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Building environment design — Indoor environment — Design process for the 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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

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

This second edition cancels and replaces the first edition (ISO 16817:2012), which has been technically revised.

Introduction

ISO 16813 defines general principles for the design of building indoor environment and helps the main participants in the design process to ensure an indoor environment of the quality required for users.

The purpose of this document is to provide design team members with a design process for the indoor visual environment to aid provision of, in a sustainable approach, required visual comfort, physiological effects of light and energy performance of buildings. Visual comfort does not necessarily only provide a suitable lighting for executing a task. For example, a window has at least 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 takes into account human needs that include elements linked to performance, visual comfort, health, safety and well-being.

The objective of this document is to provide the design team at each phase of the design process with a way to implement the nine general principles of sustainability (NGPS) in buildings, as described in ISO 15392 and how to integrate these principles in their decision-making processes, in order to be part of a sustainable approach.

Concerning research in illuminating and lighting, work by the International Commission on Illumination (CIE) should be consulted. The existing CIE and CEN standards are used and any new work is performed in close coordination with CIE and CEN.

This document

— 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, and

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

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

  — 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;

  — 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 the visual environment

1 Scope

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

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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, *Buildings and constructed assets — Service-life planning — Part 5: Life-cycle costing*

ISO 26000, *Guidance on social responsibility*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
artificial lighting
lighting that is provided by artificial light sources such as electric lights, candles, oil lamps and gas lights

3.2
circadian rhythm
biological rhythm with a period of approximately 24 h

[SOURCE: CIE S 017/E]

3.3
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

[SOURCE: CIE S 017/E]

3.4
daylighting
practice of placing *windows* (3.25) and/or *rooflights* (3.19), or other openings, and reflective surfaces so that, during the day, natural light provides internal illumination

Note 1 to entry: 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 from the reduced use of *lighting systems*.

3.5
daylight opening
area, glazed or unglazed, that is capable of admitting daylight to an interior

[SOURCE: CIE S 017/E]

3.6
design aids
set of guidelines used for conceptual details and final designs for the indoor environment, based on the requirements whether or not expressed by the client and stakeholders

[SOURCE: ISO 16813]

3.7
directionality
the quality of being directional

3.8
electric lighting
lighting by electric light sources

[SOURCE: CIE S 017/E]

3.9
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 1 to entry: This may include energy used for heating, cooling, ventilation, domestic hot water and lighting.

[SOURCE: ISO 16818]

3.10
obstruction
anything outside a building which prevents the direct view of part of the sky

[SOURCE: CIE S 017/E]

3.11
glare
condition of vision in which there is discomfort or a reduction in the ability to see details or objects, caused by an unsuitable distribution or range of *luminance* (3.16), or by extreme contrasts

[SOURCE: CIE S 017/E]

3.12
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 1 to entry: This is expressed in lux, 1 lx = 1 lm·m^{-2}.

3.13
life cycle cost
cost of an asset or its parts throughout its life cycle, while fulfilling the performance requirements

3.14
light pollution
generic term indicating the sum total of all adverse effects of artificial light

[SOURCE: CIE S 017/E]

3.15
light trespass
unwanted impingement of light from external light sources such as nearby building and street lights

3.16
luminance
L_v
⟨in a given direction, at a given point of a real or imaginary surface⟩ quantity defined by the following formula:

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

where

d Φv	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 1 to entry: This is expressed in candela per square metre, 1 $cd \cdot m^{-2} = 1\ lm \cdot m^{-2} \cdot sr^{-1}$.

[SOURCE: CIE S 017/E]

3.17
luminous flux
quantity derived from the radiant flux by evaluating the radiation according to its action upon the CIE standard photometric observer

Note 1 to entry: This is expressed in lumen lm.

[SOURCE: CIE S 017/E]

3.18
reflectance
ratio of the reflected radiant or *luminous flux* (3.17) to the incident flux in the given conditions

[SOURCE: CIE S 017/E]

3.19
rooflight
daylight opening (3.5) on the roof or on a horizontal surface of a building

[SOURCE: CIE S 017/E]

3.20
skylight
part of sky radiation capable of causing a visual sensation

[SOURCE: CIE S 017/E]

3.21
sunlight
part of direct solar radiation capable of causing a visual sensation

[SOURCE: CIE S 017/E]

3.22
transmittance
ratio of the transmitted *luminous flux* (3.17) to the incident flux in the given conditions

3.23
transparency
capacity to transmit radiative energy without altering its incoming direction

3.24
visual nuisances
subjective visual discomfort caused by unwanted views

3.25
window
daylight opening (3.5) on a vertical or nearly vertical area of a room envelope

[SOURCE: CIE S 017/E]

4 Fundamentals

4.1 General

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

The nine general principles of sustainability (NGPS) are defined in ISO 15392. The NGPS include

— continual improvement,

— equity,

— global thinking,

— holistic approach,

— involvement of interested parties,

— long-term consideration,

— precaution and risk,

— responsibility, and

— transparency.

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 project information that influences the development of visual environment design concepts, together with constraints and all requirements, shall be documented. A description of the intended use (and related requirements) of the building and end-user needs shall be included. When assumptions are made in lieu of necessary information related to the standards or regulations applicable to quality visual environment design, these assumptions shall be documented. The project information provided by the users of this document that influences the programming, development and/or the design of building components and the building service systems shall also be documented. The expected service life of the building and its components shall be specified.

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 should be flexible. In some instances, the assumptions are made under uncertain conditions. The design choices shall be focused on the limitation of adverse environmental impacts. Hence, an iterative generation process and verification and validation of the design decisions shall be established at each stage of the design process. When a decision is to be made, the design team shall make a systematic review of the potential effects of that decision during the life cycle of the building. 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 quality visual environment design criteria. The expected performance of the visual environment shall be achieved during the above processes. When the targets are not met, the design team shall determine acceptability and act accordingly. A periodic review of the management system shall be made in order to check effectiveness of existing management system and consider improvement as necessary.

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. Transparent decision-making and communication processes shall be established. Essential maintenance and replacement plans of the building components shall be documented according to the expected service life of the building. 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 quality visual environment feasible?

— Is the specified structure expected to satisfy the environmental, economic and social constraints and requirements?

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

4.5 Harmonization of architectural and system design for quality visual environment

Since quality indoor visual environment is the result of a harmonization between architectural design and technical, it is appropriate to apply the general principles of the indoor building environment design.

The general principles of building environment for quality visual environment 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 quality visual environment.

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 the design objectives of the visual environment,

— maximizes users' quality visual environment, well-being, health and productivity,

— minimizes users' complaints,

— maximizes building values to the owner,

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

— respects the sustainability policy of the client or main decision-maker: defines the key elements of the sustainability policy for the project, and

— ensures the safety of the users.

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 other lighting systems. This approach also shares appropriate decisions across the owner and the design team throughout the design process.

Efficient and responsible management throughout the process shall be implemented to establish early identification of needs and roles of interested parties, clear project organisation and planning at each phase, shared decision making, traceability, with good anticipation of risks, problems and conflicts.

Sustainability objectives should be taken into account accordingly with the project:

- **availability of resources (e.g. financial, technical, human, etc.):**
  - ensure the resources available for the project correspond to the ambitions of the project;
  - ensure the resources available for the operation and maintenance allow an optimal use of the buildings;
- **management of risks:**
  - anticipate the administrative, technical and human issues, through early planning in sufficient detail;
  - identify and assess the financial, social, environmental and technical risks, considering short-, medium- and long-term issues;
  - determine acceptability and act accordingly;
  - undertake a regular review;
- **formalization of contracts and responsibilities between parties:**
  - establish contracts suitable for the project and its specificities;
  - ensure that interfaces between actors are well organized and formalized;
- **achievement of the expected performance;**
- **learning from experience:**
  - benefit from past experiences or projects;
  - capitalize on present experience for continuous improvement;
- **consideration of a life cycle perspective**: bring into practice the life cycle thinking approach in the key stages of the project/process:
  - provision of information to successive actors to ensure they are aware of the initial principles, objectives, technical and architectural choices that are specific to the construction work, and the implications of these for its operation and its disposal at the end of life;
- **create record for the operating actors on critical features of the works that relate to sustainability issues.**

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.

- **description of the intended use (and related requirements) of the construction work and end-users needs:**
  - describe the primary functions of the work (e.g. school, offices, retail, residential, etc.);
  - define the functional performance required for each user group, space and task area;
  - spatial arrangement, connectivity and geometry (area, access, etc.);
  - operating conditions;
  - maintainability;
  - specific requirements;
  - define the profiles of performance required to achieve the expected levels of functionality, health, comfort, safety and accessibility;
- **provision of a safe and resistant construction work during exceptional events:**
  - identify exceptional events that might occur;
  - minimize the likelihood of unacceptable risks of injury or damage;
  - consider importance of functional continuity of activities supported by the building, particularly for welfare activities;
  - establish a minimum level of functional performance, during and after the event, typically based on national or local codes/regulations or required by the client's brief (e.g. resilience and resistance to flooding);
- **provision of accessibility for all:**
  - provide spaces able to be entered and used with ease by all users (with different kinds of physical or cognitive abilities);
- **functional flexibility:**
  - ensure the building ability to adapt:
    - individual user requirements;
    - change of user requirements;
    - technical changes;
    - change of use of some areas;
- **security:**
  - ensure by designing the buildings and equipment the safety of the persons and the materials;
- **contribution to social equity and improvement in the social climate:**
  - minimize disturbances and nuisances on neighbours during construction and operation.

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 spaces, task areas and clues to the depth of problem solving involved.

The sustainability objectives are expressed as a short list of statements, actions or recommendations. These are intended to make the objectives more evident for the various stakeholders consideration:

— during brief and design phases, establishment of an expected service life of the building, including maintenance, replacement and end-of-life plans;

— when making a decision, consideration of its implications for all subsequent stages of the life cycle;

— limitation of adverse environmental impacts;

— provision of economic value over time;

— adaptability and end-of-life strategy:

— adaptability for different uses:

— ease of disassembly;

— innovation: investigate whether innovative solutions/approaches have the potential to provide a more sustainable solution (technical, organisational, financial, etc.).

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 light sources, 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:

— limit the impacts on the local environment (e.g. light pollution, glare);

— contribute to local appeal and the quality of life:

  — assess the project's contribution to the improvement of the neighbourhood/district image, the local economy and the quality of life;

— create synergies within the existing context.

  — identify the factors (links, spaces, task areas, functions, continuity and contribution) that fit within and enhance the local environment

  — ensure coherence between the site development and the policy of the local community regarding sustainable development planning, including environmental protection (energy, sewage, waste, rainwater, water resource, services, transport, risks, etc.)

5.1.2.3 Number and types of spaces and task areas

The brief shall determine whether the level of serviceability is adequate to meet the profiles of performance required, and act accordingly. The number and types of spaces and task areas will give the designer an early sense of the diversity of the occupants and tasks that will need to be accommodated.

— Assess serviceability.

  — Assess the levels of performance to be attained for each user group, space and task area.

  — Determine whether the level of serviceability is adequate to meet the profiles of performance required, and act accordingly.

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 are necessary to better understand and address user's needs. It concerns

— **respect of human values:**

  — identify the relevance and significance of issues related to human values and address them appropriately (e.g. responsible behaviour, labour rights, consumer issues, equity, ethical behaviour, according to the principles of ISO 26000);

— **identification, characterisation and involvement of the future end-users and their needs:**

  — identify the demographic features and other characteristics of the end users;

  — identify the end users' needs, desires, values and requirements;

  — decide when and how the end users should be involved;

— **identification and involvement of other interested parties:**

  — identify other key interested parties [e.g. the neighbours, local authorities, local association professionals (service providers and operators)];

  — decide when and how the other interested parties should be involved;

  — establish their level, importance, influence and their role;

— **management and resolution of contradictions or conflicts among the opinions of the interested parties:**

  — take measures to ensure early identification of contradictions or conflicts and their resolution;

— **satisfaction of users and other affected parties:**

  — decide how and when the satisfaction of the users will be determined and assessed;

  — decide how and when the satisfaction of the other interested parties will be determined and assessed;

  — take into account their concerns in order to improve satisfaction and draw lessons for future projects.

5.1.2.6 Design team

The design team is responsible for addressing human and technical issues on the project. An integrated multidisciplinary approach shall be adopted throughout the process by

— identifying the necessary professional skills needed, and

— facilitating integrated working.

A design team should typically consist of an architect surrounded by a team with abilities in electrical engineering, in illuminating engineering, in HVAC systems, in landscape design, in structural engineering and in construction management.

5.1.3 Existing conditions

Before proceeding to the schematic design phase, existing conditions shall be identified. Taking inventory of the existing conditions 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 existing conditions 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.

— **Survey of the local environment:**

  — conduct a multi-criteria survey/analysis of the local environment prior to setting objectives for the project;

  — determine the needs, opportunities, constraints and limitations for the works in context (e.g. national, regional and/or local policies and regulations, etc.);

  — implement decisions or solutions based on the findings of the survey.

Table 1 — Taking inventory of existing conditions (Suggesting existing conditions)

Parameter	Existing conditions
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
Dimensions of each space and task area within it	— Length — Width — Height
Spatial form	— Rectilinear — Curvilinear — Long/narrow and tall/short — Short/wide and tall/short
Activities within each task area	— 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 — Solid and void

Table 1 *(continued)*

Parameter	Existing conditions
User feedback	— Prior complaints about environment or work — On-site feedback
Owner 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 — Sample survey questions for existing conditions

Parameter	Questions
Space or task area activities	Which activities take place in this space or task area? How is this space or task area used? What do you consider as primary tasks? How long is this space or task area occupied? How long is this space or task area used for given functions?
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 conditions, 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 and task areas.

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 and task area related activities	Primary activities Secondary activities
Visual tasks	Prioritize by importance Prioritize by time spent on each task
User age (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 Reflectance (percentage)
Daylighting	Sunlight Skylight Reflected light View or no view
Owner expectations	Image Perceived quality of planned visual environment Initial costs and planned operating costs

The programming phase consists of taking inventory on conditions of existing spaces and task areas taking inventory on givens for the planned spaces and task areas, 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 the visual environment

Category	Design requirements
Architectural factors	Visual environment: inside/outside relationship Spatial definition Spatial order (transitions and adaptations) Circulation Flexibility Controls Acoustics HVAC: Heating, ventilation, air conditioning Ceiling systems Codes and ordinances Sustainability Surface reflectance Surface transmittances Maintenance (cleanliness)
Psychological and physiological factors	Sensory responses Visual hierarchies and focal centres Visual attraction Subjective impressions Health Well-being
Task factors	Visual tasks
Surface finishes	Degree of gloss Colours Reflectance (percentage) Transparency
Lighting	Illuminance Luminance Uniformity Light sources and luminaire types and layouts Daylighting (view/no view) Colour Rendering Index (CRI) Glare control
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, quality visual environment, 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 architectural and visual environment schematic designs shall follow an iterative process.**

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 goes 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 and task areas. The areas or spaces and task areas 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 spaces and task areas 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, expected performance 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 detailed 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, and when the targets are not met, the design team shall determine acceptability and act accordingly. 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 without priority design elements of the visual environment such as colours and reflectances of interior surfaces, type of light source and luminaires, geometric and photometric characteristics of fenestration and sunlight control schemes for daylighting, light reflecting and light transmitting devices and types of controls to reduce electric lighting energy. All system designs shall be included in stage III.

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 in accordance with the sustainable approach of building design.

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

- **use of resources (materials):**
  - consider the environmental benefits of reusing existing elements;
  - establish a basis for choices of materials and set environmental targets, e.g. embodied energy, renewable materials;
  - consider potential for use of recovered/recycled materials or elements;
- **energy resources consumption:**
  - establish basis for improving energy efficiency and set targets across all phases of the project;
  - consider options available to minimize energy use;
  - review possible passive design strategies to optimize visual performance;
  - use energy efficiency options relating to lighting systems and daylighting;
  - consider options for building systems controls: automation and user interfaces, including the need for user guidance and training;
  - develop a programme for commissioning of building systems and system controls and taking account of seasonal variations;
- **reduction of GHG emissions:**
  - determine action to be taken to reduce likelihood of emissions of greenhouse gases other than through energy consumption e.g. prevention of emissions of materials such as refrigerants and other compounds that have high global warming potential (GWP);
- **waste reduction and management (construction and operation):**
  - promote resource efficiency through effective management and reduction of waste:
  - consider how design and fabrication can optimize use of materials (dimensions, off-site pre-assembly) to avoid unnecessary waste of materials;
  - establish a waste management plan for the construction work for each key phase of its life-cycle, (construction, use, demolition/disposal);
  - consider options available for reduce/recycling of waste and avoidance of long distance transportation of waste and waste going to landfill;

— set targets for waste at each stage of the process;

- **consideration of impacts of the construction work and related activities on the local economy:**
  - identify economic inter-relation with other economic activity in the area and the regions;
  - identify impacts on other business and other activity related to the project;
  - encourage positive impacts on the local economy;
- **value over time:**
  - consider maintainability, flexibility and adaptability to enable economic performance to be maintained in changing market conditions or in response to changes in user requirements;
  - minimize risk of obsolescence occurring;
- **adaptability for different uses:**
  - specify to what extent the construction work should be adaptable to alternative uses in the long term;
  - incorporate construction systems/elements that allow building elements to be modified, relocated or removed;
  - design the construction work such that there can be a change of use with little or no need to change the load-bearing structure and main equipment/systems;
  - consider specific adaptability principles of versatility, convertibility and expandability;
  - design to allow parts to be removed or upgraded without adversely affecting the performance of other parts of systems;
- **ease of disassembly:**
  - enable the products/systems to be easily taken apart and recovered at the end of its useful life;
  - design demountable systems (e.g. modular, panelised or prefabricated components);
  - consider specific disassembly principles including accessibility, exposed and/or reversible connections, refurbishability and simplicity;
  - for existing construction work: identify materials containing hazardous substances that may be released during disassembly and take appropriate measures to avoid health risks;
  - for new construction work: avoid using materials containing hazardous substances that may be released during disassembly;
- **recovery of materials for reuse and recycling potential:**
  - identify services in place in the local market that can provide a means for collection of recovered material for reuse, recycling, or for energy production;
  - choose construction products/systems that are capable of being reused, recycled or recovered for energy;
  - give preference to the use of materials with inherent finishes, i.e. materials that can be left in their most basic state without an applied finish that may prevent reuse or recycling.

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, selection of light sources, 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.

Design of daylighting including solar shading should be analysed based on various sky conditions. 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 also 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

Document IIIb is the explicit complementary description of the artificial lighting system and daylighting system. 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 quality visual environment of the building. The design team shall evaluate the lighting system under design from specific user positions and viewpoints so that uncomfortable or distracting glare is minimized. 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 lighting system should be evaluated. For a qualitative evaluation, colourful computer-rendered images can be used for judgement by the design team, clients and users.

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 lighting systems 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 daylight openings, 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 light source, 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 lighting systems 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 shall be prepared very carefully and reviewed by the design team for 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 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, lighting-related architectural integration details shall be documented in the specification. An effective integration of daylighting and lighting systems can be achieved by a collaborative work effort within the design team.

A strategy of replacement and refurbishment shall be established to:

- determine functions needed, and rank them in order of criticality;
- identify the level of performance and maintenance requirements for each critical function in addition to durability;
- collect service life data of system components in order to anticipate replacements;
- establish an initial replacement/refurbishment programme/strategy based on best available techniques/technologies, life cycle cost (LCC) analysis and life cycle environmental assessment;
- review strategy at each decision point to ensure it remains technologically, environmentally, economically and socially sound.

5.4.3 Commissioning plan

A commissioning plan shall be developed to ensure that daylighting and 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:

- **ability to operate and maintain shall be clarified:**
  - ensure a detailed program of commissioning of services and systems is undertaken at the end of the construction phase;
  - identify entities involved in operation and maintenance of the construction work;
  - ensure design intentions and objectives, operational and maintenance requirements are understood by stakeholders;
  - ensure reporting; disseminate a user-friendly document to the operation and maintenance staff.

5.4.4 Cost estimation

5.4.4.1 Output — Final document

The final documents from this phase shall include daylighting and artificial 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;
- learning from experience:
  - benefit from past experiences or projects;
  - capitalize present experience for continuous improvement;
- user feedback and lessons from experience:
  - implement a programme for post-occupancy evaluation (POE);
  - identify entity who receives user's POE feedback and how this will be used to improve both performance of the construction work and user satisfaction;
  - ensure that the received feedback is given to organization/individual responsible for maintenance and operation of the construction work;
  - ensure that decisions/actions proposed are environmentally, economically and socially sound;
  - ensure that users are informed of decisions made/actions taken in response to their feedback.
- **user behaviour:**
  - implement an energy management programme for users and maintain their awareness of this programme through ongoing appropriate communication and information;
  - implement a behavioural safety programme to protect the health and safety of themselves and their colleagues;
  - provide education and training to users about environmental, economic and social impacts of their actions and behaviour, including any particular requirements in relation to the operation of the construction work.

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 material and installation characteristics of the daylighting and lighting systems and components. 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 and lighting systems, components and artificial lighting systems.

