dA of that element

NOTE This is expressed in lux, 1 lx = 1 lm·m^{-2}.

3.15
life cycle cost
cost of an asset or its parts throughout its life cycle, while fulfilling the performance requirements

[ISO 15686-5:2008, definition 3.1.7]

3.16
life of a lamp
total time for which a lamp has been operated before it becomes useless, or is considered to be so according to specified criteria

3.17
light pollution
photopollution
luminous pollution
excessive or obtrusive artificial light

NOTE The International Dark-Sky Association defines light pollution as: Any adverse effect of artificial light including sky glow, glare, light trespass, light clutter, decreased visibility at night, and energy waste.

3.18
light trespassing
unwanted impingement of light from external light sources such as nearby building and street lights

3.19
lamp lumen maintenance factor
ratio of the luminous flux of a lamp at a given time in its life to its initial luminous flux, the lamp being operated under specified conditions

NOTE Lumen depreciation is typically expressed as lumen maintenance, the percentage of initial lumens remaining after a specified period of time.

3.20
luminance
L_v
⟨in a given direction, at a given point of a real or imaginary surface⟩ quantity defined by the following equation:

$$L_v = \frac{d^2\Phi_v}{dA \cdot \cos\theta \cdot d\Omega}$$

where

- d Φ_v is the luminous flux transmitted by an elementary beam passing through the given point and propagating in the solid angle, dΩ, containing the given direction;
- dA is the area of a section of that beam containing the given point;
- θ is the angle between the normal to that section and the direction of the beam

NOTE This is expressed in candela per square metre, 1 cd·m^{-2} = 1 lm·m^{-2}·sr^{-1}.

3.21
luminous efficacy
quotient of the luminous flux emitted by the power consumed by the source

3.22
luminous flux
quantity derived from the radiant flux by evaluating the radiation according to its action upon the CIE standard photometric observer

NOTE This is expressed in lumen lm.

3.23
luminous intensity distribution
distribution of luminous intensity having an axis of symmetry or at least one plane of symmetry

3.24
outdoor obstructions
anything outside a building which prevents the direct view of part of the sky

3.25
overcast sky
completely overcast sky for which the ratio of its luminance L_γ in the direction at an angle γ above the horizon to its luminance L_Z at the zenith is given by the following equation:

$$L_\gamma = L_\mathrm{Z}\,(1 + 2\sin\gamma)/3$$

3.26
partly cloudy sky
sky having between 30 % and 70 % cloud cover (in daylighting)

3.27
reflectance
ratio of the reflected radiant or luminous flux to the incident flux in the given conditions

3.28
silhouette phenomenon
phenomenon in which a visual target looks dark when the background is too bright

3.29
sky luminance
luminance of a sky element

NOTE This is expressed in $\mathrm{cd{\cdot}m^{-2}}$.

3.30
skylight
visible part of diffuse sky radiation

3.31
sunlight
visible part of direct solar radiation

3.32
thermal radiation
process of emission in which the radiant energy originates in the thermal agitation of the particles of matter such as atoms, molecules, ions

3.33
transmittance
ratio of the transmitted radiant or luminous flux to the incident flux in the given conditions

3.34
transparency
capacity to transmit radiative energy without altering its incoming direction

3.35
visual nuisances
subjective visual discomfort caused by unwanted views

3.36
visual target
something to be seen and recognized by human eyes

3.37
window
daylight opening on a vertical or nearly vertical area of a room envelope

4 Fundamentals

4.1 General

General principles of indoor environment design allow the clients and design teams to provide the desired quality of indoor environment in a sustainable building according to the fundamentals of the design process.

The design process aims to ensure, by visual comfort, an efficient environmental building design providing the specified quality and performance level involving safety, health, comfort, and energy use as well as sustainability, the philosophy, ethics, and assumptions taken by the people concerned. Building designers should define the goals based on the requirements, constraints, and actual conditions to be achieved, integrating the owning and operating costs during the design stage.

4.2 Project information

The available project information that influences the development of visual comfort design concepts together with constraints and all requirements shall be documented. When assumptions are made in lieu of necessary information related to the standards or regulations for building environment visual comfort design, with respect to the indoor environment, these assumptions shall be documented. The project information provided by the users of this International Standard that influences the programming, development, and/or the design of building components and the building service systems, shall also be documented.

4.3 Framework of generation and verification

Architectural design and building system design are goal-driven activities. The routes necessary to achieve the end result are not straightforward, and must be flexible. In some instances, the assumptions are made under uncertain conditions. Hence, the design process involves the iteration of generation and verification. The generation process is a sub-process where a design solution is synthesized, while the verification process is another sub-process in which the design solution depends on different visual comfort design criteria.

4.4 Framework of documentation at approval

The evaluation and approval processes shall be documented. The documentation process shall explicitly state what is to be provided by the project. The evaluation and approval process shall demonstrate that the stated goals can be achieved. Every document provided shall describe the characteristics planned and verify whether they are actually achieved. Approval should be obtained at each design stage.

The documents issued during this design process shall cover the following questions:

— Is the stated definition adequate and feasible?

— Is the environmental design for visual comfort feasible?

— Is the specified structure expected to satisfy the constraints and requirements?

— Is the building capable of providing the visual comfort quality and performance required?

4.5 Harmonization of architectural and system design for visual comfort

Since architectural design as well as the building system design contributes to the realization of the indoor environment, the general principles of building environment design should be used to harmonize the architectural and system design for visual comfort.

The general principles of building environment for visual comfort design should not restrict creative architectural design. The principles do not predefine the order or precedence of individual tasks in both the architectural and building system design for visual comfort.

5 Design process

5.1 Stage I — Formulation of project definition

5.1.1 General

A high-performance and high-quality visual environment is one that:

— meets design objectives of visual environment;

— maximizes occupant visual comfort, well-being and productivity;

— minimizes occupant complaints;

— maximizes building values to the owner;

— yields a lifetime of energy performance of a building and reduces operating costs.

In order to design a high-performance and high-quality visual environment, an integrated architectural approach is recommended. The integrated approach addresses the critical interactions between the building façade (which admits heat and light), building interior and all light sources such as daylight (skylight and/or sunlight) and artificial light. This approach also shares appropriate decisions across the owner and the design team throughout the design process.

5.1.2 Project definition (requirements)

The phases of visual environment design typically comprise parallel architectural design work and might include programming, schematic (or preliminary) design, design development, contract documents, and construction administration.

Before beginning programming, items 5.1.2.1 through 5.1.2.6 shall be well understood.

5.1.2.1 Area of the visual environment design project

The area of the visual environment design project is important. This will offer some sense of the likely variety of space types and clues to the depth of problem solving involved. Larger projects

- tend to require larger design teams and require greater number of meetings to review design options and integration issues,
- challenge the design team on minimizing the number and types of lamps, luminaires, ballasts, and lighting control devices,
- challenge the designer on preparing specification and maintenance standards.

5.1.2.2 Neighbouring outdoor environment

The neighbouring outdoor external environment shall be analysed in order to enhance the characteristics of the site.

5.1.2.3 Number and types of spaces

The number and types of spaces will give the designer an early sense of the diversity of the occupants and tasks that will need to be accommodated.

5.1.2.4 Schedule for visual environment design

The schedule for the visual environment design will affect the timing and the degree of performance by the designer for the various stages of the design effort.

5.1.2.5 Client or users

Understanding the client or users and having access to the client influences the success of designing a high-quality visual environment. Asking more pointed questions of the client and more carefully addressing programming is necessary to better understand and address user's needs.

5.1.2.6 Design team

The design team is responsible for addressing human and technical issues on the project. A team should typically consist of an architect, an electrical engineer, an interior designer, a mechanical (HVAC) engineer, a landscape architect, a structural engineer, and a construction manager.

5.1.3 Constraints

Before proceeding to the schematic design phase, constraints of existing spaces shall be identified. Taking inventory of the existing constraints of any project is critical in assessing vision, perception, and subsequently visual needs, of users. A checklist shown in Table 1 can be used as a guide for taking inventory of the constraints of existing spaces on a project. This can be gathered from a variety of sources. Some of the information is a matter of observation and measurement taking. Some information, however, requires interaction with users.

Table 1 — Inventorying existing constraints

Parameter	Existing constraints
External conditions	• Sky conditions — clear — overcast — partly cloudy • Albedo • Site altitude • Site cardinal orientation • External obstruction • Natural conditions — direct sunlight — reflected light — continuous/occasional • Artificial conditions — light pollution — light trespassing
Space dimensions	• Length • Width • Height
Spatial form	• Rectilinear • Curvilinear • Long/narrow and tall/short • Short/wide and tall/short
Space activities	• Primary (may be several) • Secondary (may be several)
Visual tasks	• Prioritize by importance • Prioritize by time spent on each
Occupants' ages (by group)	• 0 to 10 years old • 10 years old to 20 years old • 20 years old to 40 years old • 40 years old to 60 years old • 60 years or more
Furnishings	• Low and open • Low and closed • High and open • High and closed • Solid and void
Surface finishes	• Degree of gloss • Colours • Reflectances (percentage) • Transparency
Lighting	• Illuminance • Luminances • Lamp and luminaire types and layouts • Daylighting (view/no view)
Users' feedback	• Prior complaints about environment or work • On-site feedback
Owner's feedback	• Present image • Perceived quality of existing environment • Present operating costs • Relationship between indoor and outdoor environment
Designers' impressions	• Monument to prior design team • Monument to owner • Improvement to human condition

Obtaining user feedback on existing conditions requires the design team to survey the users and/or to review any file of previous complaints about the workplace. Table 2 suggests some user survey questions.

Table 2 — Survey questions for existing constraints

Parameter	Questions
Space-related activities	How is this space used? What do you consider the primary tasks to be carried out here? Are there any secondary tasks?
Visual tasks	What is the most important task? Are there any other tasks of similar importance? What are the visual aspects of your work? How much time do you spend in this room each day? How much time do you spend on each task or activity?
User feedback	The indoor visual environment is comfortable. [agree/disagree] The room is too bright. [agree/disagree] The room is too dim. [agree/disagree] The task area is too bright. [agree/disagree] The task area is too dim. [agree/disagree] The lighting causes distracting shadows. [agree/disagree] The lighting is easy to control. [agree/disagree]

After identifying the existing constraints, constraints for the new project that may significantly influence visual environment design, or alternatively that the designer should influence, should be listed and identified. Table 3 summarizes the constraints that can arise regarding the planned spaces.

Table 3 — Constraints on planned project

Parameter	Constraints on planned project
Space dimensions	Length Width Height
Spatial form	Rectilinear Curvilinear Long/narrow and tall/short Short/wide and tall/short
Space-related activities	Primary activities Secondary activities
Visual tasks	Prioritize by importance Prioritize by time spent on each
Users' ages (by group)	0 to 10 years old 10 years old to 20 years old 20 years old to 40 years old 40 years old to 60 years old 60 years or more
Furnishing and interior partition walls	Low and transparent Low and opaque High and transparent High and opaque
Surface finishes	Texture (glossy or matte) Colours Reflectances (percentage)
Daylighting	Sunlight Skylight Reflected light View or no view
Owner's expectations	Image Perceived quality of planned visual environment Initial costs and planned operating costs

The programming phase consists of inventorying conditions of existing spaces, inventorying givens for the planned spaces, establishing design goals, defining and prioritizing design criteria, and preparing programming statement.

5.1.4 Requirements

With a clear understanding of the users' existing and planned constraints, it is possible to develop specific design requirements for the visual environment. Table 4 provides a comprehensive list of design requirements categorized by architectural factors, psychological and physiological factors, and task factors.

The design requirements for the visual environment listed in Table 4 should serve as a checklist. It is recommended that the design team review the checklist, and establish which design requirements are appropriate to the specific project. For important or essential criteria, specific data should be recorded in the checklist or in report format. This allows easy future reference and helps with presentation of the various criteria to the users and/or client. Sharing such a checklist with other team members can help solidify a design. This checklist can also help identify priorities.

Table 4 — Design requirements for visual environment

Category	Design requirements
Architectural factors	Visual environment (pleasantness) Spatial definition Spatial order (transitions and adaptations) Circulation Flexibility Controls Acoustics HVAC : Heating, ventilation, air conditioning Ceiling systems Codes and ordinances Sustainability Surface reflectances Surface transmittances
Psychological and physiological factors	Sensory responses Visual hierarchies and focal centres Visual attraction Subjective impressions Circadian rhythm Health
Task factors	Visual tasks Illuminances Luminances
Visual relation between indoor and outdoor environment	View Weather Time Moon

5.1.5 Assumptions

Any issue that cannot be fully identified in the course of the design shall be assumed and the design team shall take these into account in the final design decision. For example, if the design team has no specific sky conditions for the project site, then the design team may assume that the planned building is operated under the CIE standard for overcast sky and clear sky.

5.1.6 Philosophy, ethics and theories

A building is evaluated on various aspects. The clients and the design team should decide which aspects they consider to be most important or less important on the basis of their own philosophy and ethics. The design of an indoor visual environment of the required quality for users must take into account human needs that include elements linked to task performance and productivity, visual comfort, physiological effects of light, health, safety, well-being, and energy performance and sustainability of a building.

5.1.7 Output — Document I

Document I shall be issued as an output product of the project definition process and as an explicit description of the project definition, i.e. the constraints, the requirements and the assumptions. For some projects this may be nothing more than an oral presentation of the facts as defined by the design team. For other projects, this may be a brief report that includes programmatic statements and a very preliminary guidance criteria statement or a complete design statement.

5.1.8 Evaluation I

Once the project definition has been completed, feedback from the design team is necessary in order to evaluate the interactions between the responses to the constraints and the requirements of all aspects of the design.

5.1.9 Output — Approval of document I

Once the evaluation I process has been successfully completed, an approval of document I shall be issued as a second output in order to be validated. Approval of document I should indicate how it was evaluated together with the results of the evaluation. It shall contain the constraints, the requirements and the assumptions.

Stage II cannot be started unless document I is approved.

5.1.10 Iteration

If document I was not approved, it should be revised by iterating the steps beginning with the project definition. If there is any contradiction in the compilation of the requirements and constraints described in document I, some of the requirements should be revised and iteration started with the revised requirements.

5.2 Stage II — Schematic design

5.2.1 General

Upon the completion of the programming phase, the design team is prepared to undertake schematic design: developing preliminary ideas or schemes for the visual environment of a particular project. Schematic design typically results in an understanding and agreement among the team members about visual environment criteria, penetration of daylight, general lighting approaches, styling of luminaries and the visual relationship between the inside and the outside. The work between the architectural schematic design and visual environment schematic design shall be iterative.

5.2.2 Input

As design concept material becomes available at stage I, the design team is in a position to develop a visual environment scheme while also addressing the programming. Assessing the architectural design elements must go beyond simply absorbing whatever schematic information the design team provides. This is an opportunity to interact within the design team by asking questions directly related to the visual environment.

5.2.3 Output

The visual environment, while ultimately ubiquitous on every project, starts as bits and pieces of ideas considered for various sizes of areas or spaces. The areas or spaces first addressed might be those considered most important or those for which an architectural concept is already associated. A visual environment scheme should address all areas or spaces of a project. This is an overview or road map of how visual environment might be used to meet the various programme requirements while it also enhances and integrates with the architecture. Details are not yet an issue, and should not be addressed during schematic design. Completeness is not necessary at this point – this makes it appear that the other design aspects are firmly resolved and that the visual environment problem is solved with no remaining questions or further discussions necessary. The general direction of the project, though, is important.

5.2.4 Evaluation II

The consistency of the framework described in document II shall be verified in reference to the visual environment design criteria and document I. The appropriateness of the programme and the diagrams shall be verified. The major concern is whether or not the visual environment design is headed in the right direction.

5.2.5 Output — Approval of document II

Once feedback has been received and addressed, the design scheme for the visual environment is finalized. This yields preliminary architectural and lighting plans illustrating the scope and strategies to create a comfortable and energy-efficient visual environment. As the scheme is advanced for client review and approved, the stage is set for the detail design stage.

5.2.6 Iteration from conceptual design and schematic design

If the predicted initial visual environment design concept of a building established during the design process does not meet the requirements and constraints described in document I, then an alternative concept and scheme shall be presented. Minor changes are possible in some instances; however, major changes are necessary in others.

5.2.7 Iteration from project definition

If no change in the visual environment design concept and scheme is found necessary, the visual environment design may proceed to stage III. If changes in the requirements are made to provide improved solutions, then the visual environment design project definition shall be revised.

If modification of the project definition does not improve the issue, then the project parameters shall be reconsidered.

5.3 Stage III — Detail design

5.3.1 General

Stage III is the main phase of the visual environment design process and is where a detailed design is performed. Detailed design should express design elements of the visual environment such as lamp types and luminaires for artificial lighting, geometric and photometric characteristics of fenestration and sunlight control schemes for daylighting, colours and reflectances of interior surfaces, and types of controls to reduce electric lighting energy. All system designs shall be included in stage III. Light reflecting and light transmitting devices are both important design elements in this stage.

Detailed predictions and analyses through computer simulations and/or measurements with physical models should be performed during this stage.

5.3.2 Input — Background

Document II which is approved by the design team and the client includes preliminary architectural plans, design descriptions and specifications, particularly lighting plans, illustrating the scope and strategies to create a comfortable visual environment with high energy performance of buildings.

The design team should further develop the design with more detailed data and specifications of the artificial lighting system and daylighting system and components. In addition, spatial form and dimensions also have an impact on visual comfort and therefore should be fully taken into account.

5.3.3 Output — Document IIIa

Document IIIa is the explicit description of the artificial lighting system and daylighting system. It consists of the drawing and lighting specification, including the relationship with building design. At this stage, output shall contain architectural design, daylight design, lamp selection, luminaires design/selection, and lighting control design. See Annex B for further information.

5.3.4 Analysis

The analysis of the visual environment shall be conducted during the detailed design process and be expressed both in terms of coordination with the building design, energy performance of the building and the lighting requirements of the building. At this stage, both quantitative and qualitative aspects should be analysed.

Illuminance levels on work plans should be carefully analysed. For the qualitative aspect, glare potential should be closely analysed based on the luminance distributions viewed from various viewpoints. Other qualitative aspects include colour rendering and directionality of light.

Daylighting design should be analysed based on three different components of daylight: sunlight, skylight, reflected light. Daylight performances at different hours and seasons should be analysed.

Artificial lighting design should be analysed with the consideration of control scenarios with and without daylight.

Many computer simulation programs are available to conduct such detailed analyses. An advanced computer tool will provide the designer with not only numerical data but rendered images. The designer may construct scale models or mock-ups for photometric measurements and visual inspections as well.

5.3.5 Output — Document IIIb

The artificial lighting plan (usually a modified reflected-ceiling plan) indicates the locations and luminaire types for all lighting within the scope of work. Control locations and circuits are also shown on the lighting plan.

Drawings should show mounting details, building section and elevations, custom luminaire details, and other supplemental information related to the visual environment. Document IIIb also includes luminaire attributes and catalogue numbers and lighting specifications to outline general requirements for the lighting system, such as ballasting, artificial requirements, applicable codes and standards, approved manufacturers, mounting restrictions, and custom fixture requirements.

Dimming and control specifications and schedule should be included.

5.3.6 Evaluation III

Once a detailed design has been established, feedback from the entire team is necessary in order to evaluate the indoor visual environment of the building. The design team shall evaluate the lighting system under design so that uncomfortable or distracting glare is minimized for the user. This involves knowing the location of the user, the angles of view, and the distribution of light on the room surfaces as well as familiarity with the specified lighting products.

The illuminance levels obtained from the analysis procedure shall be closely evaluated against the required levels. In addition, energy efficiency of the artificial lighting system should be evaluated in terms of power density values.

For a qualitative evaluation, colourful computer-rendered images can be used for judgement by the design team, occupants and clients.

5.3.7 Output — Approval of documents IIIa and IIIb

While evaluation III is under process, documents IIIa and IIIb shall be approved. Approval of documents IIIa and IIIb shall include how documents IIIa and IIIb were evaluated.

5.3.8 Iteration into detail design

If the current building design concept does not meet the contents described in document II, then an alternative design shall be provided. At this stage, only minor changes requested by the clients shall be made.

If documents IIIa and IIIb show that the quality and performance described in document II is not provided by the building design, then the current design shall be modified without changing the overall design concept.

5.4 Stage IV — Final design

5.4.1 General

Stage IV is the final phase of the visual environment design process where construction documents are generated. Balancing natural daylight design with adaptable and modular artificial lighting is crucial.

The final construction documents of the indoor visual environment design shall be delivered to contractors. The documents shall include the location and dimensions of windows, the level of illuminance provided by windows and other types of openings in the façade or roof, the characteristics of the glass, the colour of the surfaces, the lighting design drawings containing lighting systems graphically expressed as architectural reflected ceiling plans, elevations, and sections with accurate dimensions. The documents shall also include written specifications outlining the expected duties of the contractor and indicating specific hardware components such as lamp, ballast, transformer, and luminaire. Applicable industry standards and code references shall be cited in the specifications. In this phase a detailed commissioning plan shall be developed and cost estimations shall be conducted as well.

5.4.2 Commissioning documents

5.4.2.1 Design drawings

Lighting reflected ceiling plans shall include locations of ceiling-mounted lighting installations, spacings and aiming directions drawn on the architectural floor plans. If luminaires are to be installed on the wall or hidden from the interior surfaces, architectural elevation and section drawings shall be used. The lighting installations such as luminaires, controllers and switches/dimmers are expressed by symbols adopted as national industry standards or more diverse and realistic representations of luminaires in order to make drawings more meaningful to contractors. Final drawings shall include exact detail dimensions. The design drawings shall include location and dimensions of windows, and characteristics of the glass.

5.4.2.2 Specifications

Daylighting and artificial lighting specifications are written documents containing specific and detailed descriptions of the work to be completed with characteristics given by manufacturers. Since the specification, along with drawings, is a legal document, it must be prepared very carefully and reviewed by the design team. It is then released to the contractors to be used as a resource during bidding, shop drawing review, and construction processes.

A good specification can be prepared only after a well-organized and prudent design has been achieved. During a specific and detailed design process, a large amount of detailed information can be obtained regarding daylighting and artificial lighting installation requirements necessary to meet project criteria. All the information shall be documented clearly and in detail in the specification to help the contractors understand what equipment needs to be purchased and installed.

In addition, daylighting and artificial lighting-related architectural integration details shall be documented in the specification. An effective integration of artificial lighting and daylighting can be achieved by a collaborative work effort within the design team.

5.4.3 Commissioning plan

A commissioning plan shall be developed to ensure that all lighting systems function as close to the design intent as possible after installation and before occupancy of the building. The commissioning plan shall involve systematically testing all lighting controls in the building to ensure they provide the specified performance, interact properly as a whole system, and fulfil both the design intent and owner's needs related to user satisfaction and, if applicable, energy savings. Commissioning shall be planned after the interior has been completed and the furniture is in the building, budgeted and executed as part of the design and construction process. The lighting commissioning plan should be coordinated with other subsystem commissioning activities, e.g. mechanical systems.

5.4.4 Cost estimation

Daylighting and artificial lighting design is often constrained by the designated budget. The design team has control over both the initial construction and operating and predictive maintenance of the lighting system. Initial cost includes all design fees, lighting equipment purchasing costs, labour cost of the installation, etc. Operation and predictive maintenance costs include annual power, all lamp and ballast replacement costs, maintenance and repairs, etc.

In many cases, it can be beneficial to compare the life cycle costs of different lighting systems in order to make the best choice. The life cycle cost for a given lighting system includes initial costs, operation and maintenance costs, predictive consumption of resources and conservation measures. The time value of money is considered.

5.4.5 Output — Final document

The final documents from this phase shall include lighting design drawings, lighting specifications, operating manuals, commissioning and maintenance documents and estimated cost for installation and maintenance.

All of these documents generated by the design team in this phase shall then be validated by the client and issued as part of their respective contract documentation to contractors for pricing and/or bidding.

5.5 End of design

5.5.1 General

The design phase is followed by bidding and construction administration phases. During these phases, the design team shall perform the following services:

— bid assistance;

— review and approval of shop drawings;

— construction assistance and assessment of installation progress;

— commissioning of the installed lighting systems.

5.5.2 Lighting bid assistance

Once the project has been issued to a contractor or contractors for pricing and/or bidding, questions may arise from bidding contractors, electrical distributors, or lighting equipment manufacturers. The design team shall answer or clarify those questions. All the questions and answers shall be officially documented for future reference.

5.5.3 Review of shop drawings

The shop drawings are detailed drawings of daylighting systems and components, and luminaires and are submitted through the contractor for the design team's review. The shop drawings typically show detailed dimensional and material characteristics of the daylighting systems and components, and artificial lighting installations. By reviewing the shop drawings, the design team shall confirm that the contractor has ordered the equipment as specified to meet the design goals.

5.5.4 Construction assistance and assessment

After bidding is completed and the project has been awarded to a contractor, additional questions may arise during the material procurement and/or actual construction processes. During the construction process, there may be interferences between daylighting systems and components, lighting installations and other systems, such as structural members, mechanical and/or electrical systems. The design team shall assess the situation and address the problems as they develop and propose solutions.

As the project approaches the final phase, the design team shall review the project site to assess the lighting effects and the visual aesthetical aspect of the daylighting systems and components and artificial lighting installations.

5.5.5 Commissioning

Commissioning is a first run of the daylighting systems and components and artificial lighting system. Final calibration on the lighting system shall be made at this stage. If occupancy sensors, photocell-based controllers, timers, and other control mechanisms are installed, the hardware systems shall be calibrated in terms of their respective sensitivity settings and input/output settings.

The design team shall also provide instructions to the client's authorized personnel on their operation and programming. The building cannot be expected to operate properly if the personnel in charge of operating and maintaining the daylighting systems and components and artificial lighting systems are unfamiliar with how to service the equipment and do not fully understand how and why the systems operate the way they do.

During commissioning, each piece of the equipment should be verified to be in the right place, installed correctly, and calibrated to meet the design specifications. The commissioning test shall be carried out in order to:

— verify that all sensors have been properly placed;

— verify local control of each piece of the equipment;

— test interactions between equipment pieces;

— test system-wide operation under different anticipated scenarios.

6 Development of design criteria

The design criteria for the visual environment and energy performance of a building shall be referred to in the evaluation of the proposed design at each stage of the design process. The different design criteria indicated above shall be included in the documentation and shall make reference to the related International Standards, or regional or national standards.

7 Development of design aids

The design aids on the indoor visual environment for design teams should be developed together with the design criteria for an efficient design process.

8 Cost evaluation

8.1 Estimation of primary costs

A qualitative comparison of the initial and operating cost characteristics of the initial design is encouraged. This qualitative approach may be based on experience or by methods approved by the industry.

Since sufficient design details are not normally available at the initial design stage, cost comparisons are not necessarily based on the actual project, equipment or energy data. Unless otherwise specified by contractual arrangements, one approach is to proceed from the initial stage based on 8.2.

8.2 Evaluation of the visual environment design benefits versus costs as required by the client

There are several levels of complexity in the cost analysis:

a) basic cost of the initial construction;

b) cost including operation and predictive maintenance of systems and components (owning and operating costs), which can include building, plant and safety insurance costs;

c) life cycle cost as in a) and b) plus predictive consumption of resources and conservation measures;

d) plus whole life cycle costs, including external environmental costs and demolition costs;

e) plus the benefits to productivity in the workplace, by improving the indoor and visual environment quality.

Cost estimates at one of these five levels of detail in the selected design for the aspects of the visual environment in the design team's preview should be developed. These estimates should be based on the actual project equipment and energy data to the extent that these have been determined at the final design stage.

The cost estimates shall be documented and evaluated for acceptability in terms of overall project requirements.

If the estimates are unacceptable, the design detail or concept shall be reconsidered in an attempt to achieve cost acceptability. Changes to the performance criteria shall be considered only when changes to design details or concepts cannot achieve cost acceptability or the benefits cannot justify the extra costs.

8.3 Compliance review

The plans and specifications for the aspects of the visual environment in the design team's preview shall be reviewed and documented in order to:

— meet the legal requirements of applicable codes, regulations, and laws;

— be capable of meeting the design performance criteria;

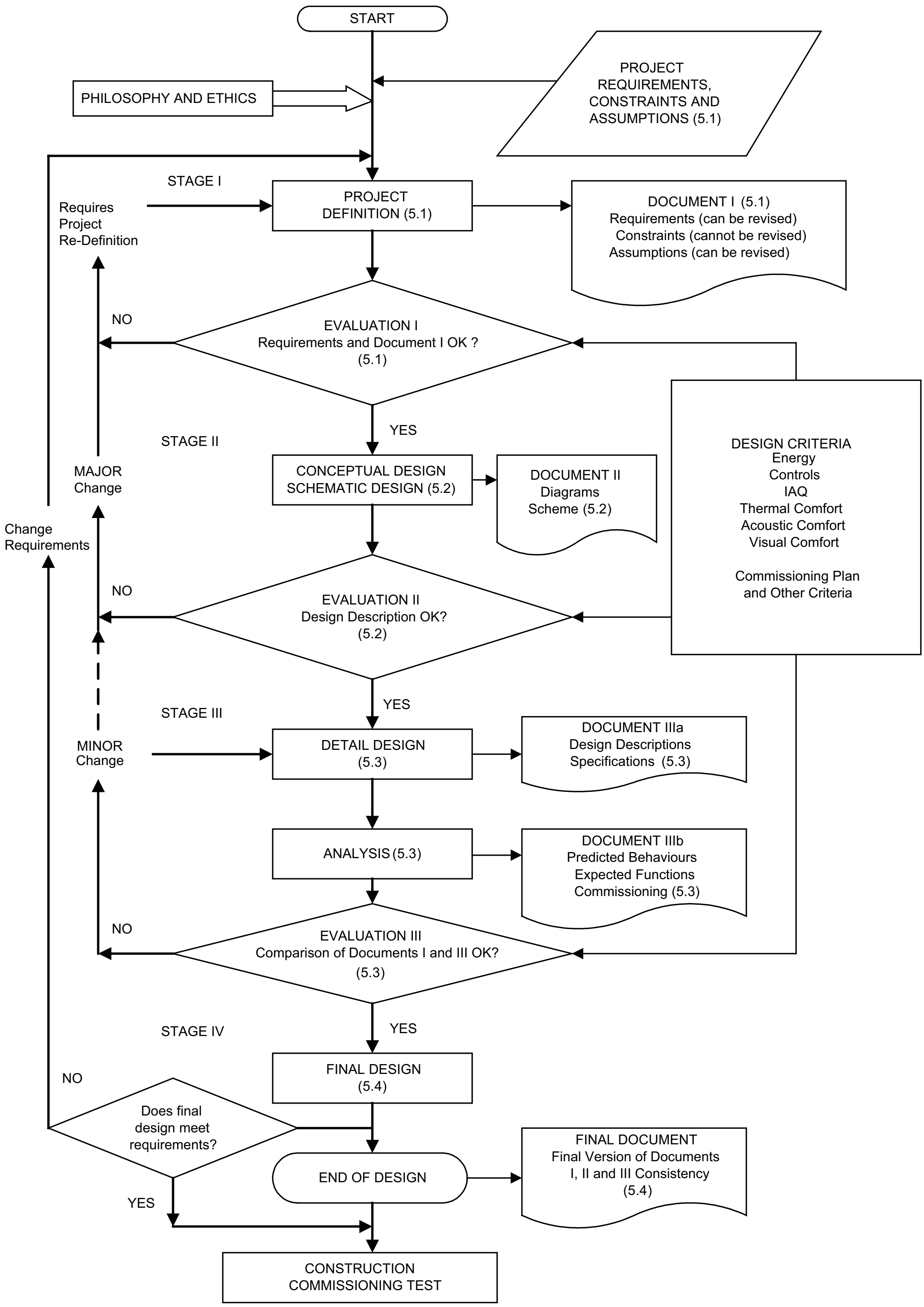
— meet the estimated cost within the project budget;

— avoid conflict with other building systems at this stage.

If the plans and specifications fail to meet any of these requirements, they shall be reconsidered to ensure compliance with these requirements. Changes to the performance criteria shall be considered only when changes to plans, specifications, design details or design concepts do not achieve these requirements.

Annex A
(informative)

Matrix



Annex B
(informative)

Output of the detail design

B.1 Architectural design

At this stage, building location, cardinal orientation, outdoor conditions, visual connection between building and surroundings, outward perspectives, internal and external surface treatment (vegetable, mineral or liquid), control methods of external visual nuisances are determined.

B.2 Daylighting design

The sunlight is carefully controlled to avoid uncomfortable glare and it is recommended to redirect it to the ceiling. Use of skylight and externally reflected light should be maximized for task illumination.

Sunlight is best controlled by building orientation and architectural devices, such as overhangs, awnings, light shelves, interior and exterior louvers and baffles, and solar shades. Skylight is more consistent than sunlight, although it is also variable to some extent in intensity and colour. Skylight must be assessed with typical sky conditions at the site. Skylight is best controlled by window size and glass transmittance. Reflected light is more consistent than direct component and is less significant than sunlight or skylight.

B.3 Lamp selection

Along with daylighting, artificial lighting equipment is the crux of the detailed design stage. Lamps are the main light producing element. The lighting designer may decide to use a lamp shade, a reflector, a refractor, a louver, a dimmer or a bare lamp. The type and dimension of the lamps should be designed or selected to make the space more comfortable. Energy, sustainability, maintenance, and life-cycle issues should be considered.

B.4 Luminaires design/selection

Luminaires include the light source, a ballast, wiring and components that provide electrical connections, the housing that protects these components, and an optical system that directs light emission in the desired direction and pattern.

Luminaires govern light distributions on room surfaces, work planes, tasks, plants, architectural elements, and people. Some luminaires are intended for use in architectural details. The lighting designer must develop the relevant detail dimensions around which the architect and/or engineer will then develop structural and architectural finish details to support and hide the luminaire.

B.5 Lighting control design

Controls for lighting can be simple electromechanical devices that literally connect a light to electricity or disconnect a light from electricity.

The use of advanced lighting controls can provide a higher level of energy performance of buildings, support flexibility of use of a space, and increase occupant satisfaction when the controls are performed with the consideration of daylight. A successful control design can help deliver the right amount of light where it is needed and when it is needed.

Lighting may be switched or dimmed, and the method chosen affects the choice of control devices and the ballasts. The designer must consider many aspects of controls such as on/off switches, time-clock system, occupancy sensors, device styles, arrangements, and function.

The lighting control system should be operated within the constraints of the building management system.

Bibliography

[1] ISO 6385, *Ergonomic principles in the design of work systems*

[2] ISO 8995-1, *Lighting of work places — Part 1: Indoor*

[3] ISO 9241-6, *Ergonomic requirements for office work with visual display terminals (VDTs) — Part 6: Guidance on the work environment*

[4] ISO 15469:2004/CIE S 011:2003, *Spatial distribution of daylight — CIE standard general sky*

[5] ISO 16813, *Building environment design — Indoor environment — General principles*

[6] CIE 13.3-1995, *Method of Measuring and Specifying Colour Rendering of Light Sources*

[7] CIE 16-1970, *Daylight*

[8] CIE 19.21-1981, *An Analytic Model for Describing the Influence of Lighting Parameters upon Visual Performance — Vol.1: Technical Foundations*

[9] CIE 19.22-1981, *An Analytic Model for Describing the Influence of Lighting Parameters upon Visual Performance — Vol.2: Summary and Application Guidelines*

[10] CIE 40-1978, *Calculations for Interior Lighting: Basic Method*

[11] CIE 58-1983, *Lighting for Sports Halls*

[12] CIE 60-1984, *Vision and the Visual Display Unit Work Station*

[13] CIE 62-1984, *Lighting for Swimming Pools*

[14] CIE 96-1992, *Electric Light Sources — State of Art — 1991*

[15] CIE 97-2005, *Maintenance of Indoor Electric Lighting Systems, 2nd ed.*

[16] CIE 103/5-1993, *The Economics of Interior Lighting Maintenance*

[17] CIE 117-1995, *Discomfort Glare in Interior Lighting*

[18] CIE 147-2002, *Glare from Small, Large and Complex Sources*

[19] CIE S 015-2005, *Lighting of Outdoor Work Places*

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