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Building environment design — Indoor environment — Daylight opening design for sustainability principles in visual environment

Conception des bâtiments — Espace intérieur — Conception des prises du jour pour les principes de durabilité dans l'environnement visuel

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Foreword

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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 of 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 www.iso.org/iso/foreword.html.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 16813 provides general principles for the design of the indoor environment for buildings. The design process for the indoor visual environment is provided by ISO 16817 to ensure required visual comfort, good physiological effects of light and building energy performance and sustainability.

This document provides design team members with a design process for daylight openings under the umbrella of ISO 16813 and ISO 16817. Receiving daylight is a fundamental human need. It is essential to ensure favourable daylight environments in buildings. Daylight opening design is an indispensable element of building design. This document is targeted at habitable rooms in all buildings to ensure sufficient, quality daylight.

For this document, both windows and rooflights are deemed daylight openings. The size and position of the daylight openings affect the amount of daylight entering a room as well as the view from the daylight opening. An appropriate sizing of the daylight opening ensures a necessary level of daylight and an impression of spaciousness. However, large daylight openings can require more control of daylight in terms of visual and thermal environments. Qualities of daylight admitted through the daylight opening vary depending on the direction in which the daylight opening faces.

This document:

— provides a framework for taking into consideration various parameters and criteria in daylight opening design;

— is intended for use by design teams (architects and engineers), building clients, contractors, government officials and academics;

— is aimed at assisting these groups in designing daylight openings in the process of building design;

— incorporates sustainability considerations into the design of indoor visual environments.

Building environment design — Indoor environment — Daylight opening design for sustainability principles in visual environment

1 Scope

This document provides a design process for daylight openings in order to ensure the principle of sustainability in the indoor visual environment. The design process for daylight openings includes the consideration of:

— sunshine duration in the building interiors;

— daylight opening ratio to the wall area of a habitable room;

— daylight opening ratio to the floor area of a habitable room;

— appropriate levels of indoor daylight based on human visual needs and the extent of sunlight;

— daylight control systems in the building;

— thermal comfort, thermal gains and energy efficiency.

This document is applicable to building environment design for new buildings and the retrofit of existing 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 8995-1, *Lighting of work places — Part 1: Indoor*

ISO 16817:2017, *Building environment design — Indoor environment — Design process for the visual environment*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

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

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

3.1
commissioning
sequence of events that ensure the building and the *technical building systems* (3.16) are functioning in accordance with the design parameters for the building lifetime

[SOURCE: ISO 16813:2006, 3.7 modified — The word “HVAC” has been replaced with “technical building”.]

3.2
daylight
part of global solar radiation capable of causing a visual sensation

[SOURCE: CIE S 017/E:2011, 17-278]

3.3
daylight opening
area, glazed or unglazed, that is capable of admitting *daylight* (3.2) to an interior

Note 1 to entry: Basic architectural forms of the daylight opening are illustrated in Annex B.

[SOURCE: CIE S 017/E:2011, 17-284, modified — Note 1 to entry has been added.]

3.4
daylight opening ratio
daylight opening ratio to the floor area
daylight opening ratio to the wall area of a habitable room
ratio of the daylight opening area to the corresponding floor or wall area of a habitable room

Note 1 to entry: "Window-to-wall ratio (WWR)" is defined as "ratio of the fenestration area to the gross exterior wall area" in ISO 16818:2008, 3.249[2].

3.5
design team
group of people who are responsible for building design

Note 1 to entry: The design team can consist of an architect, an interior designer, a lighting designer, a landscape designer, engineers in electrical engineering, illuminating engineering, HVAC systems, structural engineering and construction management and other specialists.

3.6
direct solar radiation
part of extra-terrestrial solar radiation which, as a collimated beam, reaches the earth's surface after selective attenuation by the atmosphere

Note 1 to entry: The quantity measured is the direct solar irradiance, expressed in $W \cdot m^{-2}$.

[SOURCE: ISO 9846:1993, 3.6, modified — The last sentence in the original definition has been changed to Note 1 to entry.]

3.7
habitable room
room that is continuously used for living, working, meeting, amusement and other purposes similar thereto

[SOURCE: ISO 18523-2:2018, 3.1.7]

3.8
possible sunshine duration
possible sunshine duration at a particular location
sum of the time intervals within a given time period during which the sun is above the real horizon

Note 1 to entry: The possible sunshine duration can be obscured by mountains, buildings, trees, etc.

[SOURCE: CIE S 017/E:2011, 17-972, modified — The last sentence in the original definition has been changed to Note 1 to entry.]

3.9
relative sunshine duration
ratio of *sunshine duration* (3.14) to *possible sunshine duration* (3.8) within the same time period

Note 1 to entry: The unit is 1.

[SOURCE: CIE S 017/E:2011, 17-1086]

3.10
rooflight
skylight, US
daylight opening (3.3) in a flat roof or low-pitched roof, intended primarily for lighting and consisting of a frame and glazing

Note 1 to entry: In the US, there is a homograph for the term “skylight”. See 3.11.

[SOURCE: ISO 6707-1:2017, 3.3.3.13, modified — The words "construction for closing an" have been deleted and “daylight” has been added.]

3.11
roof window
skylight, US
daylight opening (3.3) in the plane of a pitched roof, which admits light and which can provide ventilation

Note 1 to entry: In the US, there is a homograph for the term “skylight”. See 3.10.

[SOURCE: ISO 6707-1:2017, 3.3.3.14, modified — The words "construction for closing an" have been deleted and “daylight” has been added.]

3.12
spaciousness
spatial largeness and extensiveness, especially inside a building

3.13
sunlight
part of *direct solar radiation* (3.6) capable of causing a visual sensation

[SOURCE: CIE S 017/E:2011, 17-1281]

3.14
sunshine duration
sum of time intervals within a given time period (hour, day, month, year) during which the irradiance from *direct solar radiation* (3.6) on a plane normal to the sun direction is equal to or greater than 120 $W \cdot m^{-2}$

[SOURCE: CIE S 017/E:2011, 17-1282]

3.15
sustainability
maintenance of ecosystem components and functions for future generations, to address economic efficiency, social issues and environmental preservation

[SOURCE: ISO 16813:2006, 3.27]

3.16
technical building system
technical equipment for heating, cooling, ventilation, humidification, dehumidification, domestic hot water, lighting, building automation and control and electricity production

Note 1 to entry: A technical building system can refer to one or to several building services (e.g., heating, cooling, lighting and domestic hot water).

Note 2 to entry: A technical building system is composed of different sub-systems.

Note 3 to entry: Electricity production can include cogeneration, wind power and photovoltaic systems.

[SOURCE: ISO 52000-1:2017, 3.3.13, modified — The word “lighting” has been added in Note 1 to entry.]

3.17
visual comfort
occupant satisfaction which the indoor visual environment, described in terms of illumination level, glare, visibility, reflection, quality view and psychological and physiological content with natural and artificial illumination

[SOURCE: ISO 16813:2006, 3.29, modified — The words "quality view" have been added.]

3.18
window
daylight opening (3.3) on a vertical or nearly vertical area of a room envelope

[SOURCE: CIE S 017/E:2011, 17-1436]

4 Fundamentals

4.1 General

Daylight opening design is a part of designing the indoor visual environment in the process of designing a building. It shall be appropriately included in the integrated design process provided by ISO 16817 in order to achieve the quality indoor visual environment. Daylight openings influence not only the visual environment but also the thermal, acoustical and air environments in buildings. An integrated multidisciplinary approach by a design team has important implications for daylight opening design. The integrated design process ensures an efficient and effective design to obtain the specified quality and performance level of safety, health, comfort and energy efficiency in buildings. ISO 16813 provides a flow diagram of the design process. The design process for daylight openings shall follow this process, as shown in Annex A. Daylight opening design shall be started at the initial stage of building design. Daylight can provide large quantities of light indoors, with great spectral quality and variability changing though the day and seasons. Windows provide a view and information about the outside and contribute to the psychological wellbeing of occupants. Windows, rooflights and roof windows can also provide exposure to sunlight indoors, which is important in e.g. dwellings, hospitals and nurseries. However, windows can give rise to glare. Careful consideration should be given to window screens, glazing materials and the reflectance of interior surfaces.

Exposure to sunlight is an important criterion because sufficient exposure to sunlight contributes to human health and a sense of wellbeing; but some rooms have to avoid receiving sunlight for their functionality. Besides, sunlight often causes glare directly or indirectly. It is of consequence in workplaces. Adequate sunlight controls should be provided to avoid visual discomfort as well as an overheating problem.

A certain level of the sunshine duration should be ensured in a habitable room for wellbeing[3,4]. Regional characteristics of direct solar radiation are expressed by the possible sunshine duration and the relative sunshine duration. In high-latitude regions, it is difficult to receive sufficient direct solar radiation in winter. In equatorial regions, south- and north-facing façades receive less direct solar radiation, whereas east- and west-facing façades receive more during a day. Direct solar radiation incident on the building exterior should be considered at the early stages of design. Incorrect decisions about the geometrical shape of the building can prevent the admission of sunlight into rooms.

The performance of daylight openings is influenced by site characteristics. Large obstructions can have an impact both on the amount of light reaching daylight openings and on the daylight distribution within rooms, and subsequently on the indoor visual environment. The building shall be planned so that building interiors will be illuminated by daylight in accordance with need for satisfactory performance of visual tasks. One or more habitable rooms should receive sunlight except where unavoidable circumstances are produced by the surrounding conditions of the site.

4.2 General principles of sustainability

ISO 16817 provides nine general principles of sustainability (NGPS) in designing the indoor visual environment following ISO 15392[5]. Daylight opening design shall follow these principles. The NGPS are:

— continual improvement;

— equity;

— global thinking;

— holistic approach;

— involvement of interested parties;

— long-term consideration;

— precaution and risk management;

— responsibility;

— transparency.

The NGPS are based on the concept of sustainable development that meets the needs of the present without compromising the ability of future generations to meet their own needs from economic, environmental and social aspects[5]. Sustainable development of buildings brings about the required performance and functionality with minimum adverse environmental impact. It includes consideration of all components of the building from a single product to technical building systems for the life cycle.

The continual improvement is recurring activity to enhance all aspects of sustainability. The equity encompasses balanced and objective consideration of intergenerational, interregional and intra-societal ethics. The global thinking encompasses consideration of regional and global consequences of acting locally. The holistic approach encompasses inclusion of all aspects of sustainability over the life cycle of the building. The involvement of interested parties encompasses consideration of contributions and requirements of interested parties relative to their respective areas of responsibility and the timing of their involvement. The long-term consideration encompasses short-, medium- and long-term implications in decision-making. The precaution and risk management encompass avoidance of risks and unfavourable impacts. The responsibility encompasses the moral responsibility for actions. The transparency encompasses presentation of the information in a manner that is open, comprehensive, understandable, and traceable with verifiable credibility.

The daylight opening and accompanying daylight control systems are important components of the building. ISO 16817 specifies that building designers should define goals based on the requirements, constraints and actual conditions, considering the owning and operating costs during the design stage. The design team should appropriately define goals for the daylight opening design.

4.3 Project information

ISO 16817 specifies that the available project information which influences the development of design concepts, together with constraints and all requirements, shall be documented at the beginning of a project. The project information also influences design concepts of daylight openings. A description of the intended use (and related requirements) of the building and end users' needs shall be included. The information on the local climate is fundamental to designing daylight openings as well as the building. When assumptions are made in lieu of necessary information related to the standards or regulations for the daylight opening design, these assumptions shall be documented.

4.4 Framework of generation and verification

Daylight opening design is a part of architectural design and building system design, which are goal-driven activities. In designing the building environment, the routes necessary to achieve the end result are not straightforward and shall 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, the design process involves the iteration of generation, verification and validation of the design decisions. Daylight opening design shall be included in the iterative design 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 on thermal, acoustic and visual comfort. The generation process is a sub-process where a design solution is found by synthesizing different requirements and constraints, while the verification process is another sub-process in which the design solution is rated against different design criteria. The expected performance of the daylight openings shall be achieved during the above processes. When the targets are not met, the design team shall determine the acceptability and act accordingly.

4.5 Framework of documentation at approval

The evaluation and approval processes shall be documented for the daylight opening design as well as the other factors in the project. 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 plans for maintenance of the daylight openings and the control systems shall be documented according to the expected service life of the building. Approval should be obtained at each design stage.

The documents issued during the design process for daylight openings shall cover the following questions:

— Is the daylight opening design in compliance with regulation and standard requirements?

— Is the daylight opening design for the quality visual environment feasible?

— Is the specified daylight opening design expected to satisfy the environmental, economic and social constraints and requirements?

— Is the daylight opening design capable of providing the performance required?

4.6 Harmonization of architectural and daylight opening design

Architectural design and the building system design influence the design and construction of the indoor visual environment. The daylight opening design is directly connected with the architectural design. The general principles of building environment design for visual comfort should support creative architectural design. The principles do not pre-define the order or precedence of individual tasks in both the architectural and daylight opening designs.

5 Design elements of daylight openings

5.1 General

In order to design a high-performance and high-quality visual environment, an integrated architectural approach is recommended. The daylight opening design shall be a part of this integrated approach that addresses the critical interactions among the building envelope (that admits heat and light), building interior and all light sources such as daylight (skylight and/or sunlight) and electric light. This approach also shares appropriate decisions across the owner and the design team throughout the design process.

ISO 16817 defines the design process to ensure the quality of the indoor visual environment. In designing daylight openings, the following elements should be taken into consideration at each stage of the design process:

— daylight opening ratio to the wall area of a habitable room;

— daylight opening ratio to the floor area of a habitable room;

— levels of indoor daylight based on human visual needs and the extent of sunlight;

— quality of views to exterior;

— control of glare caused by daylight;

— daylight control systems in the building.

Designing daylight openings does not consider daylight alone. Other visual, thermal, acoustic, privacy and security issues need to be addressed. During the design process, the glare control and thermal comfort especially should be considered along with the above elements. Achieving a balance between luminous and thermal environments is of primary importance in sustainable building design. Thermally, glazed openings are a sensitive point in the building envelope. They admit more heat in summer and lose more heat in winter than the solid part. Sunlight penetration permits solar heat gain. It can cause preferable heating effects or unwanted overheated spots even in winter depending on circumstances.

Designing daylight openings requires local and vernacular considerations. Local climates and related outdoor daylight conditions are fundamental existing conditions.

In very-high-latitude regions with very low solar altitudes in winter, the design issues related to sunlight should be covered in the relevant national standards. The design team shall carefully consider the glare problem from the sun shining close to the horizontal. The sunlight from the low altitudes penetrates deep inside the room. It requires blinds or curtains on south-facing windows in the Northern Hemisphere or for north-facing windows in the Southern Hemisphere to be closed all day long. However, the solar heat gain is inevitably reduced.

As to the heating effect, in cold winters, people near windows facing south in the Northern Hemisphere or facing north in the Southern Hemisphere could feel the excessive heat from the sunlight depending on situations, whereas those near windows facing the opposite direction feel cold in the same room. It would be an operational issue for sunlight control or heating. Overheating is likely to occur in the afternoon depending on the window orientation in winter even in middle-latitude regions. Perimeter zones with glazed curtain walls are sometimes planned as a circulation or meeting space in large open offices.

Another indirect consequence of the difficult heating/cooling design constraints is the metallic layers used to create a selective barrier to IR-transmission through the window glazing. However, special metallic films of Low-E double glazing, having a low surface resistance, are liable to reflect radio waves including WiFi signals and obstruct cellular phones and wireless network communication. Attention is required when this kind of glazing is used together with exterior and/or insulating materials that transmit less radio waves. The design team should keep this in mind in the use of the IR-selective glazing.

Glazing materials affect the indoor environment. They are available in a wide range of thickness, in clear or tinted form, in single or multiple glazed configurations. The most important parameters for the performance of glass types are visible transmittance, thermal transmittance, solar heat gain coefficient and emissivity. In general, the glazing specification required is high visible transmittance and low thermal transmittance. The solar heat gain increases cooling loads but reduces heating loads. Light reflectance to the outside should be evaluated when considering the aesthetics of the building and the risk of glare reflected to the surrounding space and to the other buildings. Concave glass façades shall be carefully designed, as the reflected sunlight would be focused somewhere and cause an overheating problem.

5.2 Matrix of aspects of daylight opening design

The design of daylight openings has a direct impact on the sustainability of a building. Since their role is more than just lighting in the building, the sustainability requirements shall be addressed from various aspects of daylight opening design at each stage of building design. Table C.1 in Annex C shows links between the aspects of daylight opening design and sustainability requirements enumerated in ISO 16817. Table D.1 in Annex D shows output required to satisfy daylight opening design.

5.3 Daylight opening ratio to the wall area

The daylight opening ratio to the wall area should be determined in the project information. It is related to the visual comfort, thermal comfort, acoustics comfort, air quality, energy performance and sustainability of the building. The daylight and thermal conditions are often in conflict with one another. However, the minimum daylight opening ratio should be secured for the health management of the building environment. It can be subject to national or regional regulations.

5.4 Daylight opening ratio to the floor area

The daylight opening ratio to the floor area should be determined in the project information. It is related to the visual comfort, thermal comfort, acoustics comfort, air quality, energy performance and sustainability of the building. The daylight and thermal conditions are often in conflict with one another. However, the minimum daylight opening ratio should be secured for the health management of the building environment. It can be subject to national or regional regulations.

It should be noted that the minimum daylight opening ratio to the floor area alone is not enough to get an acceptable indoor visual environment, as the minimum daylight opening ratio means that a small room should have only a small daylight opening. The quality of views to exterior is indispensable even for the acceptable indoor visual environment.

5.5 Levels of indoor daylight and the extent of sunlight

The amount of outdoor daylight varies throughout the day depending on sky conditions, and the indoor daylight availability varies accordingly. The amount of daylight in interiors first depends on the position and size of the daylight openings, obstructions, and skylight and sunlight conditions. The level of indoor daylight shall follow the illumination levels at the task area and its surroundings in indoor workplaces specified in ISO 8995-1.

The extent of sunlight into the habitable rooms should be determined in the project information. Sunlight is undesirable from the viewpoint of glare, excessive luminance contrast and overheating. However, it can create pleasing patterns of light and shadows on surfaces in interiors and make the space vivid and cheerful. Exposure to sunlight in the morning is essential to maintain good circadian rhythms.

The extent of sunlight in a room depends on that received by the façade. Site layout is an important factor affecting sunlight onto façades. In an urban environment, the building is often designed to completely occupy the site. If the building is in a densely-built urban area, the amount of sunlight can be limited due to other buildings blocking the sunlight.

It is the duration of sunlight in an interior, rather than its intensity or the size of the sunny patch, which correlates best to the occupants' satisfaction[3]. Actual sunshine duration can be expected by the relative sunshine duration. The possible sunshine duration at equinox (vernal or autumnal) should be included in the project information.

For a daylighting purpose, daylight hours are referenced as the basis of daylight availability[6]. Daylight hours are the total number of hours between sunrise and sunset.

5.6 Quality of views to exterior

The views to exterior are defined as the views out of windows and/or rooflights. They should be considered in the project information. It is essential to get openness and quality views to ensure occupants' visual comfort and connection to the exterior through daylight openings. However, some spaces need to avoid visual transparency between the inside and outside due to their use. In that case, looking in a room from the outside is often avoided by some sort of interrupting means.

A view to the exterior provides not only an outdoor scene but also information on the outside, for example, the weather and time. It provides a key to finding a way inside the building. Ideally daylight openings provide a sky view and a view of the surrounding scenery. However, the quality of a view

is determined by the site conditions. The neighbouring outdoor environment shall be analysed at the stage of project definition. Views to the exterior are influenced by the climate. In regions with snowfall, snow covering the windows and rooflights reduces the view to the exterior. Even a limited view to the exterior can be valuable under these circumstances. If an external view cannot be provided, an internal view, for example, into an atrium can substitute for the external view to some extent[3].

5.7 Daylight control systems in the building

The larger the daylight opening is, the more important glazing selection and shading effectiveness are to control glare and heat gain by users. The requirements for the daylight control systems should be determined in the project information.

In high-latitude regions, the shading control shall be easy to adjust on a daily basis, or have automatic adjustment, so that it provides both shading sunlight from low altitudes and a view to the exterior. The shading needs to be adjusted according to the sun movement during the day. Alternatively, for example, open-plan offices need to have multiple shading elements so that both sun shading and a line of sight can be provided simultaneously. Ideally, the shading would be individual for every worker.

6 Design process of daylight openings

6.1 General

The design team is responsible for addressing human and technical issues on the project. Designing daylight openings involves balancing benefits and disadvantages in the indoor environment and energy performance. One is the need to access sufficient skylight and sunlight as well as good views through the daylight openings, and the other is the need to control its adverse or unwanted effects. The design team need to work together to achieve this balance. The daylight opening design dominates the building design including the architectural style, structure and materials. Though the structure of the design team depends on the scale of projects, an integrated multidisciplinary approach shall be adopted throughout the design process by:

— identifying the necessary professional skills needed;

— sharing information on their tasks and issues;

— facilitating integrated working.

6.2 Stage I — Formulation of project definition

6.2.1 Project definition

The project definition process is defined in ISO 16817. It is the basis to make decisions on the daylight opening design. The design team shall consider the following aspects in the project definition:

— description of the intended use (and related requirements) of the construction works and end-users needs;

— provision of safe and resistant construction works during exceptional events;

— provision of accessibility for all;

— functional flexibility;

— security;

— contribution to social equity and improvement in the social climate;

— neighbouring outdoor environment;

— number and type of spaces (serviceability);

— constraints (see ISO 16817:2017, Tables 1, 2 and 3);

— respect of human values;

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

— identification and involvement of other interested parties;

— satisfaction of users and other affected parties.

6.2.2 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 can be nothing more than an oral presentation of the facts as defined by the design team. For other projects, this can be a brief report that includes programmatic statements and a very preliminary criteria statement or a complete design statement.

6.2.3 Evaluation I

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

6.2.4 Output — Approval of document I

Once the evaluation I process has been successfully completed, an approval of document I shall be issued as the second output in order to be validated. The approval of document I should indicate how it was validated 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.

6.2.5 Iteration

If document I is 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 the iteration started with the revised requirements.

6.3 Stage II – Schematic design

6.3.1 General

Upon the completion of the programming phase, the design team is prepared to undertake schematic design: developing preliminary ideas or schemes for daylight openings in the project. Schematic design typically results in an understanding and agreement among the design team members about visual environment criteria, the penetration of skylight and sunlight, and the visual relationship between the inside and the outside. The architectural schematic design including daylight openings shall follow an iterative process.

6.3.2 Input

Since document I becomes available at stage I, the design team is in a position to develop a daylight opening scheme. The design team shall consider the site characteristics and the sunshine condition for the building in order to satisfy the requirements. Main concerns at this stage are the penetration of

daylight and the visual relationship between the inside and outside of the building. Site characteristics shall be defined.

6.3.3 Output

At this stage, the design team shall write a document to inform the client on how the schematic design satisfies the various requirements identified in the project definition (with respect to the human values, functional flexibility, etc.). A visual environment scheme is available for all areas or spaces of the project at this stage. Consequently, a complementary daylight-opening scheme shall be developed. However, the visual environment scheme at this stage is an overview or a road map of the targeted indoor visual environment. Details are not yet an issue and should not be addressed during the schematic design.

The output of the daylight-opening scheme shall describe the penetration of daylight and the visual relationship between the inside and outside of the building. At this stage, the design team shall provide a site plan with orientation, dimensions, a building shape and gross simulation that includes calculation. The calculation should include other factors such as surrounding buildings and/or obstructions, and topography that affect the daylight design.

6.3.4 Evaluation II

The consistency of the framework described in document II shall be verified with reference to the design criteria for the daylight openings, expected performance and document I. The appropriateness of the program and the diagrams shall be verified. The major concern is whether the daylight opening design is headed in the right direction in the context of the targeted visual environment design.

At this stage, a rough initial cost shall be evaluated in estimating the total cost of the building. The schematic design shall be evaluated in terms of the cost estimate.

6.3.5 Approval of document II

Once feedback is received and addressed, the design scheme for the daylight openings shall be finalized. The preliminary architectural plan shall include the design scheme for the daylight openings. After the design scheme is advanced for client review and approved, the stage is set for the detailed design stage.

6.4 Stage III – Detailed design

6.4.1 General

Stage III is the main phase of the visual environment design process. A detailed design of the daylight openings and daylight control systems shall be performed at this stage. The detailed design shall define the particular specifications of the building components. All system designs shall be included in the stage III. Detailed predictions and analyses through computer simulations and/or measurements with physical models should be performed during this stage.

6.4.2 Input

Document II, that is to be approved by the design team and clients, includes preliminary architectural plans, design descriptions, lighting plans and specifications illustrating the scope and strategies to create the required visual environment.

The design team shall take into consideration:

— value over time;

— adaptability for different uses;

— energy resources consumption;

— reduction of greenhouse gas (GHG) emissions;

— use of resources (material);

— recovery of materials for reuse and recycling potential.

6.4.3 Output – Document IIIa

Document IIIa is the explicit description of the daylighting systems. It consists of the drawing and lighting specification, including the relationship with the building design. At this stage, the output shall contain the architectural design including the daylighting design and the design of the lighting control systems.

In designing daylighting, sunlight is carefully controlled to avoid glare. It is recommended to redirect sunlight to the ceiling. Use of skylights and externally reflected diffused light should be maximized for task illumination. Sunlight is controlled by building orientation and architectural devices such as overhangs, awnings, light shelves, exterior and interior louvers and baffles, solar shades and dynamic glasses. Skylights should be assessed with typical sky conditions at the site. Skylights are controlled by the size and position of daylight openings and glass transmittance. Reflected diffused light is more consistent than the direct component and is less significant than sunlight and skylight. Nevertheless, attention should be paid when the reflectance of the relevant surfaces is high.

At this stage, the design team shall provide the following documents:

— an impact evaluation of alternative designs;

— a justification of the daylight opening design from a long-term perspective;

— a justification of the daylight opening design for different uses of the rooms;

— calculations and/or simulations;

— a list of reused or recycled daylight control systems.

At this stage, the design team shall write a document to inform the client of how the detailed design satisfies the various requirements identified in the project definition (with respect to the human values, functional flexibility, etc.).

6.4.4 Analysis

The analysis of the daylight openings shall be conducted during the detailed design stage in terms of the coordination with the building design, the requirements for the visual environment and the energy performance of the building. The design team shall quantitatively and qualitatively evaluate the certainty of the following elements:

— daylight opening ratio to the wall area of a habitable room;

— daylight opening ratio to the floor area of a habitable room;

— levels of indoor daylight and the extent of sunlight;

— quality of views to the exterior;

— daylight control systems in the building.

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

6.4.5 Output – Document IIIb

Document IIIb is the explicit complementary description of the daylight control systems. The plan of the daylight control systems indicates the types and locations of the control devices for all daylight

openings within the scope of work. The system specifications and schematic circuit diagrams are also shown in plans.

Drawings should show mounting details, building sections and elevations, and supplemental information related to the indoor visual environment. Document IIIb includes catalogue numbers of the control devices and their specifications to outline general requirements for the daylight control systems.

6.4.6 Evaluation III

Once a detailed design has been established, feedback from the entire design team is necessary in order to evaluate it with respect to the requirements of all aspects of design. The design team shall evaluate the distribution of daylight on the room surfaces and the specifications of the daylight control systems.

The illuminance levels obtained from the analysis procedure shall be closely evaluated against the required levels. In addition, the evaluation should be done on the contribution of the daylight openings to the energy efficiency of the electric lighting system. For a qualitative evaluation, computer-rendered coloured images can be used for judgement by the design team, clients and users.

At this stage, initial and operating costs shall be roughly estimated. The current detailed design shall be evaluated from a standpoint of the budget. It shall be evaluated that the estimated costs are kept within the budget. If the estimated costs are unacceptable, the design detail shall be reconsidered in an attempt to achieve the cost acceptability. Changes to the performance criteria shall be considered only when changes to design details cannot achieve the cost acceptability or the benefits cannot justify the extra costs.

6.4.7 Approval of documents IIIa and IIIb

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

6.4.8 Iteration into detail design

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

If documents llla and lllb show that the quality and performance described in document II are not provided by the building design, the current design shall be modified without changing the overall design concept.

6.5 Stage IV – Final design

6.5.1 General

Stage IV is the final phase of the daylight opening design process where construction documents are generated. The final construction documents of the daylight opening design shall be delivered to contractors. The construction documents shall include final design drawings, specifications of glazing and the daylight control systems. Shadow diagrams and simulations on daylight levels should be attached to the final construction documents as reference documents. The final design drawings shall include detailed plans, sections and elevations with accurate dimensions. Those drawings shall show the exact location and dimensions of the daylight openings, installing details of the sun-shading devices such as curtains, blinds and screens. The construction documents shall also include written specifications outlining the expected duties of the contractor and, if necessary, indicating specific hardware components of the daylighting and/or control systems. Applicable industry standards and code references shall be cited in the specifications. In this phase, a detailed commissioning plan shall be developed. Cost estimations shall also be conducted.

Daylighting specifications are written documents containing specific and detailed descriptions of the work to be completed with characteristics given by manufacturers. Since the specifications, along with

drawings, are legal documents, the design team should prepare them very carefully and review them. They are released to the contractors to be used as a resource during bidding, shop drawing review and construction processes.

6.5.2 Commissioning documents

A commissioning plan shall be developed to ensure that the daylighting systems properly function after the installation and before the occupancy of the building. The commissioning plan shall involve systematically testing all daylight controls and adjustable shading devices in the building to ensure they provide the specified performance. Commissioning shall be planned after the interior is completed and the furniture is in the building, budgeted and implemented as part of the design and construction process.

The commissioning plan shall cover the daylighting systems in conjunction with electric lighting systems and other sub-systems to:

— clarify ability in operation and maintenance;

— ensure detailed commissioning programs for services and systems;

— ensure that design intentions and objectives, and operation and maintenance requirements are understood by stakeholders;

— ensure that the operation and maintenance staff (internal and/or external) have, as appropriate, skills necessary to meet the requirements and achieve the objectives; if needed, by developing a training plan;

— provide a user-friendly document such as a manual and logbook for operation and maintenance processes, procedures and reporting; disseminate it to the operation and maintenance staff;

— ensure continual training of the operation and maintenance staff especially after a control system software update.

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

— verify all the sensors are properly placed;

— verify each piece of the equipment is correctly controlled;

— test interactions between equipment pieces;

— test system-wide operation under different anticipated scenarios;

— verify interactions and bi-directional communication with base building control systems.

6.5.3 Cost estimation

Cost estimation shall be done for construction and installation of the daylight openings and daylight control systems, their operation and maintenance. The estimates shall be documented and evaluated for acceptability in terms of overall project requirements.

6.5.4 Output: the final documents

The final documents from this phase shall include detailed drawings of the daylight opening design, glazing specifications, specifications of the daylight control systems, simulations, operating manuals, and commissioning and maintenance documents including the maintenance schedule, and estimated costs for installation, operation and maintenance. The design team can include a document to conduct post-occupancy evaluations (POEs) after the building is occupied.

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

At this stage the design team shall write a document to inform the client on how the final design satisfies the various requirements identified in the project definition (with respect to the human values, functional flexibility, etc.).

Annex A
(normative)

Flow diagram of the design process

ISO 16813 provides a flow diagram of the design process for achieving the quality and heathy indoor environment and sustainability of the building. See Figure A.1.

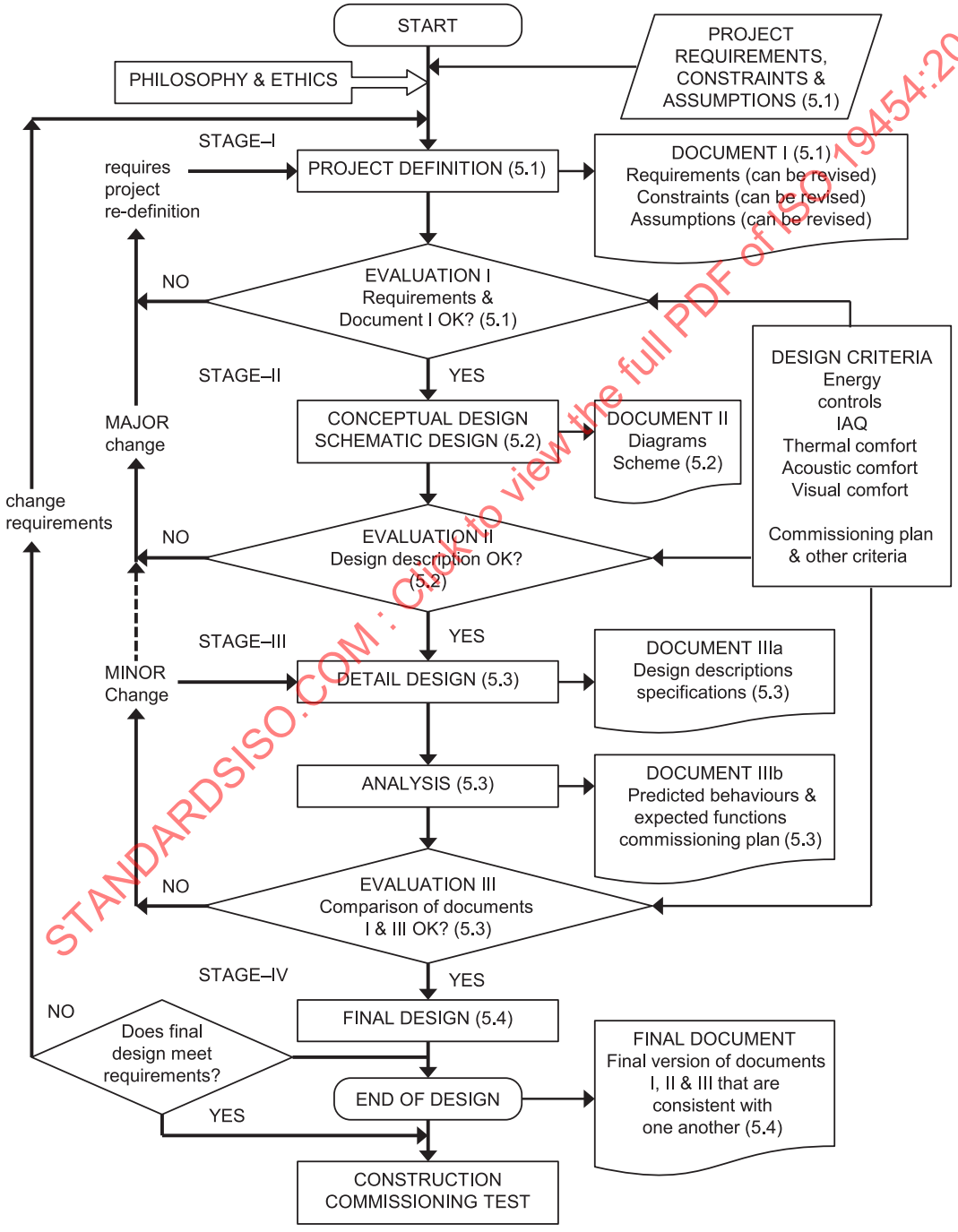


Figure A.1 — Flow diagram of the design process from ISO 16813

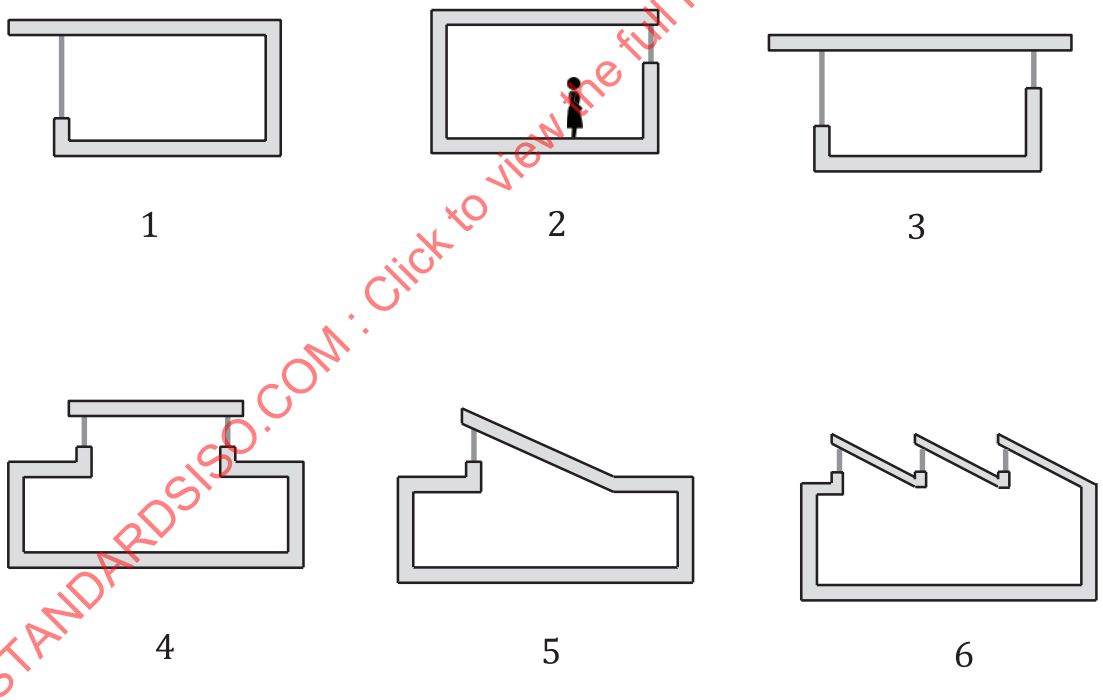
Annex B
(informative)

Basic architectural forms of the daylight opening

B.1 Side lighting

Side lighting has various architectural forms[7-9]. Windows permit the lateral penetration of daylight and solar radiation. A high window tends to permit deep penetration of daylight in the room. Overhangs or eaves can be used to reduce sunlight penetration in latitude where the sun is high in the sky[7]. The daylight distribution by unilateral lighting is non-uniform from the window wall to the inner wall. Bilateral daylighting balances the admission of daylight.

A roof monitor is a raised section of the roof, including the ridge, with vertical openings. Clerestory is a vertical or titled opening constructed on the roof. It can help to overcome the limited daylight penetration by the unilateral window. A sawtooth roof consists of a series of successive parallel slopes with vertical or tilted linear openings, which often face north in the Northern Hemisphere or south in the Southern Hemisphere. A scoop-shaped roof can be used in place of the slanted roof. See Figure B.1[7].



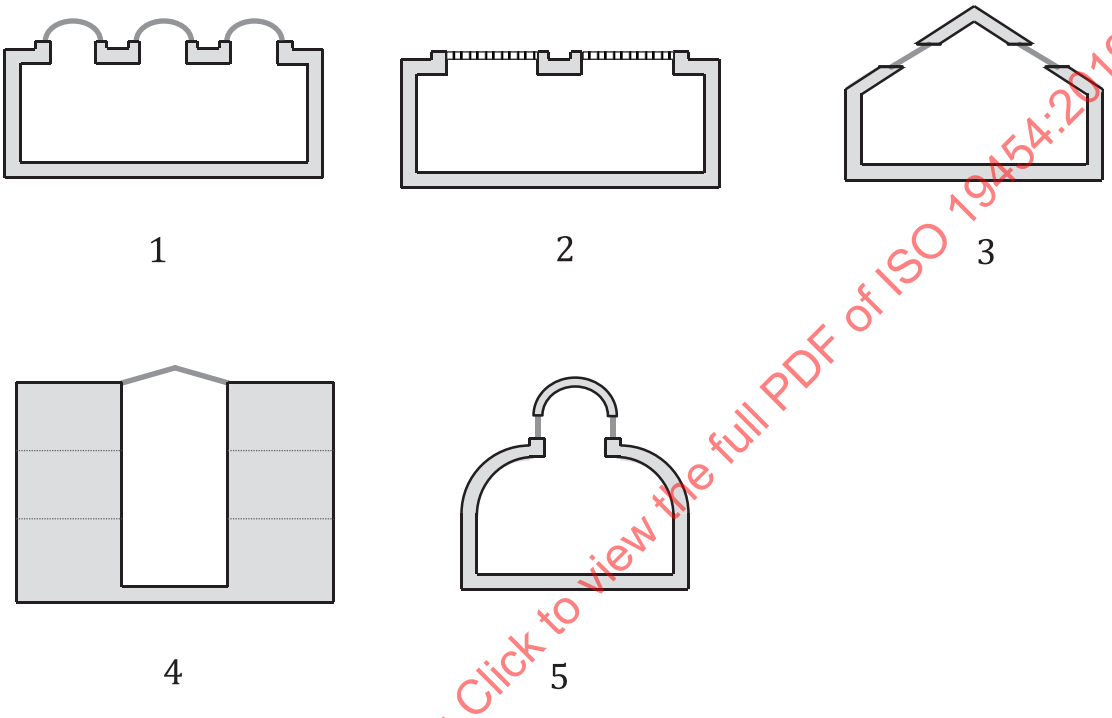
Key

1 unilateral lighting
2 unilateral lighting (high sidelight)
3 bilateral lighting
4 roof monitor lighting
5 clerestory lighting
6 sawtooth lighting

Figure B.1 — Examples of side lighting

B.2 Top lighting

Top lighting has various architectural forms[7-10]. Rooflights (or skylights) permit the zenithal penetration of daylight and solar radiation. A rooflight is an opening situated in a horizontal or tilted roof. There are many variations in the design of rooflights and a variety of products. Operable rooflights can provide ventilation and cooling by discharging air warmed indoors. An atrium is a space enclosed laterally by the walls of a building and covered with transparent or translucent material. A lantern is an elevated part of the roof, often at the highest point. It has vertical openings but can be included in top lighting. Vertical light ducts which have a highly-reflective mirror on the inner surface are also included in top lighting. See Figure B.2[7].



Key

1 rooflight/skylight
2 rooflight/skylight
3 roof window
4 atrium
5 lantern lighting

Figure B.2 — Examples of top lighting

Annex C
(informative)

Matrix of aspects of daylight opening design

Table C.1 shows aspects and viewpoints in daylight opening design to address the considerations enumerated in ISO 16817.

Table C.1 — Aspects of daylight opening design

			extent of sunlight	views to exterior	daylight opening ratio to the wall/ floor area	appropriate levels of indoor daylight	daylight control systems
Design requirements	Stage 1: Project definition	intended use	building and room type	building and room type	building and room type	building and room type	building and room type
		provision of safe and resistant building during exceptional events	—	—	size of daylight openings and glazing material	—	control systems
		functional flexibility	long-term vision	long-term vision	long-term vision	long-term vision	long-term vision
		security	glazing properties and locking systems	glazing properties and locking systems	glazing properties and locking systems	glazing properties and locking systems	—
		neighbouring outdoor environment	—	obstructions outside the building	obstructions outside the building	obstructions outside the building	obstructions outside the building
		constraints (ISO 16817:2017, Tables 1, 2 and 3)	location on earth, site and regional characteristics	site characteristics	site characteristics	site characteristics	energy use and costs
		respect of human values	health and wellbeing	openness, visual comfort and wellbeing	sense of daylight sufficiency	sense of daylight sufficiency and wellbeing	visual and thermal comfort
		identification, characterisation and involvement of the future end-users and their needs	long-term vision	long-term vision	long-term vision	long-term vision	long-term vision
		satisfaction of users and other affected parties	health and wellbeing	openness, visual comfort and wellbeing	sense of daylight sufficiency	sense of daylight sufficiency and wellbeing	visual and thermal comfort

Table C.1 *(continued)*

			extent of sunlight	**views to exterior**	**daylight opening ratio to the wall/ floor area**	**appropriate levels of indoor daylight**	**daylight control systems**
Design requirements	Stage 2: Schematic design	penetration of daylight	orientation of the daylight opening and glazing properties	glazing properties	position and size of the daylight opening	position, size and number of the daylight opening	size and number of the daylight opening
		visual relationship between the inside and the outside	—	glazing properties	—	—	glazing properties and shading systems
	Stage 3: Detailed design	value over time	—	—	position and size of the daylight opening and glazing properties	position, size and number of the daylight opening and glazing properties	glazing properties and shading systems
		adaptability for different users	—	glazing properties	position and size of the daylight opening and glazing properties	position, size and number of the daylight opening and glazing properties	glazing properties and shading systems
		energy resources consumption	—		position and size of the daylight opening and glazing properties	position, size and number of the daylight opening and glazing properties	glazing properties and shading systems
		reduction of green-house gas emissions	—	—	position and size of the daylight opening and glazing properties	position, size and number of the daylight opening and glazing properties	glazing properties and shading systems
		use of resources (materials)	—	—	—	—	shading systems
		recovery of materials for reuse and recycling potential	—	—	—	—	shading systems (retrofit)