Chapter 9: Commissioning of lighting systems

Topics covered

9 Commissioning of lighting systems

9.1 Definition of Commissioning

The demands of building users regarding the built environment are growing. We all want a comfortable and healthy indoor environment but excessive use of natural resources and pollution of outdoor environment we do not accept any more. The energy consumption and the energy costs should indeed be kept on a low level. The heating, ventilation and air conditioning (HVAC) industry seeks solutions to fulfil these higher requirements. Many new products and systems are developed such as high efficiency generation systems using renewable energy sources, low energy cooling systems, natural ventilation systems and integrated control systems. We are clearly leaving the time of low efficiency stand alone products and entering the period of high efficiency integrated systems.

Moving from simple products to large systems enables us to develop more efficient and flexible solutions, but leads to a higher level of complexity. Complexity increases for the building owner, who has to define the Owner's Project Requirements (OPR) in greater detail. It also increases for the designer who has to design and define a full system on the basis of a growing number of attractive components. Complexity increases for the installer who has to install large systems which are all different, often innovative and have complex control and complex interactions. Complexity increases for the users who have access to more and more choices for the operation of the building.

The management of this complexity requires new approaches, new skills and new tools. Most of these were not available 20 years ago and are not yet taught at school. Commissioning is one of the new approaches to manage the complexity of today's building and HVAC systems.

Commissioning

Commissioning is done for the number of reasons: clarifying building system performance requirements set by the owner, auditing different judgments and actions by the commissioning related parties in order to realize the performance, writing necessary and sufficient documentation, and verifying that the system enables proper operation and maintenance through functional performance testing. Commissioning should be applied through the whole life cycle of the building. In the coming years, commissioning will probably develop for three main reasons:

- Energy and environment related reasons: Global warming has increased the pressure to reduce energy use in buildings.
- Business related reasons: Many companies are developing new services to diversify their activities in the building and energy industries. They see the commissioning as a way to develop new business for the benefit of their customers.
- Technological reasons: Building automation systems are now standard in new buildings and are being installed in many older ones. These systems automatically collect building and plant operating data and offer possibilities for innovative commissioning services.

The primary obstacles that impede the adoption of commissioning as a routine process for all buildings are clearly lack of awareness, lack of time, and too high costs. Hence, efforts for improvement should consider how new tools, methods and organizations can increase the awareness of commissioning, decrease the cost and demonstrate the benefits obtained by performing commissioning.

9.2 Definition of the Commissioning Process

Commissioning is a quality-oriented process for achieving, verifying, and documenting whether the performance of a building's systems and assemblies meet defined objectives and criteria.

Commissioning is too often viewed as a task performed to check operational performance after a building is constructed and before it is handed over to the building owner. A broader view was clearly favoured, which starts at the predesign phase, goes through the construction process, and continues during operation. This broader view aims at bridging the gaps among four different visions: the expectations of the building owner, the project of the designer, the assembled system of the contractor, and the running system of the operator. Bridging these gaps will consist in:

- clarifying the expectation of the building owner to obtain the owner's project requirements so that the owner and designer understand each other and are in agreement
- translating the project of the designer to specifications which can be understood and realized and verified by the contractor
- applying functional performance testing procedures which will enable the contractor the building owner and the designer to verify that the system is clearly operating as expected
- producing system manuals which will enable the operator to take the best profit of the ideas of the designers and of the system realized by the contractor to fulfill owner requirements
- producing reports at regular interval which will enable the operator and the building owner to check that the operation continues to fulfill these requirements

In this broader view, the Commissioning process begins at project inception during the predesign phase and continues for the life of the facility through the occupancy and operation phase. This global view aims at providing a uniform, integrated, and consistent approach for delivering and operating facilities that meet the on-going requirements of the owner. This broad view could appear to many users as a dream which could be realized in a few projects but which is too far from their day to day practice to be applicable to their projects. In practice, one can differentiate four types of commissioning which are represented in Figure 9-1:

- Initial Commissioning (I-Cx) is a systematic process applied to production of a new building and/or an installation of new systems.
- Retro-Commissioning (Retro-Cx) is the first time commissioning which is implemented in an existing building in which a documented commissioning process was not previously implemented.
- Re-Commissioning (Re-Cx) is a commissioning process implemented after I-Cx or Retro-Cx when the owner hopes to verify, improve and document the performance of building systems.
- On-Going Commissioning (On-Going Cx) is a commissioning process conducted continually for the purposes of maintaining, improving and optimizing the performance of building systems after I-Cx or Retro-Cx.

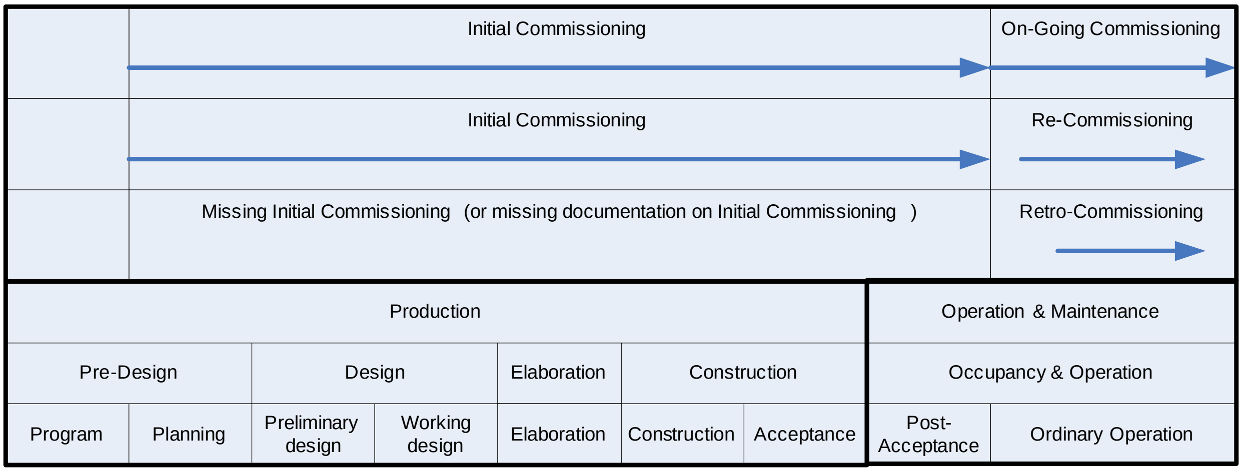

Figure 9-1. *The 4 different types of commissioning.*

The building process from design to operation is described in relation to the HVAC commissioning activities.

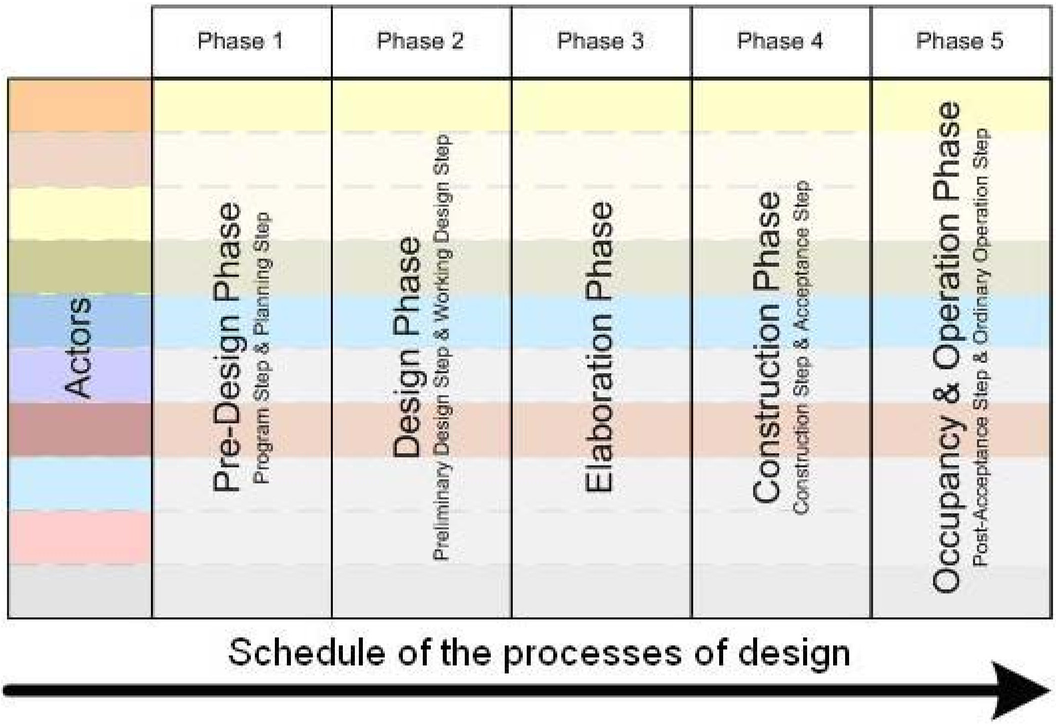

Figure 9-2. *Different building processes.*

Pre-Design Phase

Pre-Design Phase is the first phase of the I-Cx process, divided into two steps, namely:

- Program Step
- Planning Step

Program Step

The Owner's Program (OP) is established and the owner generates request for proposal and solicits a Cx-Authority (CA). At this stage, the owner can ask for inside and/or outside professionals for advice on technology, finance, business and construction.

Planning Step

The appointment of the CA typically defines the beginning of the planning step. The CA consults the construction manager, facility manager, financial advisor, operation and maintenance staff, occupant, etc., to identify the systems targeted for Commissioning and documents. In addition, the CA will assist the owner and consultants in estimating costs for design, construction, Testing Adjusting & Balancing (TAB) and investigate the necessary regulations related to the Commissioning. The scope of the work varies widely depending on the project size and owner's requirements for Commissioning. But in general, for a successful Cx Process, the CA develops a commissioning plan and with the owner formulates the design requirements. The design requirement in conjunction with the owner's requirement is used to generate the Owner's Project Requirement (OPR). The OPR allows a design professional to propose a firm design. Consequently, an request for proposal is generated and used to select a design professional for the project.

Design Phase

Design phase begins with drafting schematic planning documents and ends with completion of design documents and their handover to the owner and is divided into two steps, namely:

— Preliminary Design Step
— Working Design Step

Preliminary Design Step

The preliminary design step begins with schematic planning documents and ends with the submission of the preliminary design documents. The CA verifies that these documents are appropriate and clarifies the procedure and schedule of Commissioning. The CA coordinates the commissioning plan with the design intent so that the design professional can state the commissioning specification in the design documents.

Working Design Step

The final design documents are developed. The design professional updates the draft design intent document in the preliminary design documents and completes the final design documents. The CA audits these documents for completeness. The design is the responsibility of the design professional. Inconsistencies with the OPR, however, should be highlighted to the owner by the CA.

Elaboration Phase

The elaboration phase is the transitional phase between completion of design and commencement of construction. In this period, the completion of the construction documents, bid submission, bid assessment and selection of the contractor for the construction is carried out. The CA helps to coordinate the commissioning related parties.

Construction Phase

Includes construction, testing adjusting & balancing, Functional Performance Testing (FPT) and acceptance, under the guidance of the CA and is described in two steps:

— Construction Step
— Acceptance Step

Construction Step

Shop drawings are created from the design documents. Work is installed and testing adjusting & balancing is carried out. The CA conveys changes of OPR to the commissioning related parties or proposes design changes to ensure performance is achieved. The CA audits performance of the construction supervision and control, and supervises the TAB work confirming the maintainability of building systems with the owner.

Acceptance Step

The CA verifies the TAB work, the correctness of the as-built records and determines from FPT results whether the operations of the equipment and systems meet the OPR. Deficiencies are addressed by the appropriate party. The CA plans and manages the training program.

Occupancy & Operation Phase

The occupancy and operation phase takes place after handover when the building systems are operating acceptably. Some seasonal FPT will still be required with certain systems. There are two steps:

- Post-Acceptance Step
- Ordinary Operation Step

Post-Acceptance Step

The post-acceptance step applies to building systems in which the performance is seasonally changed and the design requirement demands confirmation of the annual performance (HVAC systems). This is the final step of the I-Cx process. The role of the CA in this step is to identify the seasonal system performance. This might include (for HVAC systems) determining the system performance for the peak-cooling season, the peak heating season, and the intermediate season when cooling and heating modes are both required. FPT is used in conjunction with the BEMS after faults identified in the acceptance step have been rectified. The term of the post-acceptance step mostly overlaps with the warranty term of the construction and the seasonal FPT mentioned above is considered to be requested in the range of the construction.

Ordinary Operation Step

In the ordinary operation step, the evaluation work for the Re-Cx and/or On-Going Cx to identify the unresolved issues, desired changes, weaknesses identified, desirable improvements identified during Commissioning, warranty action items, etc., may be addressed. The repeated Re-Cx could correct faults and the evolution to the On-Going Cx may maintain the building systems in optimal condition through the life of the building.

9.3 The commissioning plan: A tool to structure the commissioning process

Whatever organization approach is chosen, the key challenge to commission a building or system is to follow a well managed process. A central document for that purpose is the Commissioning Plan which defines the actions to be performed.

The Commissioning Plan is the key tool that gives the different players an understanding of what is meant by commissioning on a specific project, what amount of effort and money will be required and how it will be managed. The global content of this Commissioning Plan will be defined at the beginning of the project and will be refined all along the project.

Three types of tools were used within the Annex to support the definition and application of the Commissioning Plan. The following table gives an overview of these three types of tools:

Table 9-1. *Tools used in commissioning plans.*

Tool	Description	Level of detail
Standard Models of Commissioning plans (SMCxP)	A typical description of commissioning actions during a project. To be used as a guideline to define commissioning plan for a given project.	Medium
Checklists	Medium level of definition of a commissioning plan is specific to a given type of HVAC system.	low
Matrix for Quality Control (QMC)	An extensive tool for the management of the quality of the whole construction project. Includes commissioning plan as well as other elements in a very structured way.	high

9.3.1 Standard model of commissioning plans

These standard models include typical lists of tasks with a description of the content of each task. They can be used as a basis to define customized Commissioning Plans adapted to a given project. Five standards models of Commissioning Plans are defined. The appropriate model can be selected by a risk evaluation which takes into account building size, HVAC system complexity and the accepted risk level.

Building size

The risk of malfunctions increases when one moves from small heated buildings to large air conditioned buildings.

HVAC system complexity

HVAC packaged units designed to perform multiple functions to meet specifications which have been selected for a given building. Distributed systems, such has hydronic heating system or centralized air conditioning systems, are connected through air or water networks to constitute unique systems. The risk of poor design and installation is clearly higher with distributed systems. Therefore, they require more intensive commissioning.

The accepted risk level

The accepted risk level depends on:

- The building owner and operator strategy: When the future user of the building is involved in the project from the beginning, the approach chosen to look at future operation of the building is often much more detailed. So, the effort put in commissioning can be much more intensive.
- Criticality of building operation: Laboratories, computer centers, industrial and headquarter buildings are examples of buildings where malfunction may have high economic or image impacts. In such buildings the commissioning effort can also be more intensive than in other buildings.

9.3.2 Checklist

The minimum version of a Commissioning Plan is a checklist defining the verifications to be performed as the project progresses to ensure that critical actions were effectively performed. The key advantage of the checklist is its simplicity. There would be no need to use a special software or for in-depth training of the users. The main disadvantage is that it defines what to do but not how to do it and does not include a documentation of the results obtained.

In simple projects, where an independent commissioning authority generally will not be involved, the checklist enables the project manager to apply a minimum of quality control. Checkpoints are especially important when proceeding from one project phase to the next. These checklists will be used by each party involved in the project.

9.3.3 Matrix for quality control

Matrix for Quality Control (MQC) was initially developed in the Netherlands as a tool for the overall quality control of climate control Climate Installations. In the Netherlands, the MQC structure has been elaborated for heating systems and domestic ventilation systems. Its intention is to control the total production process including specifications, design, construction, hand-over and operation. It focuses on avoiding failures on all strategic aspects and phases in this process.

The most important characteristic of MQC for HVAC systems is a structure that follows through all the process phases. This enables planners to build in a number of strategic decision points in the building and system process and to assess if a system meets the targets and requirements, as defined in the program phase. The total quality required is determined by several aspects (not only technical but also financial, organisational and communications).

This leads to a so-called quality control matrix. On the horizontal axis of the matrix, the phases of the process are presented. On the vertical axis of the matrix, quality control elements are listed.

9.4 How to execute the commissioning plan

The commissioning plan defines a list of tasks to achieve, verify and document the performance of the building. Users need some tools to be able to perform tasks defined in the commissioning plan. Annex 40 identified three types of tools to perform these kinds of tasks. These three tasks are listed below:

- Functional performance testing (FTP)
- Using the building control system for commissioning
- Using models at the component level

9.4.1 Functional performance testing (FTP)

Many actors around the world have already developed some performance procedures. The main challenges today consists in making the best use of existing procedures adapted to national building industry and contract standards, and only develop new ones when required.

IEA Annex 40 (IEA 2001) strategy consisted in specifying the commissioning process and the tools actually required for the application of each commissioning plan, in addition to transferring existing procedures from one country to another one and in developing new required procedures. The main information sources were localized, among them in US, where an important data base is available. This source was very much used in the frame of IEA Annex 40. Each component has a well defined function inside the whole HVAC system. Any malfunction can compromise the correct behaviour of the whole system. The malfunction may occur due to:

- Design faults
- Selection or sizing mistakes
- Manufacturing fault or initial deterioration
- Installation faults
- Wrong tuning
- Control failure

— Abnormal conditions of use.

The FPT is devoted to the detection of such possible malfunction and to its diagnosis. The test can be active or passive, according to the way of analyzing the component behaviour i.e. with or without artificial perturbation. Active tests are mostly applied in initial commissioning, i.e. at the end of the building construction phase. Later in the Building Life Cycle (BLC), i.e. in re-, retro- and on-going commissioning, a passive approach is usually preferred, in order to preserve health and comfort conditions inside all the building occupancy zones. A generic description of a FPT includes:

— A description of the system, subsystem or component considered
— A presentation of the testing procedure
— Some additional possibilities (model use and possibility of automation

FPT can be realized on the whole system, a subsystem (several interconnected components) or on specific components that are considered as critical. The selection of the appropriate level is made on the basis of risk in relation with the acceptance criteria. The search for malfunctions can either follow a top-down or bottom-up route:

Top-down

The whole system functional performances are first verified, moving on to subsystems and then onto specific components as malfunctions are found and require investigation. The goal is not to verify if a component is good or bad in itself, but to check if it's correctly integrated in the system considered.

One problem is the possibility that energy-wasting situations could be missed. For example, a poorly-tuned control may cause an air handling unit to cycle between heating and cooling. If the zone temperature doesn't vary too much and stays very near to its set point, the problem might not be apparent. Such faults may be found at the system level only, if the losses are great enough to be obvious when compared with expectations.

Bottom-up

Starts by confirming the performance of an elementary component and progressively working up to the whole system. This may be more appropriate for initial commissioning, following construction. It allows a safer identification of local defaults, but it may require excessive effort.

9.4.2 Using the building control system for commissioning

Today, microprocessor-based control systems are used to automatically operate many of the major energy systems in buildings. As technology continues to evolve, the trend is for more systems to come under the action of automatic control and for disparate systems to be integrated across communication networks. Automatic control systems eliminate the need for dedicated manual operators and can reduce costs. Modern control systems also allow the operation of multiple energy systems to be coordinated according to advanced building-level strategies. The proliferation of automation in buildings has led to a situation in which realizable building performance is fundamentally dependent on the control system. An important part of commissioning should therefore be to ensure that the control system is operating properly.

It is useful at this point to define what components constitute the building control system. First, it is assumed that the control system encompasses both hardware and software. On the hardware side, the scope of definition is limited to the components such as sensors, actuators, wiring, switches, and (microprocessor-based) control devices. The boundary for the hardware side is, therefore, the point of interface to the energy systems and the controlled environment. Scope on the software side is limited to the control algorithms, user interface, and other miscellaneous functionality that is typically packaged in modern systems. Control systems are becoming more modular and, from a commissioning perspective, modularization helps to move some of the onuses of testing onto the factory and component vendor. A valid expectation is therefore that components, whether hardware or software, have been tested before arriving at a building for installation. The most important aspects then to verify and commission on-site will be those that have been affected by the installation process. For example, checking wiring and panel connections is very important as is verifying that all on-site software downloads and/or configurations have been successful. Pre-calibrated sensors are reducing the need for wide-scale sensor validation but an important and related commissioning task is to check whether sensor points have been correctly mapped into the control logic.

In addition to commissioning the control system itself, the control system can also be used as a tool for carrying out commissioning on the energy systems. A control system can serve as a commissioning tool by making use of its ability to manipulate energy systems through interfaces such as actuators and switches. The idea is to carry out tests that involve making changes to a particular system through the control system rather than by direct manipulation. Sensors connected to the control system allow the effects of changes to be measured and recorded. Different levels of automation can be applied when using the control system as a commissioning tool. A human operator can perform tests through a user-interface portal or test procedures can be programmed into the control system and be activated by a user. Varying degrees of automation can also be employed in the analysis of test results.

9.4.3 Using models at the component level

The following steps comprise a *use case* for a general purpose, component-level, and model based commissioning tool that can be used both for initial commissioning and for performance monitoring during routine operation:

- For automated functional performance testing, the model is configured using manufacturers' performance data and system design information. In general, the model parameters will be determined by a combination of direct calculation and regression.
- An active test is performed to verify that the performance of the component is acceptably close to the expected performance. This test involves forcing the equipment to operate at a series of selected operating points specifically chosen to verify particular aspects of performance (e.g. capacity, leakage).
- The test results are analyzed, preferably in real time, to detect and, if possible, to diagnose faults.
- If necessary, the test is performed again to confirm that any faults that resulted in unacceptable performance have been fixed. Once the results of this test are deemed acceptable, they are taken to define correct (i.e. acceptable) operation.
- The model is re-calibrated using the acceptable test results.
- The tool is used to monitor performance during on-going operation. This will typically be done in passive mode, though active testing could be performed at particular times, e.g. every weekend, after routine maintenance, after system modifications or retrofit, on change of ownership, etc.

9.5 Applying commissioning process to the lighting control system

The aim of the commissioning applied to the lighting control system is to verify if the performance of this system meet the defined performance and criteria. The first step consists of collecting the performance targets of the system and defining the criteria to assess these performance.

9.5.1 Objectives of lighting systems

Adequate and appropriate lighting should be provided so that people are able to perform visual tasks efficiently and accurately. The illumination can be provided by daylight, artificial lighting or a combination of both. The level of illuminance and comfort required in a wide range of work places is governed by the type and duration of activity.

9.5.2 Criteria for lighting systems quality

For good lighting practice, it is essential that the qualitative and quantitative needs are satisfied in addition to the required illuminance. Lighting requirements are determined by the satisfaction of three basic human needs:

- Visual comfort which enables the workers to have a feeling of well-being (in an indirect way) also contributing to a high productivity level
- Visual performance which enables the workers to perform their visual tasks, even under difficult circumstances and during longer periods with comfort.
- Safety

Main parameters determining the luminous environment are:

- Luminance distribution
- Illuminance
- Glare
- Directionality of light
- Color rendering and color appearance of the light
- Flicker and stroboscopic effects
- Maintenance factor
- Energy considerations
- Daylight

Methods of calculation of all these parameters are available in the European standard EN 15251.

9.5.3 Indicators to evaluate the performance of lighting system

Previous paragraph defines a list of criteria for lighting system. Some indicators are necessary to evaluate these criteria.

Luminance distribution

The luminance distribution in the field of view controls the adaptation level of the eyes which affects task visibility. A well balanced adaptation luminance is needed to increase:

- Visual acuity (sharpness of vision)
- Contrast sensitivity (discrimination of small relative luminance differences)
- Efficiency of the ocular functions (such as accommodation, convergence, pupil contraction, eye movements etc.)

The luminance distribution in the field of view also affects visual comfort. The following situations should be avoided for the reasons given:

- Too high luminances which may give rise to glare
- Too high luminance contrasts which will cause fatigue because of constant re-adaptation of the eyes
- Too low luminances and too low luminance contrasts which result in a dull and non-stimulating working environment

Illuminance

The illuminance and its distribution on the task area and the surrounding area have a great impact on how quickly, safely and comfortably a person perceives and carries out the visual task. All values of illuminances specified in the European standard EN 12464 are maintained illuminances and will provide for visual comfort and performance needs.

Glare

Glare is the sensation produced by bright areas within the field of view and may be experienced either as discomfort glare or disability glare. Glare caused by reflections in specular surfaces is usually known as veiling reflections or reflected glare. It is important to limit the glare to avoid errors, fatigue and accidents. In interior work places, discomfort glare may arise directly from bright luminaires or windows. If discomfort glare limits are met, disability glare is not usually a major problem.

Directionality of light

Directional lighting may be used to highlight objects, reveal texture and improve the appearance of people within the space. This is described by the term modelling. Directional lighting of a visual task may also affect its visibility.

Color aspects

The color qualities of a near-white lamp are characterised by two attributes:

- The color appearance of the lamp itself,
- Its color rendering capabilities, which affect the color appearance of objects and persons illuminated by the lamp.

These two attributes shall be considered separately

Flicker

Flicker causes distraction and may give rise to physiological effects such as headaches. Stroboscopic effects can lead to dangerous situations by changing the perceived motion of rotating or reciprocating machinery. Lighting systems should be designed to avoid flicker and stroboscopic effects.

Maintenance factor

The lighting scheme should be designed with an overall maintenance factor calculated for the selected lighting equipment, space environment and specified maintenance schedule. The recommended illuminance level for each task is given as maintained illuminance. The maintenance factor depends on the maintenance characteristics of the lamp and control gear, the luminaire, the environment and the maintenance programme. The designer shall:

- state the maintenance factor and list all assumptions made in the derivation of the value
- specify lighting equipment suitable for the application environment
- prepare a comprehensive maintenance schedule to include frequency of lamp replacement, luminaire and room cleaning intervals and cleaning method.

Energy considerations

A lighting installation should meet the lighting requirements of a particular space without waste of energy. However, it is important not to compromise the visual aspects of a lighting installation simply to reduce energy consumption. This requires the consideration of appropriate lighting systems, equipment, controls and the use of available daylight.

Daylight

Daylight may provide all or part of the lighting for visual tasks. It varies in level and spectral composition with time and thus provides variability within an interior. Daylight may create a specific modelling and luminance distribution due to its nearly horizontal flow of light from side windows. Windows may provide visual contact with the outside environment, which is preferred by most people.

In interiors with side windows, the amount of available daylight decreases rapidly with the distance from the window. Supplementary lighting is needed to ensure the required illuminance level at the work place and to balance the luminance distribution within the room. Automatic or manual switching and/or dimming may be used to ensure appropriate integration between electric lighting and daylight. To reduce glare from windows, screening should be provided where appropriate.

9.6 Example of a Commissioning Plan applied to the lighting system

The purpose of the commissioning plan is to provide direction for the commissioning process during the life cycle of the building. It provides resolution for issues such as scheduling, roles and responsibilities, lines of communication and reporting, approvals, and coordination.

The commissioning plan defined at each step of the process the list of tasks to perform to assess the performance of the system. Associated tools could be also associated to help the commissioning provider to perform tasks. Tasks defined in the commissioning plan could be shared in two parts, namely; organisational part and technical part. The commissioning plan could also provide a general description of the commissioning team in order to identify persons relevant to the commissioning process.

The objective is to be able to contact the right person in case of malfunctioning of buildings or systems of the building. Each related actors should be identified by his name, address, phone number and e-mail address.

Program step	*Cx Organizational*
Program step	Check that the list of the relevant to take into account has been defined.
Program step	*Cx Technical*
Program step	Check that the occupant's lighting needs (Lighting requirement and calculation & lighting zone assumptions) have been defined.
Program step	Check that the energy performance of the lighting system has been defined.
Working design step	*Cx Organizational*
Working design step	Check that the lighting system control method is defined.
Working design step	Check that each room has its own control system.
Working design step	Check that each local, luminaires of the row closet to the windows could be controlled separately.
Working design step	Check that the designer specified lighting equipment are suitable for the application environment.
Working design step	*Cx Technical*
Working design step	Check that time delay and sensitivity are defined for each work space.
Working design step	Check that the sensitivity to change in daylight is defined for local room conditions.
Working design step	Check that the ranges of the reflectance for the major interior surfaces are in accordance with EN-12464
Working design step	Check that lamps with a color rendering index lower than 80 are not used in interiors where people work or stay longer periods.
Working design step	Check that the designer states the maintenance factor and lists all assumptions made in the derivation of the value.
Working design step	Check that the designer prepares a comprehensive maintenance schedule to include frequency of lamp replacement, luminaries and room cleaning intervals and cleaning method.
Working design step	Check that the uniformity of the illuminance is superior at 0.7 for the work plane and 0.5 for immediate surroundings.
Working design step	For offices check that the minimum shielding angles shall be applied for the specified lamp luminance.
Elaboration step	*Cx Organizational*
Elaboration step	Check that the plans of the offer answer the initial requirements.
Elaboration step	Check that the hypotheses of calculation are justified.
Elaboration step	Check that plans take into account the location of the components of the installation.
Elaboration step	Check that the plans take into account the accesses allowing the maintenance.
Elaboration step	Check that the list of the tests and controls is included in the answer to the offer.
Elaboration step	*Cx Technical*
Elaboration step	Check that the description of the heating system is complete (design, components, performance):
Elaboration step	a) List and description of the main components
Elaboration step	b) Location of the components
Elaboration step	Check that the access to the sensors is easy but not so accessible that unauthorized personnel can interfere with it.
Elaboration step	Check that DC electrical supply is used for incandescent lamps or that incandescent or discharge lamps are of high frequencies.
Elaboration step	For offices check that the installed power in interior to 2.2 W/m^2/100 lux and 2.5 W/m^2/100 lux for corridors.
Construction step	*Cx Organizational*
Construction step	*Cx Technical*
Construction step	Check that lighting systems control is well connected.
Construction step	Check that schedule of the lighting system is implemented into the building energy management system.
Construction step	For sweep-off system, check that appropriate start and stop times are set to accommodate weekdays, weekends and holidays operation.
Construction step	For daylight-linked system be sure all furnishings and interior surface materials are installed before calibration.
Construction step	For manual dimming, check that the dimmer has been installed in correct position adjacent to the wall switch as par drawings
Acceptance step	*Cx Organizational*
Acceptance step	Provide building maintenance personnel with all necessary documentation and operation instructions to re-commission and maintain the system.
Acceptance step	Check that a user's guide has been written.
Acceptance step	Check the periodicity of the maintenance's inspection.
Acceptance step	*Cx Technical*
Acceptance step	Check that placements and orientation of the sensors are correct according to the plans.
Acceptance step	Check that the sensitivity of the occupancy sensor is adjusted.
Acceptance step	Check that the time delay of the occupancy sensor is adjusted according to the room.
Acceptance step	Check that the schedule of the lighting system meets the effective functioning of the lighting system.
Acceptance step	Check that local and/or central overrides are well taken into account.
Acceptance step	Check that the lighting system is well controlled.
Acceptance step	For dimming system, check burn in new lamps by operating the lamps at full power continuously for 100 hours.
Acceptance step	For daylight-linked system, check that the light sensor is calibrated in order to obtain desired light level at the work surface.
Post accepta ce step	*Cx Organizational*
Post accepta ce step	Inform occupants about the functionality of the controls and, particularly, the overrides.
Post accepta ce step	*Cx Technical*
Post accepta ce step	Check that the operation of the lighting system meets the requirement defined in the book of specifications.
Post post-acceptance step	*Cx Organizational*
Post post-acceptance step	Check that the performance of lighting equipments is yearly evaluated.
Post post-acceptance step	Check that the sensors are yearly cleaned up (every six months for outside sensors).
Post post-acceptance step	*Cx Technical*
Post post-acceptance step	Check that the re-calibration of the sensors is done if the environment of the building has changed (construction of the new building, for example)
Post post-acceptance step	In the case of modification of the zone destination, check that scheduling defined in the building energy management system still corresponds to the zone.

Figure 9-3. *Tasks of the Commissioning plan for lighting systems.*

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