PERFECTION – Performance Indicators for Health, Comfort and Safety of the Indoor Environment
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D1.5 Annex B: Assessment methods of Health & Comfort Key Indoor Performance Indicators (KIPIs)

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CONTENTS

1. INTRODUCTION

In this annex, additional information on the specific assessment methods applied to evaluate the performance indicators for health and comfort is provided. The annex serves as a supplementary document providing guidelines with respect to the applied methodology for expert reviews, building simulations and experimental methods. For each indicator, a detailed description of the assessment method is presented as well as the specific requirements and target values for classification of the indicator in classes A to E. Here, class A represents the best performance of the specific indicator, where class E is related to the worst performance.

The outline of the annex is as follows: For each indicator a simple and detailed level with respect to the assessment level is presented, and then each level is divided into a assessment method applied in design and in operation.

A main part of the guidelines and methodologies presented, are a synthesis of the work reported by the ASTM Standards for Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995), ASHRAE's Performance Measurement Protocols for Commercial Buildings (ASHRAE 2009), and the FISIAQ's Classification of Indoor Climate. While it may be straightforward to the reader only to refer these documents, the authors of this report decided to include significant and important parts of these documents in the present work. This results in a more concise guideline and enables a wider application of the presented assessment methods. However, the reader should notice that the assessment methods proposed in this document are not a (one-to-one) copy of the standards and guidelines published by ASTM, ASHRAE, and FISIAQ. Nevertheless, the proposed assessment methods are designed, developed and tuned according to the specific needs of the building designers and users in order to enlarge the quality of the Perfection KIPI framework and its applicability in practice.

In this document, target values are presented for the illustration of the assessment methods. : These target values should be considered as example values and may be adjusted according to the requirements of the specific building.

2. ASSESSMENT METHODS OF HEALTH AND COMFORT KIPIs

2.1. Indoor air quality

2.1.1. Effective temperature

Simple assessment
Assessment in design

The effective temperature, i.e. a combination of temperature and relative humidity, affects the perception of indoor air quality (IAQ) and measurement of outside air ventilation rate. The temperature and relative humidity are not IAQ measurements directly, but are useful to confirm a typical indoor environment and indicate outdoor extremes that may exist. However, the indicator effective temperature (evaluated on the surface of a building component) is particularly relevant with respect to the evaluation of mould growth in a building.

The presence of and the risk for development of mould growth on building surfaces is evaluated:
1. Conduct a facility pre-evaluation and survey preparation.
a. Review facility operational documentation. Review building and tenant descriptions, drawings, and information on the facility construction. Document the occupancy types and operations for each space type within the facility. Review building plans, including HVAC designs.

2. A building assessment is conducted and the conditions for mould growth in the building are characterized, based on technical drawings and calculation available in the design phase:
a. Building components. Inspect the building construction for building components which may be susceptible to mould growth. Inspect the construction for possible thermal bridges, where low surface temperatures and high relative humidities may occur.
b. Moisture production. Characterize the spaces where excessive moisture production may occur, for example kitchen facilities, bath rooms, etc. If a strong moisture source is observed, an increase risk for mould growth development exists.
c. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.

Table 1: Assessment in design

	Effective temperature		
	Mould growth	Local conditions	IAQ
A	Excellent , no risk for development of mould growth.	No (excessive) moisture sources in the neighborhood of the building.	Operative temperature class D or higher; Effective ventilation class A/B
B	Good, moisture sources are present in the building; however, the risk for	Moisture sources are present in the building; no building materials susceptible to	Operative temperature class D or higher; Effective ventilation class A/B

	accumulation (relatively high local relative humidity) is limited.	mould growth applied; no thermal bridges, imperfections, etc.	
C	Adequate, moisture sources are present in the building; however, the risk for accumulation (relatively high local relative humidity) is limited.	Moisture sources are present in the building. Particular spaces where moisture sources are present are isolated from other spaces (pressurization, air flows, (self-closing) doors, etc.)	Operative temperature class D or higher; Effective ventilation class C or higher
D	Poor, moisture sources are present in the building; The risk for accumulation (relatively high local relative humidity) is considerable.	Moisture sources are present in the building. No isolation of spaces where moisture sources are present. Materials susceptible to mould growth or thermal bridges are present.	Operative temperature class D or higher; Effective ventilation class C or lower
E	Bad, moisture sources are present in the building; The risk for accumulation (relatively high local relative humidity) is high.	Moisture sources are present in the building. No isolation of spaces where moisture sources are present. Materials susceptible to mould growth or thermal bridges are present.	Operative temperature class E or lower; Effective ventilation class D or lower

Simple assessment

Assessment in operation

The effective temperature, i.e. a combination of temperature and relative humidity, affects the perception of indoor air quality (IAQ) and measurement of outside air ventilation rate. The temperature and relative humidity are not IAQ measurements directly, but are useful to confirm a typical indoor environment and indicate outdoor extremes that may exist. However, the indicator effective temperature (evaluated on the surface of a building component) is particularly relevant with respect to the evaluation of mould growth in a building.

The presence of and the risk for development of mould growth on building surfaces is evaluated:
1. Conduct a facility pre-evaluation and survey preparation.
a. Review complaints log and similar unstructured reports of continuing or episodic concerns, and related environmental and health surveys, which may indicate mould growth related problems. Additionally, a BSI survey could be carried out (Raw 1995) to evaluate the presence of mould growth related complaints.

2. A site/building assessment is conducted and the conditions for mould growth in the building are characterized:
a. Building components. Inspect the building construction for building components which may be susceptible to mould growth. Inspect the construction for thermal bridges, where low surface temperatures and high relative humidities may occur.
b. Moisture production. Characterize the spaces where excessive moisture production may occur, for example kitchen facilities, bath rooms, etc. If a strong moisture source is observed, an increase risk for mould growth development exists.
c. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.
d. Inspect for staining or permanent wetness to indicate moisture problems.

Table 2: Assessment in operation

	Effective temperature	
	Mould growth	IAQ
A	Excellent , no staining on or permanent wetness of building component's surfaces. No (excessive) moisture sources in the building.	Operative temperature class D or higher; Effective ventilation class A/B
B	Good, e.g. no staining on or permanent wetness of building component's surfaces. Moisture sources are present in the building; No building materials susceptible to mould growth applied; no thermal bridges, imperfections, etc	Operative temperature class D or higher; Effective ventilation class A/B
C	Adequate, e.g. no staining on or permanent wetness of building component's surfaces. Moisture sources are present in the building. Particular spaces where moisture sources are	Operative temperature class D or higher; Effective ventilation class C or higher

	present are isolated from other spaces (pressurization, air flows, (self-closing) doors, etc.)	
D	Poor, permanent wetness of building component's surface(s) is observed during some part of the year. Moisture sources are present in the building. Materials susceptible to mould growth or thermal bridges are present.	Operative temperature class D or higher; Effective ventilation class C or lower
E	Bad, staining and permanent wetness of the building component's surface(s) are observed during a considerable part of the year. Complaints indicating mould growth related health problems have been observed.	Operative temperature class E or lower; Effective ventilation class D or lower

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment
Assessment in design

A building simulation is used in for obtaining information about the indoor environmental conditions over an entire year. The building simulation results in an data set of hourly values including indoor air temperature, relative humidity, and local surface temperature and relative humidity for those building components where mould growth may develop. These quantities are evaluated in the Lowest Isopleth for Mould growth (LIM) (Sedlbauer, Krus & Breuer 2003) (Peuhkuri, Viitanen & Ojanen 2008) for biodegradable materials and porous building materials.

Table 3: Assessment in design

	Effective temperature	
	Mould growth	IAQ
A	Excellent , e.g. no critical conditions; no risk for development of mould growth.	Operative temperature class D or higher Effective ventilation class A/B
B	Good, e.g. critical surface conditions are observed locally, only few times[1] in the year; The risk for development of mould growth is limited.	Operative temperature class D or higher; Effective ventilation class A/B
C	Adequate, critical indoor environmental conditions are observed, only few times[1] in the year; the risk for development of mould growth is limited.	Operative temperature class D or higher; Effective ventilation class C or higher
D	Poor, critical surface conditions are observed during a considerable[1] part of the year; the risk for development of mould growth is considerable.	Operative temperature class D or higher; Effective ventilation class C or lower
E	Bad, critical indoor environmental conditions surface conditions are observed during a considerable[1] part of the year; the risk for development of mould growth is large.	Operative temperature class E or lower; Effective ventilation class D or lower

[1] Subjective descriptions should be defined more detailed, for example as the number of hours, at which specific conditions occur, related to the total number of hours over the year.
Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

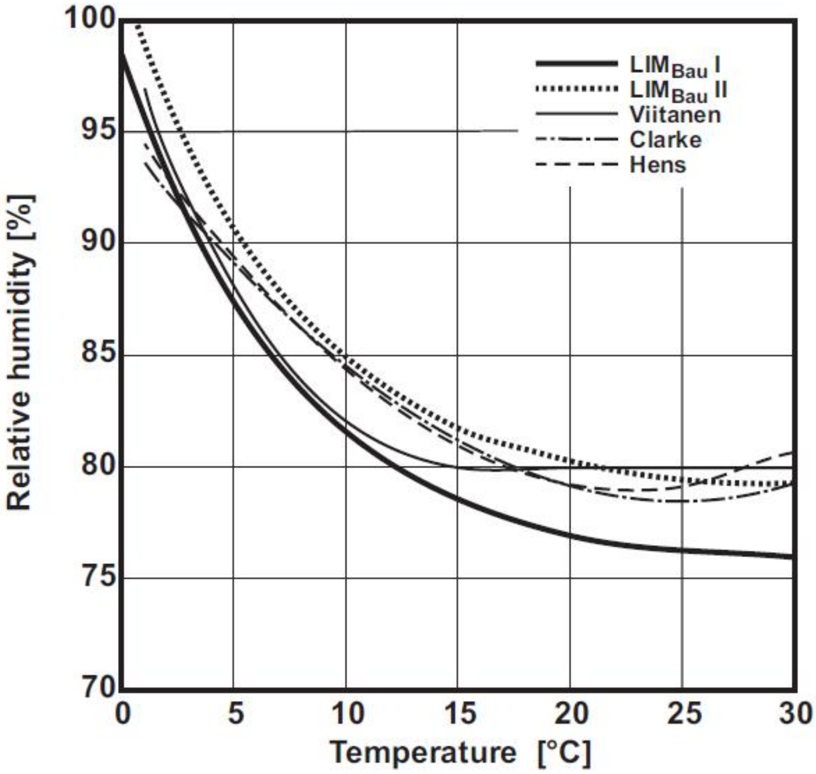

Figure 1: Lowest Isopleth for Mould growth of substrate class I (LIM_{BAU}I: for biodegradable materials) and of substrate class II (LIM_{BAU}I: for porous building materials) (Sedlbauer, Krus & Breuer 2003).

Detailed assessment

Assessment in operation

Measurements are used in for obtaining information about the indoor environmental conditions and local surface conditions over an entire year:

1. Indoor environmental conditions:

The experimental results consist of a data set of hourly values including indoor air temperature, and relative humidity,

2. Local surface conditions:

Building components are inspected for staining or permanent wetness to indicate moisture problems. Measurement of internal moisture content beneath surfaces where moisture or mould growth is observed is carried out. Moreover, thermography may be used. If there is persistent wetness, consider a sample and culture to clarify if and how intense a hidden microbial growth may be. Local surface temperature and relative humidity for those building components where moisture problems have developed are analyzed.

3. The measured conditions are evaluated in the Lowest Isopleth for Mould growth (LIM) (Sedlbauer, Krus & Breuer 2003) (Peuhkuri, Viitanen & Ojanen 2008) for biodegradable materials and porous building materials.

Table 4: Assessment in operation

	Effective temperature
A	Excellent , no staining on or permanent wetness of building component's surfaces. No critical conditions; no risk for development of mould growth.
B	Good, e.g. no staining on or permanent wetness of building component's surfaces. Critical surface conditions are observed locally, only few times in the year; The risk for development of mould growth is limited.
C	Adequate, e.g. no staining on or permanent wetness of building component's surfaces. Critical indoor environmental conditions are observed, only few times in the year; the risk for development of mould growth is limited.
D	Poor, permanent wetness of building component's surface(s) is observed during some part of the year. Critical surface conditions are observed during a considerable part of the year; the risk for development of mould growth is considerable.
E	Bad, staining and permanent wetness of the building component's surface(s) are observed during a considerable part of the year. Critical indoor environmental conditions surface conditions are observed during a considerable part of the year; the risk for development of mould growth is large.

2.1.2. Effective ventilation / CO_2

Simple assessment

Assessment in design

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). If the site is in a non-attainment zone, then check that proper filters are installed.

2. Conduct a facility pre-evaluation and survey preparation:
a. Review facility operational documentation. Review building and tenant descriptions, drawings, and information on the facility construction. Document the occupancy types and operations for each space type within the facility. Review building plans, including HVAC designs.
b. Assessment based on technical drawings and calculations available in the design phase. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.

Assessment of the effective ventilation is carried out along the lines of ASTM Standards on Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995)

Table 5: Assessment in design

	Effective ventilation
A	Excellent, e.g. ventilation rates (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)) and volume of air entering the space are maintained at all times that the rooms are in use. Local control of ventilation exists in all rooms, including temporary flushing with 100% outside air.
B	Good, e.g. sufficient ventilation rates (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)) per person. The volumes of fresh air never fall below required ventilation rates. Capability exists for added ventilation.
C	Adequate, e.g. ventilation rates reach target (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)). Ventilation is controlled using fixed setpoints which cannot be adjusted by occupants. Limited capability exists for added ventilation.
D	Poor, e.g. ventilation rates per person are not at target (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)). Limited capability exists for some added ventilation, but not sufficient to meet target.
E	Bad, e.g. ventilation rates per person are effectively lower than the requirements(current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)), are not increased for the density of population, and more ventilation cannot be added.

Simple assessment

Assessment in operation

1. Conduct a facility pre-evaluation and survey preparation:
a. Review complaints log and similar unstructured reports of continuing or episodic concerns, previous occupant satisfaction surveys and/or IAQ audits, and related environmental, health and safety surveys. Document response and actions taken.
b. Review facility operational documentation. Review building and tenant descriptions, as-built drawings, and information on the facility construction. Document the occupancy types and operations for each space type within the facility. Review building plans, including HVAC designs. Note any remodeling and HVAC projects in-progress or completed since occupancy, recommissioning or the last tenant satisfaction survey.
c. Prepare for site assessment. Contact building managers and tenant facility coordinators for the purpose of conducting a telephone in-briefing. Obtain HVAC system attribute information. The attribute list will be provided by the building owner to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.

2. Conduct a site assessment (qualitative) and characterize condition of the building and its HVAC system as it might affect IAQ:
a. Perform opening interview with the Building Manager, operation and maintenance contractor, custodial contractor and interested tenant representatives.

3. Conduct an occupant survey, concurrent with IAQ physical and environmental evaluation, to determine occupant satisfaction with IAQ and rate the building's satisfaction levels against benchmarks in a database of previously measured buildings. This should include perceptions of fresh air, stuffiness, presence of odours, healthful air, temperature/humidity adequacy, etc. For example, the CBE survey (ASHRAE 2009) or BSI survey could be carried out (Raw 1995).

Table 6: Assessment in operation

	Effective ventilation
A	Excellent, e.g. no IAQ related complaints reported. Ventilation rates (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)) and volume of air entering the space are maintained at all times that the rooms are in use. Local control of ventilation exists in all rooms, including temporary flushing with 100% outside air.
B	Good, e.g. only a few[1] of IAQ related complaints. Sufficient ventilation rates (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)) per person. The volumes of fresh air never fall below required ventilation rates. Capability exists for added ventilation.
C	Adequate, e.g. only a few[1] of IAQ related complaints. Ventilation rates reach target (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)). Ventilation is controlled using fixed setpoints which cannot be adjusted by occupants. Limited capability exists for added ventilation.
D	Poor, e.g. the number of IAQ related complaints is considerable[1]. Ventilation rates per person are not at target (current ASHRAE Standards 62 (ASHRAE 62-2007 2007) and 55 (ASHRAE 55-2004R 2004)). Limited capability exists for some added ventilation, but not sufficient to meet target.
E	Bad, e.g. IAQ related complaints are reported frequently[1]. Ventilation rates per person are effectively lower than the requirements (current ASHRAE Standards 62 (ASHRAE 62-2007

	2007) and 55 (ASHRAE 55-2004R 2004)), are not increased for the density of population, and more ventilation cannot be added.

[1] Subjective descriptions should be defined more detailed, for example as the number of complaints related to the total number of building occupants or related to a reference building.

Detailed assessment

Assessment in design

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). If the site is in a non-attainment zone, then check that proper filters are installed. If a strong local ambient source is suspected, the quality of outdoor air at the site should be documented. This consists of an observational survey of the building site and immediate surroundings to identify local contaminants that may be of concern if allowed to enter the building. A procedure for this is presented in Sections 4.2 and 4.3 of Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Using predicted/designed OA flow rates, calculate supply less exhaust flow rates and building pressure differential to confirm that exhaust ducts are at negative pressure to avoid cross contamination.

3. The zone-to-outdoor air differential CO_2 levels in each zone (return air) and in selected spaces are evaluated using a building simulation of the airflow in the building, for example using a zonal/nodal airflow model or computational fluid dynamics. The building simulation results in a prediction of the CO_2 levels in the building. Such predictions can be useful in assessing outdoor air ventilation relative to occupancy levels, i.e., to determine if the effective OA rate per person is less than the rate required (ASHRAE 62-2007 2007). The CO_2 concentrations should be analyzed in the spaces or in preference in the return air duct or plenum. Predictions should be available in the selected zones under design and off-design (steady state) occupancy conditions for at least a one-week period, but preferably on a continuous, permanent basis.

Assessment of the predicted carbondioxide concentrations is carried out along the lines of the target values for indoor air quality presented by in the Finnish Classification of Indoor Climate (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008).

Table 7: Target values for assessment in design

	Effective ventilation	
	CO2 concentration [ppm]	Stability of Environment[1] [% of operating time]
A	<750	≥ 95%
B	<900	≥ 95%
C	<900	≤ 95%
D	<1200	≥ 90%
E	>1200	-

[1] Defined as the percentage of the operating/occupation time a condition is fulfilled

Additional comments

Levels exceeding 1000 ppm are generally indicative of inadequate ventilation and signal a need to investigate and take corrective action. However, because appropriate CO_2 levels vary with the occupancy of the space and the activity level of the occupants, no single value, or range of values, applies to all spaces. Tables of recommended CO_2 concentrations (i.e., expected design levels under default conditions) for ventilation monitoring or demand controlled ventilation have been presented by Lawrence (Lawrence 2008) and (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008). Concentrations range from 800 to over 3,000 ppm. Note, however, that these values are based on several assumptions including steady state in a single zone, the default design occupancy and activity levels, an air distribution effectiveness of 1.0, and an ambient concentration of 400 ppm. In Table 7, absolute values for the CO_2 concentrations are presented. While the CO_2 concentration in a building is also influenced by the outdoor air concentration, the ambient concentration is included in the target value indirectly (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008).

Detailed assessment

Assessment in operation

1. The quality of the outdoor air at the site is characterized based on measurement of the CO_2 concentrations of the outdoor air. A procedure for characterization of the outdoor air is presented in ASHRAE Standard 62 (ASHRAE 62-2007 2007)

2. Using measured OA flow rates, calculate supply less exhaust flow rates and building pressure differential to confirm that exhaust ducts are at negative pressure to avoid cross contamination.

3. Measure zone-to-outdoor air differential CO_2 levels in each zone (return air) and in selected spaces. Such measurements can be useful in assessing outdoor air ventilation relative to occupancy levels, i.e., to determine if the effective OA rate per person is less than the rate required at design. (However, CO2 is a poor metric for sparsely occupied spaces and those with high amounts of pollutant emitting building components). Sensors should be in the space (or placed in a central measurement station) in preference to the return air duct or plenum. These measurements should be made continuously in selected zones under design and off-design (steady state) occupancy conditions for at least a one-week period, but preferably on a continuous, permanent basis. For additional information regarding the measurement of CO_2 levels the reader is referred to ASHRAE Performance Measurement Protocols for Commercial Buildings (ASHRAE 2009).

Assessment of the predicted carbondioxide concentrations is carried out along the lines of the target values for indoor air quality presented by in the Finnish Classification of Indoor Climate (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008).

Table 8: Target values for assessment in operation

	Effective ventilation	
	CO2 concentration [ppm]	Stability of Environment[1] [% of operating time]
A	<750	≥ 95%
B	<900	≥ 95%
C	<900	≤ 95%
D	<1200	≥ 90%
E	>1200	-

[1] Defined as the percentage of the operating/occupation time a condition is fulfilled

Additional comments

Levels exceeding 1000 ppm are generally indicative of inadequate ventilation and signal a need to investigate and take corrective action. However, because appropriate CO_2 levels vary with the occupancy of the space and the activity level of the occupants, no single value, or range of values, applies to all spaces. Tables of recommended CO_2 concentrations (i.e., expected design levels under default conditions) for ventilation monitoring or demand controlled ventilation have been presented by Lawrence (Lawrence 2008) and (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008). Concentrations range from 800 to over 3,000 ppm. Note, however, that these values are based on several assumptions including steady state in a single zone, the default design occupancy and activity levels, an air distribution effectiveness of 1.0, and an ambient concentration of 400 ppm. In Table 8, absolute values for the CO_2 concentrations are presented. While the CO_2 concentration in a building is also influenced by the outdoor air concentration, the ambient concentration is included in the target value indirectly (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008).

2.1.3. Combustion sources / infiltration

Simple assessment

Assessment in design

1. The quality of the outdoor air at the site is determined, while focusing on the presence of carbon monoxide sources in the neighborhood of the building (for example in an industrial area, smoking areas in the vicinity of entrances to the building). If a strong local ambient source is suspected, the quality of outdoor air at the site, determined by local microclimate data, should be documented to supplement the EPA National Ambient Air Quality Standards data for the site. This consists of an observational survey of the building site and immediate surroundings to identify local contaminants that may be of concern if allowed to enter the building. A procedure for this is presented in Sections 4.2 and 4.3 of Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Inspection for combustion sources should be carried out. If combustion sources are present and combustion takes place in particular spaces, they should be isolated from other spaces by for example pressurization, air flows, self-closing doors, etc. Particular attention should be paid to combustion, cooking, gymnasiums, natatoriums, smoking areas etc.

Assessment of the combustion sources/infiltration is carried out along the lines of ASTM Standards on Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995)

Table 9: Assessment in design

		Combustion sources/infiltration	
		Sources	Infiltration
A	Excellent	No carbon monoxide sources in the building	No carbon monoxide sources in the neighborhood of the building.
B	Good	No carbon monoxide sources in the building	Carbon monoxide sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.
C	Adequate	Carbon monoxide sources are present in the building. Particular spaces where combustion sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is good and the risk for contamination of the indoor air is limited.
D	Poor	Carbon monoxide sources are present in the building. Particular spaces where combustion sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.
E	Bad	Carbon monoxide sources are present in the building. No	Carbon monoxide sources are present in the building's

		isolation of particular spaces where combustion sources are present (pressurization, air flows, self-closing doors, etc.)	surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Simple assessment

Assessment in operation

1. The quality of the outdoor air at the site is determined, while focusing on the presence of carbon monoxide sources in the neighborhood of the building (for example in an industrial area). If a strong local ambient source is suspected, the quality of outdoor air at the site, determined by local microclimate data, should be documented to supplement the EPA National Ambient Air Quality Standards data for the site. This consists of an observational survey of the building site and immediate surroundings to identify local contaminants that may be of concern if allowed to enter the building. A procedure for this is presented in Sections 4.2 and 4.3 of Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Inspection for combustion sources should be carried out. If combustion sources are present and combustion takes place in particular spaces, they should be isolated from other spaces by for example pressurization, air flows, self-closing doors, etc. Particular attention should be paid to combustion, cooking, gymnasiums, natatoriums, smoking areas, etc.

Assessment of the combustion sources is carried out along the lines of ASTM Standards on Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995)

Table 10: Assessment in operation

		Combustion sources/infiltration	
		Sources	Infiltration
A	Excellent	No carbon monoxide sources in the building	No carbon monoxide sources in the neighborhood of the building.
B	Good	No carbon monoxide sources in the building	Carbon monoxide sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.
C	Adequate	Carbon monoxide sources are present in the building. Particular spaces where combustion sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is good and the risk for contamination of the indoor air is limited.
D	Poor	Carbon monoxide sources are present in the building. Particular spaces where combustion sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.
E	Bad	Carbon monoxide sources are present in the building. No isolation of particular spaces where combustion sources are present (pressurization, air flows, self-closing doors, etc.)	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in design

1. The quality of the outdoor air at the site is determined, while focusing on the presence of carbon monoxide sources in the neighborhood of the building (for example in an industrial area, smoking areas in the vicinity of entrances to the building). If a strong local ambient source is suspected, the quality of outdoor air at the site, determined by local microclimate data, should be documented to supplement the EPA National Ambient Air Quality Standards data for the site. This consists of an observational survey of the building site and immediate surroundings to identify local contaminants that may be of concern if allowed to enter the building. A procedure for this is presented in Sections 4.2 and 4.3 of Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Inspection for combustion sources should be carried out. If combustion sources are present and combustion takes place in particular spaces, they should be isolated from other spaces by for example pressurization, air flows, self-closing doors, etc. Particular attention should be paid to combustion, cooking, gymnasiums, natatoriums, smoking areas etc.

Assessment of the combustion sources/infiltration is carried out along the lines of ASTM Standards on Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995)

Table 11: Assessment in design

		Combustion sources/infiltration	
		Sources	Infiltration
A	Excellent	No carbon monoxide sources in the building	No carbon monoxide sources in the neighborhood of the building.
B	Good	No carbon monoxide sources in the building	Carbon monoxide sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.
C	Adequate	Carbon monoxide sources are present in the building. Particular spaces where combustion sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is good and the risk for contamination of the indoor air is limited.
D	Poor	Carbon monoxide sources are present in the building. Particular spaces where combustion sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.
E	Bad	Carbon monoxide sources are present in the building. No isolation of particular spaces where combustion sources are present (pressurization, air flows,	Carbon monoxide sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and

		self-closing doors, etc.)	the risk for contamination of the indoor air is considerable.

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in operation

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). Inspection for carbon monoxide sources in the neighborhood of the building is carried out. If combustion sources (for example industrial activities) are present, carbon monoxide concentrations are measured.

2. Inspection for combustion sources should be carried out. If combustion sources are present, CO concentrations should be measured near those sources and should be below a threshold of 9 ppm for 8 hours, and 35 ppm for one hour (ASHRAE 2009). While other contaminants are emitted from combustion sources, CO is immediately dangerous and is readily measured. For additional information on the measurement of CO concentrations in buildings, measurement protocols and techniques, the reader is referred to the EPA publication A Standard Protocol for Characterizing Indoor Air Quality in Large Office Buildings (Indoor Environments Division, Office of Radiation and Indoor Air & U.S. Environmental Protection Agency (EPA) 2003).

Table 12: Assessment in operation (ASHRAE 2009)

	Combustion sources/infiltration	
	CO concentration (8hrs) [ppm]	CO concentration (1hr) [ppm]
A	<9	<35
B	-	-
C	-	-
D	<9	>35
E	>9	>35

2.1.4. Odour acceptance

Simple assessment

Assessment in design

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). If a strong local ambient odour source is suspected, the quality of outdoor air at the site should be documented. This consists of an observational survey of the building site and immediate surroundings to identify local contaminants that may be of concern if allowed to enter the building. A procedure for this is presented in Sections 4.2 and 4.3 of Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Building assessment.
a. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.
b. Evaluation of the applied building materials. The applied materials should be characterized according to the guidelines provided by the Finnish Building Information Foundation (Rakennustieto) (The Building Information Foundation (Rakennustieto) 2008) (ECA-IAQ (European Collaborative Action, Urban Air, Indoor Environment and Human Exposure) 2005).
c. Evaluation of the odour sources and odour dispersal through the building. If odour sources are present in particular spaces, they should be isolated from other spaces by for example by pressurization, air flows, self-closing doors, etc. Particular attention should be paid to cooking and kitchen facilities.

Table 13: Assessment in design

		Odour acceptance		
		Infiltration	Sources	Building materials
A	Excellent	No odour sources in the neighborhood of the building.	No odour sources in the building	M1
B	Good	Odour sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	No odour sources in the building	M1
C	Adequate	Odour sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	Odour sources are present in the building. Particular spaces where odour sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	M2
D	Poor	Odour sources are	Odour sources are	-

		present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	present in the building. Particular spaces where sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	
E	Bad	Odour sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	Odour sources are present in the building. No isolation of particular spaces where sources are present (pressurization, air flows, self-closing doors, etc.)	-

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Simple assessment
Assessment in operation

1. Conduct a facility pre-evaluation and survey preparation:
a. Review complaints log and similar unstructured reports of continuing or episodic concerns, previous occupant satisfaction surveys and/or IAQ audits, and related environmental, health and safety surveys. Document response and actions taken.

2. Conduct a site assessment (qualitative) and characterize condition of the building and its HVAC system as it might affect IAQ:
a. Perform opening interview with the Building Manager, operation and maintenance contractor, custodial contractor and interested tenant representatives.

3. Conduct an occupant survey, concurrent with IAQ physical and environmental evaluation, to determine occupant satisfaction with IAQ and rate the building's satisfaction levels against benchmarks in a database of previously measured buildings. This should include perceptions of fresh air, stuffiness, presence of odours, healthful air, temperature/humidity adequacy, etc. For example, the CBE survey (ASHRAE 2009) or BSI survey could be carried out (Raw 1995).

Table 14: Assessment in operation

		Odour acceptance			
		Complaints log	Infiltration	Sources	Building materials
A	Excellent	No IAQ related complaints reported	No possible odour sources in the neighborhood of the building.	No possible odour sources in the building	M1
B	Good	Only a few[1] of IAQ related complaints	Odour sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	No odour sources in the building	M1
C	Adequate	Only a few[1] of IAQ related complaints	Odour sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	Odour sources are present in the building. Particular spaces where odour sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	M2
D	Poor	The number of IAQ related	Odour sources are present in the	Odour sources are present in the	-

		complaints is considerable[1]	building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	building. Particular spaces where sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	
E	Bad	IAQ related complaints are reported frequently[1]	Odour sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	Odour sources are present in the building. No isolation of particular spaces where sources are present (pressurization, air flows, self-closing doors, etc.)	-

[1] Subjective descriptions should be defined more detailed, for example as the number of complaints related to the total number of building occupants or related to a reference building.
Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in design

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). If a strong local ambient odour source is suspected, the quality of outdoor air at the site should be documented. This consists of an observational survey of the building site and immediate surroundings to identify local contaminants that may be of concern if allowed to enter the building. A procedure for this is presented in Sections 4.2 and 4.3 of Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Building assessment.
a. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.
b. Evaluation of the applied building materials. The applied materials should be characterized according to the guidelines provided by the Finnish Building Information Foundation (Rakennustieto) (The Building Information Foundation (Rakennustieto) 2008) (ECA-IAQ (European Collaborative Action, Urban Air, Indoor Environment and Human Exposure) 2005).
c. Evaluation of the odour sources and odour dispersal through the building. If odour sources are present in particular spaces, they should be isolated from other spaces by for example by pressurization, air flows, self-closing doors, etc. Particular attention should be paid to cooking and kitchen facilities.

Table 15: Assessment in design

		Odour acceptance		
		Infiltration	Sources	Building materials
A	Excellent	No odour sources in the neighborhood of the building.	No odour sources in the building	M1
B	Good	Odour sources are present in the building’s surroundings; however, the risk for contamination of the indoor air is limited.	No odour sources in the building	M1
C	Adequate	Odour sources are present in the building’s surroundings; however, the risk for contamination of the indoor air is limited.	Odour sources are present in the building. Particular spaces where odour sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	M2
D	Poor	Odour sources are present in the building’s surroundings; Analysis of the outdoor air at the site	Odour sources are present in the building. Particular spaces where sources	-

		showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	
E	Bad	Odour sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	Odour sources are present in the building. No isolation of particular spaces where sources are present (pressurization, air flows, self-closing doors, etc.)	-

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in operation

1. Conduct a facility pre-evaluation and survey preparation:
a. Review complaints log and similar unstructured reports of continuing or episodic concerns, previous occupant satisfaction surveys and/or IAQ audits, and related environmental, health and safety surveys. Document response and actions taken.

2. Conduct a site assessment (qualitative) and characterize condition of the building and its HVAC system as it might affect IAQ:
a. Perform opening interview with the Building Manager, operation and maintenance contractor, custodial contractor and interested tenant representatives.

3. Conduct an occupant survey, concurrent with IAQ physical and environmental evaluation, to determine occupant satisfaction with IAQ and rate the building's satisfaction levels against benchmarks in a database of previously measured buildings. This should include perceptions of fresh air, stuffiness, presence of odours, healthful air, temperature/humidity adequacy, etc. For example, the CBE survey (ASHRAE 2009) or BSI survey could be carried out (Raw 1995).

Table 16: Assessment in operation

		Odour acceptance			
		Complaints log	Infiltration	Sources	Building materials
A	Excellent	No IAQ related complaints reported	No possible odour sources in the neighborhood of the building.	No possible odour sources in the building	M1
B	Good	Only a few[1] of IAQ related complaints	Odour sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	No odour sources in the building	M1
C	Adequate	Only a few[1] of IAQ related complaints	Odour sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	Odour sources are present in the building. Particular spaces where odour sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	M2
D	Poor	The number of IAQ related	Odour sources are present in the	Odour sources are present in the	-

		complaints is considerable[1]	building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	building. Particular spaces where sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	
E	Bad	IAQ related complaints are reported frequently[1]	Odour sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	Odour sources are present in the building. No isolation of particular spaces where sources are present (pressurization, air flows, self-closing doors, etc.)	-

[1] Subjective descriptions should be defined more detailed, for example as the number of complaints related to the total number of building occupants or related to a reference building.
Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

2.1.5. Particulate matter

Simple assessment

Assessment in design

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). If local ambient particle sources are suspected, for example industrial facilities, the quality of outdoor air at the site should be documented. This consists of an observational survey of the building site and immediate surroundings to identify local contaminants that may be of concern if allowed to enter the building. A procedure for this is presented in Sections 4.2 and 4.3 of Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Building assessment.
a. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.
b. Evaluation of the applied building materials. The applied materials should be characterized according to guidelines provided by the Finnish Building Information Foundation (Rakennustieto) (The Building Information Foundation (Rakennustieto) 2008) (ECA-IAQ (European Collaborative Action, Urban Air, Indoor Environment and Human Exposure) 2005) .
c. Evaluation of the particle sources and particle dispersal through the building. If particle sources are present in particular spaces, they should be isolated from other spaces by for example by pressurization, air flows, self-closing doors, etc.

Table 17: Assessment in design

		Particular matter		
		Infiltration	Sources	Building materials
A	Excellent	No particle sources in the neighborhood of the building.	No particle sources in the building	M1
B	Good	Particle sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	No particle sources in the building	M1
C	Adequate	Particle sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	Particle sources are present in the building. Particular spaces where odour sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	M2

D	Poor	Particle sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	Particle sources are present in the building. Particular spaces where sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	-
E	Bad	Particle sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	Particle sources are present in the building. No isolation of particular spaces where sources are present (pressurization, air flows, self-closing doors, etc.)	-

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Simple assessment

Assessment in operation

1. Conduct a facility pre-evaluation and survey preparation:
a. Review complaints log and similar unstructured reports of continuing or episodic concerns, previous occupant satisfaction surveys and/or IAQ audits, and related environmental, health and safety surveys. Document response and actions taken.

2. Conduct a site assessment (qualitative) and characterize condition of the building and its HVAC system as it might affect IAQ:
a. Perform opening interview with the Building Manager, operation and maintenance contractor, custodial contractor and interested tenant representatives.

3. Conduct an occupant survey, concurrent with IAQ physical and environmental evaluation, to determine occupant satisfaction with IAQ and rate the building's satisfaction levels against benchmarks in a database of previously measured buildings. This should include perceptions of fresh air, stuffiness, presence of odours, healthful air, temperature/humidity adequacy, etc. For example, the CBE survey (ASHRAE 2009) or BSI survey could be carried out (Raw 1995).

Table 18: Assessment in operation

		Particular matter			
		Complaints log	Infiltration	Sources	Building materials
A	Excellent	No IAQ related complaints reported	No particle sources in the neighborhood of the building.	No particle sources in the building	M1
B	Good	Only a few[1] of IAQ related complaints	Particle sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	No particle sources in the building	M1
C	Adequate	Only a few[1] of IAQ related complaints	Particle sources are present in the building's surroundings; however, the risk for contamination of the indoor air is limited.	Particle sources are present in the building. Particular spaces where odour sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	M2
D	Poor	The number of IAQ related	Particle sources are present in the	Particle sources are present in the	-

		complaints is considerable[1]	building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	building. Particular spaces where sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	
E	Bad	IAQ related complaints are reported frequently[1]	Particle sources are present in the building's surroundings; Analysis of the outdoor air at the site showed that the OA quality is poor and the risk for contamination of the indoor air is considerable.	Particle sources are present in the building. No isolation of particular spaces where sources are present (pressurization, air flows, self-closing doors, etc.)	-

[1] Subjective descriptions should be defined more detailed, for example as the number of complaints related to the total number of building occupants or related to a reference building.

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment
Assessment in design

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). Evaluation of the particle sources and particle dispersal should be carried out using continuous measurement of fine particulates (PM_{10}), which are an indicator of pollutants that may be emitted. A variety of air sampling systems are commercially available that include centralized location of instrumentation and data recording. Particles (PM_{10}) are collected at the building site during one day or if possible during one year. Target values and guidelines for outdoor air quality are presented in Standard 62.1-2007 (ASHRAE 62-2007 2007).

2. Building assessment.
a. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect IAQ, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.
b. Evaluation of the applied building materials. The applied materials should be characterized according to guidelines provided by the Finnish Building Information Foundation (Rakennustieto) (The Building Information Foundation (Rakennustieto) 2008) (ECA-IAQ (European Collaborative Action, Urban Air, Indoor Environment and Human Exposure) 2005) .
c. Evaluation of the particle sources and particle dispersal through the building. If particle sources are present in particular spaces, they should be isolated from other spaces by for example by pressurization, air flows, self-closing doors, etc.

Table 19: Assessment in design

		Particular matter		
		Outdoor Particulate concentration (PM_{10}) [$\mu g/m^3$]	Sources	Building materials
A	Excellent	<150 (daily average) < 50 (yearly average)	No particle sources in the building	M1
B	Good	<150 (daily average) < 50 (yearly average)	No particle sources in the building	M1
C	Adequate	<150 (daily average) < 50 (yearly average)	Particle sources are present in the building. Particular spaces where odour sources are present are isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	M2
D	Poor	<150 (daily average) > 50 (yearly average)	Particle sources are present in the building. Particular spaces where sources are present are	-

			isolated from other spaces (pressurization, air flows, self-closing doors, etc.)	
E	Bad	>150 (daily average) > 50 (yearly average)	Particle sources are present in the building. No isolation of particular spaces where sources are present (pressurization, air flows, self-closing doors, etc.)	-

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in operation

1. The quality of the outdoor air at the site is determined and characterized based on the US EPA National Ambient Air Quality Standards data and associated US Weather Service data for the site (or closest airport measuring station). If local ambient particle sources are suspected, for example industrial facilities, the quality of outdoor air may be analyzed using additional measurements of the particulate concentration ($PM_{2.5}$) in the outdoor air.

2. Evaluation of the particle sources and particle dispersal through the building. To establish a baseline for detection of unexpected events in occupancy or HVAC system operation that need to be addressed, continuous measurement of fine particulates ($PM_{2.5}$), which are an indicator of pollutants that may be emitted from materials or introduced by occupant activities (copy machines, whiteboard markers, cooking, etc). A variety of air sampling systems are commercially available that include centralized location of instrumentation and data recording. Particles ($PM_{2.5}$) are collected at a height of 1.1m above the floor at fixed sites in the building during one day.

$PM_{2.5}$measurements should be used only to establish normal operating conditions (baseline), against which excursions may be identified. Such excursions, typically short term events, may or may not require corrective action. Sampling is recommended only in representative (especially in critical spaces with highly varying occupancy) spaces.

It is recommended only to measure particulate matter concentrations only if they are known or suspected to be present. For background information relative to the IAQ, procedure concentrations could be compared with limits listed in the references cited in Tables B-1 and B-2 of Standard 62.1, Appendix B (ASHRAE 62-2007 2007). However, specialized expertise should be sought before selecting a value for use in estimating outdoor airflows based on the concentrations listed. Meeting some or all of the listed values does not ensure acceptable IAQ. For additional information, the reader is referred to (ASHRAE 62-2007 2007) and (Steskens, Loomans 2010). Within the Perfection project, the target value of 40 $\mu g/m^3$ recommended by Schuh (Schuh 2000) is used.

Table 20: Assessment in operation

	Particulate matter concentration
	$PM_{2.5}$ (average) [$\mu g/m^3$]
A	< 10
B	-
C	< 40
D	> 40
E	-

2.2. Water quality

2.2.1. Drinking water quality

Simple assessment

Assessment in design

In order to guarantee drinking water quality in buildings, authorities responsible for building safety should be responsible for developing and implementing water safety plans (WSPs) (World Health Organization (WHO) 2008) for example the water safety plan presented in Table 16 of the PERFECTION's Subtask 1.3 Report (Steskens, Loomans 2010).

Table 21: Assessment in design

	Drinking water quality
A	A water safety plan is available and implemented
B	-
C	-
D	-
E	A water safety plan is not available and implemented

Simple assessment

Assessment in operation

In order to guarantee drinking water quality in buildings, authorities responsible for building safety should be responsible for developing and implementing water safety plans (WSPs) (World Health Organization (WHO) 2008), for example the water safety plan presented in Table 16 of the PERFECTION's Subtask 1.3 Report (Steskens, Loomans 2010).

Table 22: Assessment in design

	Drinking water quality
A	A water safety plan is available and implemented
B	-
C	-
D	-
E	A water safety plan is not available and implemented

Detailed assessment

Assessment in design

In order to guarantee drinking water quality in buildings, authorities responsible for building safety should be responsible for developing and implementing water safety plans (WSPs) (World Health Organization (WHO) 2008) for example the water safety plan presented in Table 16 of the PERFECTION's Subtask 1.3 Report (Steskens, Loomans 2010).

If a problem with respect to the quality of the drinking water at the building site is suspected, laboratory tests are carried out to evaluate the quality of the available drinking water and the availability of possible contaminants. The measured contaminant concentrations should meet the requirements provided by WHO (World Health Organization (WHO) 2008).

The assessment of the indicator drinking water quality considers the evaluation of six conditions by which the quality of the drinking water is maintained.

Table 23: Assessment in design

	Drinking water quality
A	A water safety plan is available and implemented. The drinking water quality, evaluated using a laboratory test, meets the requirements set by WHO (World Health Organization (WHO) 2008)
B	-
C	-
D	-
E	1. A water safety plan is not available and implemented, OR 2. The drinking water quality, evaluated using a laboratory test, does not meet the requirements set by WHO (World Health Organization (WHO) 2008)

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in operation

In order to guarantee drinking water quality in buildings, authorities responsible for building safety should be responsible for developing and implementing water safety plans (WSPs) (World Health Organization (WHO) 2008) for example the water safety plan presented in Table 16 of the PERFECTION's Subtask 1.3 Report (Steskens, Loomans 2010).

If a problem with respect to the quality of the drinking water is suspected, laboratory tests are carried out to evaluate the quality and the availability of possible contaminants. The measured contaminant concentrations should meet the requirements provided by WHO (World Health Organization (WHO) 2008).

The assessment of the indicator drinking water quality considers the evaluation of seven conditions by which the quality of the drinking water is maintained.

Table 24: Assessment in design

	Drinking water quality
A	Good 1. A water safety plan is available and implemented. 2. Measurement, registration and control of the water temperature (legionella can proliferate at temperatures between 25-55^{o}C) 3. The drinking water quality, evaluated using a laboratory test, meets the requirements set by WHO (World Health Organization (WHO) 2008)
B	-
C	-
D	-
E	Bad. One or more conditions (presented in class A) is/are not fulfilled

2.2.2. Rain/re-use water quality

Simple assessment

Assessment in design

In a similar fashion to all drinking water supplies, the quality of rain/re-use water in a building should be guaranteed by development and implementation of a water safety plan (WSP). A range of visual inspections (and laboratory testing of rainwater quality) should be scheduled. The recommended regime of inspections and associated maintenance is not particularly onerous, but it is necessary for quality assurance. For additional information the reader is referred to PERFECTION's Subtask 1.3 Report (Steskens, Loomans 2010).

Table 25: Assessment in design

	Rain/re-use water quality
A	A water safety plan is available and implemented
B	-
C	-
D	-
E	A water safety plan is not available and implemented

Simple assessment

Assessment in operation

In a similar fashion to all drinking water supplies, rain/re-use water systems need to be monitored. Monitoring of domestic rainwater tanks consists of a range of visual inspections rather than laboratory testing of rainwater quality. The recommended regime of inspections and associated maintenance is not particularly onerous, but it is necessary for quality assurance. Instead of monitoring rainwater quality using laboratory tests, a proactive approach which prevents development of problems that can lead to deterioration of water quality, may be sufficient.

Once a rainwater tank is installed, it is recommended that the following components of the roof catchment and tank be inspected at least every six months:

- Gutters – generally will need cleaning as well as inspection. If inspection finds large amounts of leaf material or other debris, then inspection and cleaning frequency may need to be increased.
- Roof – check for the presence of accumulated debris including leaf and other plant material. Accumulated material should be cleared. If tree growth has led to overhanging branches these should be pruned.
- Tank inlets, insect-proofing and leaf filters – if necessary these should be cleaned and repaired.
- Tank and tank roof – check structural integrity of the tank including the roof and access cover. Any holes or gaps should be repaired.
- Internal inspection – check for evidence of access by animals, birds or insects including the presence of mosquito larvae. If present, identify and close access points. If there is any evidence of algal growth (green), find and close points of light entry.
- Pipework – check for structural integrity. Sections of pipework that are not self-draining should be drained.

In addition to biannual inspections, tanks should be inspected every 2-3 years for the presence of accumulated sediments. If the bottom of the tank is covered with sediment the tank should be cleaned.

Table 26: Assessment in operation

	Rain/re-use water quality
A	A water safety plan is available and implemented. Visual inspection of gutters, roof, tank inlets, tank and tank roof, internal inspection and inspection of pipe work is carried out twice a year and tanks are inspected every 2-3 years for the presence of accumulated sediments.
B	-
C	-
D	-
E	One or more conditions (presented in class A) is/are not fulfilled.

Detailed assessment
Assessment in design

In a similar fashion to all drinking water supplies, the quality of rain/re-use water in a building should be guaranteed by development and implementation of a water safety plan (WSP). A range of visual inspections (and laboratory testing of rainwater quality) should be scheduled. The recommended regime of inspections and associated maintenance is not particularly onerous, but it is necessary for quality assurance. For additional information the reader is referred to PERFECTION's Subtask 1.3 Report (Steskens, Loomans 2010).

Table 27: Assessment in design

	Rain/re-use water quality
A	A water safety plan is available and implemented
B	-
C	-
D	-
E	A water safety plan is not available and implemented

Detailed assessment

Assessment in operation

Requirements have been developed based on the guidelines provided by the German Association for Rainwater Harvesting and Water Utilisation (FBR (Fachvereinigung Betriebs- und Regenwassernutzung e.V., Association for Rainwater Harvesting and Water Utilisation) 2005). The hygiene requirements for total coliform and faecal coliform bacteria are oriented towards the EU Guidelines for Bathing Water (76/160/EEC) (EU-Directive for Bathing Water 1975). This was based on the assumption that persons having body contact with this water and moreover, those who even occasionally swallow some of it will not be subjected to a health risk if the limit values are held. Moreover, the quality requirements for grey water and rain water are recommended for laundry activities. For additional information the reader is referred to PERFECTION's Subtask 1.3 Report (Steskens, Loomans 2010).

<table>
<tr><td></td><td colspan="3">Rain/re-use water quality</td></tr>
<tr><td></td><td>General requirements</td><td colspan="2">Chemical/Biological Requirements</td></tr>
<tr><td rowspan="6">A</td><td rowspan="6">Good
1. A water safety plan is available and implemented
2. Visual inspection of gutters, roof, tank inlets, tank and tank roof, internal inspection and inspection of pipe work is carried out twice a year and tanks are inspected every 2-3 years for the presence of accumulated sediments.</td><td>Biochemical oxygen demand (BOD_7)</td><td>$BOD_7 < 5$ mg/l</td></tr>
<tr><td>Total coliform bacteria</td><td>100 /ml</td></tr>
<tr><td>Faecal coliform bacteria (E. coli)</td><td>10 /ml</td></tr>
<tr><td>Turbidity</td><td>2 NTU</td></tr>
<tr><td>pH</td><td>6-9</td></tr>
<tr><td>Biochemical oxygen demand (BOD_7)</td><td>$BOD_7 < 5$ mg/l</td></tr>
<tr><td>B</td><td colspan="3">-</td></tr>
<tr><td>C</td><td colspan="3">-</td></tr>
<tr><td>D</td><td colspan="3">-</td></tr>
<tr><td>E</td><td colspan="3">Bad
One or more conditions (presented in class A) is/are not fulfilled</td></tr>
</table>

2.3. Thermal comfort

2.3.1. Operative temperature

Simple assessment

Assessment in design

1. Conduct a facility pre-evaluation of the thermal systems in the building:
a. Review facility operational documentation. Review building and tenant descriptions, drawings, and information on the facility construction. Document the occupancy types and operations for each space type within the facility. Review building plans, including HVAC designs.
b. Prepare for site assessment. Obtain HVAC system attribute information. The attribute list will be provided by the building owner/designer to include a list of systems that affect thermal comfort, scheduled operation, typical setpoints, and control of outside air. Ensure all pertinent facility information is provided by the building owner prior to initiating the site visit.

Assessment of the thermal comfort is carried out based on the evaluation of the operative temperatures along the lines of the technical target values which have been specified by the Finnish Society of Indoor Air Quality and Climate (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008). The target values are defined as function of the 24h moving average of the outside temperature t_u.

Table 28: Assessment in design

	A	B	C	D	E
	Excellent	Good	Adequate	Poor	Bad
Operative temperature t_{op} [^oC] $t_u \le 10^oC$ $10< t_u \le 20^oC$ $t_u > 20^oC$	 21.5 $21.5+0.3(t_u-10)$ 24.5	 21.5 $21.5+0.3(t_u-10)$ 24.5	 21.5 $21.5+0.4(t_u-10)$ 24.5	 21.5 $21.5+0.4(t_u-10)$ 24.5	 - - -
Deviation allowed from set value [^oC]	± 0.5	± 1.0	± 1.0	± 1.0	-
Maximum t_{op} [^oC]	t_{op} + 1.5	$t_u \le 10^oC$: $t_{op}+1.5$ $10< t_u \le 20^oC$: $23+0.4(t_u-10)$ $t_u > 20^oC$: 27	$t_u \le 15^oC$: 25 $t_u > 15^oC$: t_u+5	$t_u \le 15^oC$: 25 $t_u > 15^oC$: t_u+5	-
Minimum t_{op} [^oC]	20	20	18	18	-
Stability of environment [% of operating time]	95%	95%	90%	80%	-

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Simple assessment

Assessment in operation

The following tools are used for obtaining information about the building, its environment, and the occupants' responses to the environment.

- Complaint logs, if available, may be reviewed for evidence of occupant dissatisfaction and its causes. Trends in complaint rates over time may indicate occupant reactions to changes in building operation. Complaint logs do not provide systematic evaluation of a building's IEQ.
- Occupant survey of satisfaction with indoor environmental quality, including overall thermal comfort, and the impact of the thermal environment on self-reported job performance. The most effective surveys of this type address satisfaction with a full range of environmental attributes (e.g., thermal comfort, indoor air quality, lighting, acoustics, etc.) and may therefore be also appropriate for other assessment of other performance indicators at this level. Examples are the CBE survey and the BUS occupant survey in the U.K. (ASHRAE 2009).

The occupant survey is used for the prediction of the Percentage People Dissatisfied in the building.

Table 29: Assessment in operation

		Operative temperature/PPD		
		PMV index	PPD [%]	Stability of Environment[1] [% of operating time]
A	Excellent	-0.2<PMV<+0.2	<6	≥ 95%
B	Good	-0.2<PMV<+0.2	<6	≥ 80%
C	Adequate	-0.5<PMV<+0.5	<10	≤ 80%
D	Poor	-0.7<PMV<+0.7	<15	≥ 80%
E	Bad	PMV<-0.7 V PMV>+0.7		-

[1] Defined as the percentage of the operating/occupation time a condition is fulfilled

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in design

A building simulation is used for obtaining information about the building, its environment, and the occupants' response to the environment. The building simulation results in a data set of physical quantities. These quantities are used to compare the building's thermal environment against the technical target values which have been specified by the Finnish Society of Indoor Air Quality and Climate (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008). The target values are defined as function of the 24h moving average of the outside temperature t_u.

Table 30: Assessment in design

	A	B	C	D	E
	Excellent	Good	Adequate	Poor	Bad
Operative temperature t_{op} [^oC] $t_u \leq 10^oC$ $10< t_u \leq 20^oC$ $t_u > 20^oC$	21.5 21.5+0.3(t_u-10) 24.5	21.5 21.5+0.3(t_u-10) 24.5	21.5 21.5+0.4(t_u-10) 24.5	21.5 21.5+0.4(t_u-10) 24.5	- - -
Deviation allowed from set value [^oC]	± 0.5	± 1.0	± 1.0	± 1.0	-
Maximum t_{op} [^oC]	t_{op} + 1.5	$t_u \leq 10^oC$: t_{op}+1.5 $10< t_u \leq 20^oC$: 23+0.4(t_u-10) $t_u > 20^oC$: 27	$t_u \leq 15^oC$: 25 $t_u > 15^oC$: t_u+5	$t_u \leq 15^oC$: 25 $t_u > 15^oC$: t_u+5	-
Minimum t_{op} [^oC]	20	20	18	18	-
Stability of environment [% of operating time]	95%	95%	90%	80%	-

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in operation

The following tools are used in for obtaining information about the building, its environment, and the occupants' response to the environment.

- Background data: Obtain the same background data as in the simple level about the building, its environmental control system, and its occupancy.
- Physical data sufficient to describe the thermal environment near the occupants. This needs to be continuously monitored, so that the local conditions are known. Occupant presence may be monitored as part of the environmental conditions. In perimeter spaces, the operation of windows, shades, blinds may be recorded through photography or visual observation.

Physical measurements are primarily used to identify causes of problems, but can also be used to compare the building's thermal environment against the requirements of standards such as Standard 55 (ASHRAE 55-2004R 2004), ISO 7730 (ISO 7730-2005 2005), and EN 15251 (BS EN 15251-2007 2007). The PMV model is the basis for Standard 55 comfort zone. SET thermophysiological model is more applicable for conditions with air movement above 0.15m/s. The Adaptive Comfort Model in ASHRAE Standard 55 is used for occupants of non-air conditioned buildings having access to operable windows, while in EN 15251 an Adaptive Model is applied for buildings (with or without air conditioning available) when they are in free-running mode.

A number of parameters are measured continuously during the period of performance measurement appraisal. Loggers can be used with many of these sensors.

- The parameters temperature and relative humidity are the most conveniently and inexpensively measured and logged. If the space has relatively still air, and there are no solar or longwave radiant loads impacting the occupant through windows, these two parameters should be adequate. The globe thermometer best represents temperature effects on the occupant. With significant longwave radiant loads, taking both shielded and globe temperature readings will identify the mean radiant temperature and its difference from air temperature.
- For perimeter zones with solar radiation, pyranometer data loggers are available. The inexpensive ones are not very accurate, but adequate to show the relationship between potential presence of radiation at a workstation and the actual presence of radiation, as affected by blind or shade usage.
- For natural ventilation, anemometers are needed that either measure omnidirectionally (eg, spherical hotwire sensors), or are directional but with a sufficiently wide range of acceptance that they can be confidently oriented in the expected wind direction.
- Vertical temperature gradient limits, floor surface temperature limits in Standard 55. The ASHRAE Database has temperatures and air velocities measured at heights above the floor of 0.1m, 0.6m (midbody when seated), and 1.1 (head height when seated). 1.7 m is head height for a standing person.
- Radiant asymmetry limits (horizontal and vertical) given in Standard 55. These are primarily used for limiting longwave radiation from building surfaces. The impact of direct sun on building occupants is not yet adequately addressed in Standard 55. A report for the National Fenestration Rating Council (Huizenga 2006b) proposes approaches to evaluating comfort in the presence of radiation in perimeter zones. For workstations, there should be no direct solar gain allowed on the occupant, even when filtered through screens; as little as 5% of incident radiation produces warmth discomfort.

- Rates of allowed temperature change specified in Standard 55.

Logging the hours of occupancy and related occupant-based measurements would be useful for reporting comfort in relation to occupied periods. The presence of occupant(s) can be measured at individual workstations or in zones with a group of workstations. Moreover, the clothing and thermal sensation of the occupants should be analyzed.

The data logging interval depends on the comfort effects being investigated, with values ranging between 1 and 15 minutes. Loggers may internally sample and average the data within the recorded interval, which in most cases is the meaningful mode of measurement. Air movement measurements, for example, should be based on 3-minute mean values.

The usual first step is to graph the trend logs of environmental conditions, and tabulate means and distributions of each. Comfort metrics such as thermal sensation, comfort, and thermal acceptability should be accumulated for the number of hours they exceed a limit. This can be done per building zone, for normal working hours, or per accumulated occupied workstation-hours. (An accumulated metric might be: total hours of discomfort, divided by total occupied hours). There are no standard procedures for accumulating point-in time comfort metrics. In addition to accumulated metrics, the report should also identify occupant adaptations (such as usage of blinds, shades and operable windows, clothing and activity changes), rates of thermal change indoors, and other thermal characteristics of the building's normal operation.

Based on the physical measurements of the thermal comfort in the building the Predicted Mean Vote (PMV) index can be determined and analyzed.

Table 31: Assessment in operation

		Operative temperature/PPD		
		PMV index	PPD [%]	Stability of Environment[1] [% of operating time]
A	Excellent	-0.2<PMV<+0.2	<6	≥ 95%
B	Good	-0.2<PMV<+0.2	<6	≥ 80%
C	Adequate	-0.5<PMV<+0.5	<10	≤ 80%
D	Poor	-0.7<PMV<+0.7	<15	≥ 80%
E	Bad	PMV<-0.7 V PMV>+0.7		-

[1] Defined as the percentage of the operating/occupation time a condition is fulfilled

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

2.4. Visual comfort

2.4.1. Illuminance

Simple assessment
Assessment in design

1. Location/orientation. The location and orientation of the building is analyzed focusing on the entrance of direct solar radiation. Inspection of the window coverings with respect to the facades were direct solar radiation may lead to uncomfortable visual conditions in the spaces is carried out.

2. Artificial lighting. The artificial lighting in the building is analyzed focusing on the adjustability, control, and relocation of the lighting in order to obtain the required illuminance levels for the visual task(s) carried out in the spaces and to avoid visual defects (BS EN 12464-1:2003 2003)

Table 32: Assessment in design

		Illuminance		
		Illuminance	Visual defects due to direct solar radiation	Visual defects due to artificial lighting
A	Excellent	The level of illuminance is varied as required, i.e to provide lower levels for example for VDU screens and higher level for paper work.	Window coverings are operable by occupants, or automated to respond to prevailing external conditions	Lights are switched on/off and dimmed by occupants in the zone. Ceiling light fixtures can be easily relocated within ceiling grid without technical expertise
B	Good	The level of illuminance is sufficient and meets the corresponding requirements. Lower levels are provided if required or could be readily provided.	Window coverings are easily operable by occupants	Lights are switched on/off by occupants in the zone. Ceiling light fixtures can be easily relocated within ceiling grid by a technician (without the need for rewiring a circuit or group of fixtures).
C	Adequate	The level of illuminance is sufficient and meets the requirements in all spaces. No lower levels of illuminance are provided, and it is not practicable to make the necessary changes	Window coverings are operable by occupants, but because of the type of covering material, e.g. opaque blinds, or floor plate configuration, it is difficult to adjust against glare and still have daylight entering the space	Lights are switched on/off on request of the occupants in the zone. Ceiling lights can be relocated within ceiling grid, but nearby occupants will be distracted, circuits or groups of fixtures need to be rewired.

D	Poor	The level of illuminance is excessively high, or too low, for the intended visual task(s), in a few of the areas used.	Window coverings are operable by facilities people, on request from occupants	Occupants can request lights to be switched on/off over an entire floor or area of tenancy. Ceiling fixtures are difficult and expensive to relocate.
E	Bad	The level of illuminance is excessively high, or too low, for the intended visual task(s), in most of the areas used.	There are no window coverings, or coverings are not operable	There is no local control of ceiling lights. Switching is controlled by the building operator or designated person. Ceiling light fixtures can only be relocated by major reconstruction of the ceiling

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Simple assessment

Assessment in operation

1. Location/orientation. The location and orientation of the building is analyzed focusing on visual defects due to direct solar radiation. Inspection of the window coverings with respect to the facades were direct solar radiation may lead to uncomfortable visual conditions in the spaces is carried out.

2. Illuminance. The lighting in the building is analyzed focusing on the required illuminance levels for the visual task(s) carried out in the spaces (BS EN 12464-1:2003 2003). Moreover, the spaces in the building are inspected for visual defects and glare.

Table 33: Assessment in operation

		Illuminance		
		Illuminance	Visual defects	Glare
A	Excellent	The level of illuminance is varied as required, i.e to provide lower levels for example for VDU screens and higher level for paper work*.	There are no apparent lighting defects	There is no glare from windows and/or artificial lights
B	Good	The level of illuminance is sufficient and meets the corresponding requirements*. Lower levels are provided if required or could be readily provided, .e.g. by partial delamping	Any lighting defects do not affect staff at their workstations, and are not reported as a problem	Glare from windows and/or lights is barely visible, and can easily be decreased.
C	Adequate	The level of illuminance is sufficient and meets the requirements in all spaces*. No lower levels of illuminance are provided, and it is not practicable to make the necessary changes	There is one visual defect, e.g. gloomy appearance of the ceiling, flicker, extreme contrasts, or different colour fluorescent lamps	Glare from windows and/or lights is clearly visible, but could be decreased at moderate cost, e.g. by installing parabolic reflectors on ceiling luminaries
D	Poor	The level of illuminance is excessively high, or too low, for the intended visual task(s), in a few of the areas used.	There are one or two visual defects, e.g. gloomy appearance of the ceiling, flicker, and extreme contrasts.	At many workstations, e.g. 40% - 60%, there is unavoidable glare from windows and lights, with no effective glare control
E	Bad	The level of illuminance is excessively high, or too low, for the intended visual task(s), in most of the areas used.	There are three or more visual defects, e.g. gloomy appearance of the ceiling, flicker, and extreme contrasts.	At all workstations there is or would be unavoidable glare from windows and lights, with no effective glare control

*In spaces where higher levels are required the illuminance level should be sufficient to read fine print. For additional information the reader is referred to ASTM Standards on Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995)

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment
Assessment in design

1. Prediction of Illuminance.
The level of illuminance is predicted using a computer model, such as DIALux or RADIANCE.
A regular 'grid' of points of evaluation is used to completely cover the surface under consideration. Typically the spacing between measurement points is set to one-fourth the spacing between luminaires. The height of these points depends on where the primary task is performed. For most office spaces, where the task is found at desk level, points will be measured at 0.76 meters above the floor. In some spaces where the primary task is walking, the measurements might be taken at floor level.

For luminance predictions the lighting practitioner is interested in what the various workers in a space see with regards to the 'brightness' of various points in the room. For each worker position and orientation, luminance predictions would be made in the following points in the room:

- On all luminaires within the normal field of view.
- On the ceiling near any luminaire
- On the ceiling between any two luminaires
- On the opposite wall above, even with, and below eye level, in line with a luminaire
- On the opposite wall above, even with, and below eye level, between two luminaires
- The floor
- Any windows, shades and blinds within the normal field of view
- The task
- The area immediately surrounding the task
- The peripheral surroundings of the task
- The highest luminance in the field of view

Average illuminance levels, max-to-min uniformity ratio, and average-to-min uniformity ratio are calculated. The calculated values are compared to the requirements set by the corresponding standards (BS EN 12464-1:2003 2003). In order to limit the effects of adaptation and disability glare, luminance ratios generally should not exceed the following:
Over the task itself – 1.4:1

- Between the task and an adjacent VDT screen – 3:1 (or 1:3)
- Between the task and the immediate surroundings – 3:1 (or 1:3)
- Between the task and remote surfaces – 10:1 (or 1:10)

However, keep in mind that it is generally not desirable to maintain these last three ratios throughout the entire space. To maintain visual interest and distant eye focus, small areas exceeding those ratios are desirable. Such areas might include artwork, accent finishes on room surfaces, windows and furniture and accent lighting.

2. Discomfort glare
At this level, computations are made based on the lighting systems as designed. Software, for example DIALux and RADIANCE, is generally available from European organizations to make computations of Unified Glare Rating (Commission Internationale de l'Eclairage (CIE) 1995). The level of visual discomfort at the worst location is determined based on the Unified Glare Rating. Target values for the Unified Glare Rating are presented in (BS EN 12464-1:2003 2003).

Table 34: Assessment in design

		Illuminance	
		Illuminance	Glare
A	Excellent	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR meets the requirements in all spaces.
B	Good	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR meets the requirements in all spaces.
C	Adequate	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR meets the requirements in all spaces.
D	Poor	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR does not meet the requirements in all spaces.
E	Bad	The measured level of illuminance is not sufficient and does not meet the requirements in all spaces.	The UGR does not meet the requirements in all spaces.

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in operation

1. Illuminance measurements.
A regular 'grid' of measurement points is used to completely cover the surface under consideration. Typically the spacing between measurement points is set to one-fourth the spacing between luminaires. It is also typical to not measure right out to the walls unless it is known that there are work stations there. The height of these points depends on where the primary task is performed. For most office spaces, where the task is found at desk level, points will be measured at 0.76 meters above the floor. In some spaces where the primary task is walking, the measurements might be taken at floor level.

For luminance measurements the lighting practitioner is interested in what the various workers in a space see with regards to the 'brightness' of various points in the room. For each worker position and orientation, luminance measurements would be made with a luminance meter of the following points in the room:

- On all luminaires within the normal field of view.
- On the ceiling near any luminaire
- On the ceiling between any two luminaires
- On the opposite wall above, even with, and below eye level, in line with a luminaire
- On the opposite wall above, even with, and below eye level, between two luminaires
- The floor
- Any windows, shades and blinds within the normal field of view
- The task
- The area immediately surrounding the task
- The peripheral surroundings of the task
- The highest luminance in the field of view

Average illuminance levels, max-to-min uniformity ratio, and average-to-min uniformity ratio are calculated. The calculated values are compared to the requirements set by the corresponding standards (BS EN 12464-1:2003 2003). In order to limit the effects of adaptation and disability glare, luminance ratios generally should not exceed the following:
Over the task itself – 1.4:1

- Between the task and an adjacent VDT screen – 3:1 (or 1:3)
- Between the task and the immediate surroundings – 3:1 (or 1:3)
- Between the task and remote surfaces – 10:1 (or 1:10)

However, keep in mind that it is generally not desirable to maintain these last three ratios throughout the entire space. To maintain visual interest and distant eye focus, small areas exceeding those ratios are desirable. Such areas might include artwork, accent finishes on room surfaces, windows and furniture and accent lighting.

For additional information regarding the measurement methods and protocols, the reader is referred to ASHRAE Performance Measurement Protocols for Commercial Buildings (ASHRAE 2009).

2. Discomfort glare
At this level, computations are made based on the lighting systems as designed. Software is generally available from European organizations to make computations of Unified Glare Rating (Commission Internationale de l'Eclairage (CIE) 1995). The level of visual discomfort at the worst location is

determined based on the Unified Glare Rating. Target values for the Unified Glare Rating are presented in (BS EN 12464-1:2003 2003).

3. Occupant Survey
The Center for the Built Environment (CBE) has developed the Occupant Indoor Environmental Quality (IEQ) Survey. This survey covers several indoor quality issues including lighting. Accumulation and review of composite results is required. Recurrent themes and severe problem areas are analyzed. Care must be taken, though, to accept the fact that responses may vary significantly based on individual preferences. The same light level, in the same work station design will be deemed as too dark for one group of employees while other employees may say it is too bright. It must be decided if individual modifications in the lighting design will be allowed to address such findings. Current lighting system design is trending towards allowing the individual to have more control over the lighting specific to their work station (ASHRAE 2009).

Table 35: Assessment in operation

		Illuminance		
		Illuminance	Glare	Percentage People Dissatisfied [%]
A	Excellent	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR meets the requirements in all spaces.	< 6
B	Good	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR meets the requirements in all spaces.	< 10
C	Adequate	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR meets the requirements in all spaces.	< 15
D	Poor	The measured level of illuminance is sufficient and meets the requirements in all spaces.	The UGR does not meet the requirements in all spaces.	> 15
E	Bad	The measured level of illuminance is not sufficient and does not meet the requirements in all spaces.	The UGR does not meet the requirements in all spaces.	> 15

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

2.4.2. Daylight factor

Simple assessment

Assessment in design

1. Location/orientation. The location and orientation of the space in the building is analyzed focusing on the view to outside and daylight entrance.

Table 36: Assessment in design

		Daylight factor
A	Excellent	The space is located at the outside of the building. Daylight entrance is relatively high, i.e. the surface of the windows is 50%[1] or larger compared to the facade. The user has an unblocked view to the outside.
B	Good	The space is located near an atrium. Daylight entrance is relatively high, i.e. the surface of the windows is 50%[1] or larger compared to the facade. The user has an unblocked view to the outside.
C	Adequate	The space is located at the outside near an atrium. The surface of the windows is smaller than 50 %[1] compared to the facade. The user has an unblocked view to the outside.
D	Poor	The space is located at the outside near an atrium. The surface of the windows is smaller than 50 %[1] compared to the facade. The user has a blocked view to the outside.
E	Bad	The space is located at the inside of the building or at the outside with no windows.

[1] Please notice that this percentage may be changed arbitrarily according to the specific requirements of the building design

Simple assessment

Assessment in operation

1. Location/orientation. The location and orientation of the space in the building is analyzed focusing on the view to outside and daylight entrance.

Table 37: Assessment in operation

		Daylight
A	Excellent	The space is located at the outside of the building. Daylight entrance is relatively high, i.e. the surface of the windows is 50%[1] or larger compared to the facade. The user has an unblocked view to the outside.
B	Good	The space is located near an atrium. Daylight entrance is relatively high, i.e. the surface of the windows is 50%[1] or larger compared to the facade. The user has an unblocked view to the outside.
C	Adequate	The space is located at the outside near an atrium. The surface of the windows is smaller than 50 %[1] compared to the facade. The user has an unblocked view to the outside.
D	Poor	The space is located at the outside near an atrium. The surface of the windows is smaller than 50 %[1] compared to the facade. The user has a blocked view to the outside.
E	Bad	The space is located at the inside of the building or at the outside with no windows.

[1] Please notice that this percentage may be changed arbitrarily according to the specific requirements of the building design

Detailed assessment
Assessment in design

1. Prediction of daylight factor.
The daylight factor is predicted using a computer model, such as DIALux or RADIANCE. The simulation method which is applied corresponds to the protocol described with respect to the performance indicator Illuminance.

The daylight factor is determined based on the following equation:
$D_F = 100. E_{in}/E_{ext}$
Where:
E_{in} = the inside illuminance at a fixed point [lux]
E_{ext} = the outside horizontal illuminance under an overcast (CIE sky) (Commission Internationale de l'Eclairage (CIE) 1995) [lux]
D_F = the daylight factor at a fixed point [-]

Table 38: Assessment in design

		Daylight
		Average Daylight factor (D_F) [-]
A	Excellent	≥ 5%
B	Good	
C	Adequate	≥ 3%
D	Poor	≥ 1%
E	Bad	< 1%

Detailed assessment

Assessment in operation

1. Measurement of daylight factor.

The daylight factor is measured according to the measurement corresponding to the protocols described in the section considering Illuminance.

The daylight factor is determined based on the following equation:

$D_F = 100. E_{in}/E_{ext}$

Where:

E_{in} = the inside illuminance at a fixed point [lux]

E_{ext} = the outside horizontal illuminance under an overcast (CIE sky) (Commission Internationale de l'Eclairage (CIE) 1995) [lux]

D_F = the daylight factor at a fixed point [-]

Table 39: Assessment in operation

		Daylight
		Average Daylight factor (D_F) [-]
A	Excellent	$\geq$ 5%
B	Good	
C	Adequate	$\geq$ 3%
D	Poor	$\geq$ 1%
E	Bad	< 1%

2.5. Acoustic comfort

2.5.1. Background noise level

Simple assessment

Assessment in design

An expert review of the acoustic comfort in the building is carried out based on the information available in the design stage. The objective of the assessment is the identification of daily or seasonal conditions that may degrade the acoustic performance of the building. For example, seasonal changes will change the operating conditions of HVAC equipment, which may change the location and level of background noise in the building.

1. Location/Site. The location of the building is analyzed focusing on the presence of external sources, such as road traffic, industrial area, in the vicinity of the building. Based on the location of the building, the sound pressure level of the sources external to the building is estimated.

2. Conduct a facility and building evaluation:
a. Review of weighted sound reduction of the facade. Based on the composition of the construction and the applied construction materials the sound pressure level of sources external to and internal in the building are estimated.
b. Review facility operational documentation. Document the occupancy types and operations for each space type within the facility. Review building plans, including HVAC designs. The HVAC equipment sound pressure level is predicted based on the available documentation.
c. Review of building plans and floor plans in order to evaluate the risk of distracting sounds due to the movement of people or carts.

Assessment of the background noise level is carried out along the lines of ASTM Standards on Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995). The location of the building, the building construction, floor plan, and occupancy are analyzed in such a way in order to predict the external noise, internal noise and reflected sound in the building.

Table 40: Assessment in design

		External noise	Internal noise
A	Excellent	There is no risk for problems due to external noise sources and noise from outside the building or from other floors is very small. If external noise sources are present, then these have been accounted for in the building design	There is no risk for distraction from internal sounds, e.g. from printers or ringing phones. There is no chance of distraction from the movement of people or carts in main aisles. (If internal noise sources are present, then these have been accounted for in the building design)
B	Good	The risk that there may be a problem due to continuous external noise sources or noise from outside the building or	Distracting sounds, e.g. from printers or ringing phones, are only observed a few times a week for a few occupants, or in

		from other floors is rare. If external noise sources are present, then these have been accounted for in the building design	localized areas. The layout and width of main aisles result in only occasional or localized disturbance from movement of people or carts.
C	Adequate	Noise from outside the building or from other floors is not generally intrusive or disturbing, usually less than 10 minutes per day.	Distracting sounds, e.g. from printers or ringing phones, are only sometimes distracting for most occupants. Because of the floorplate configuration, may locations are adjacent to main aisles and high screens are required to prevent localized disturbance from movement of people and carts.
D	Poor	External noise, e.g. traffic, aircraft or nearby activity, is present during some working hours, but particularly distracting or annoying at some times of the day.	Distracting sounds, e.g. from printers or ringing phones, are very distracting at some times of the day, with unpredictable and sudden shifts between low levels and high peaks.
E	Bad	External noise, e.g. traffic, aircraft or nearby activity, is present during all working hours and distracting or annoying.	Sounds, e.g. from printers or ringing phones, are very distracting at all times, with unpredictable and sudden shifts between low levels and high peaks. Because of the floorplate configuration, the required location and width of main aisles results in major distraction to all or most occupants.

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Simple assessment

Assessment in operation

An expert review of the acoustic comfort in the building is carried out. The objective of the assessment is the identification of daily or seasonal conditions that may degrade the acoustic performance of the building.

1. Location/Site. The location of the building is analyzed focusing on the external sources, such as road traffic, industrial area, in the vicinity of the building. The sound pressure levels of the sources external to the building are evaluated.

2. Conduct a facility and building evaluation:
a. Review of weighted sound reduction of the facade. Based on the composition of the construction and the applied construction materials the sound pressure level of sources external to the building is evaluated.
b. Review facility operational documentation. Document the occupancy types and operations for each space type within the facility. Review building plans, including HVAC designs. The HVAC equipment sound pressure level is predicted based on the available documentation.
c. Review of building plans and floor plans in order to evaluate the risk of distracting sounds due to the movement of people or carts.
d. Complaint logs, if available, may be reviewed for evidence of occupant dissatisfaction and its causes. Trends in complaint rates over time may indicate occupant reactions to changes in building operation. Complaint logs do not provide systematic evaluation of a building's IEQ.

Assessment of the background noise level is carried out along the lines of ASTM Standards on Whole Building Functionality and Serviceability (American Society for Testing of Materials (ASTM) 1995). The location of the building, the building construction, floor plan, and occupancy are analyzed in such a way in order to evaluate the acoustic control, the external noise, internal noise and reflected sound in the building.

Table 41: Assessment in operation

		Acoustic control	External noise	Internal noise
A	Excellent	Excellent, e.g. raised voices or amplified sounds are not heard in adjacent spaces, and sounds from adjacent spaces are never distracting. It is easy to understand soft-spoken speech from across the room, and no echo or reverberation from loud or abrupt sounds.	There is no risk for problems due to external noise sources and noise from outside the building or from other floors is very small. If external noise sources are present, then these have been accounted for in the building design	There is no risk for distraction from internal sounds, e.g. from printers or ringing phones. There is no chance of distraction from the movement of people or carts in main aisles. (If internal noise sources are present, then these have been accounted for in the building design)
B	Good	Good, e.g. raised voices or amplified sounds are not understood in adjacent spaces, and	The risk that there may be a problem due to continuous external noise sources or noise	Distracting sounds, e.g. from printers or ringing phones, are only observed a few times a

		sounds from adjacent spaces are rarely distracting. Soft-spoken speech from across the room can be understood. Only slight echo or reverberation from loud or abrupt sounds; or, only slight muffling of speech and loud sounds	from outside the building or from other floors is rare. If external noise sources are present, then these have been accounted for in the building design	week for a few occupants, or in localized areas. The layout and width of main aisles result in only occasional or localized disturbance from movement of people or carts.
C	Adequate	Sufficient, only raised voices or amplified sounds are understood in adjacent spaces. Sounds from adjacent spaces are occasionally distracting; difficult and costly to fix. Easy to understand normal speaking voice across the room. Soft-spoken speech is sometimes hard to understand, or distinct but hard to hear.	Noise from outside the building or from other floors is not generally intrusive or disturbing, usually less than 10 minutes per day.	Distracting sounds, e.g. from printers or ringing phones, are only sometimes distracting for most occupants. Because of the floorplate configuration, may locations are adjacent to main aisles and high screens are required to prevent localized disturbance from movement of people and carts.
D	Poor	Poor, e.g. discussion is understood in adjacent spaces, and sounds from adjacent spaces are often distracting. Fixing this is possible, but difficult and costly. In some parts of the room a normal speaking voice is hard to understand, or hard to hear	External noise, e.g. traffic, aircraft or nearby activity, is present during some working hours, but particularly distracting or annoying at some times of the day.	Distracting sounds, e.g. from printers or ringing phones, are very distracting at some times of the day, with unpredictable and sudden shifts between low levels and high peaks.
E	Bad	Bad, e.g. discussion is understood in adjacent spaces, and sounds from adjacent spaces are continually distracting.	External noise, e.g. traffic, aircraft or nearby activity, is present during all working hours and distracting or annoying.	Sounds, e.g. from printers or ringing phones, are very distracting at all times, with unpredictable and sudden shifts between low levels and high peaks. Because of the floorplate configuration, the required location and width of main aisles results in major distraction to all or

				most occupants.

Note: Classification is based upon fulfilling all the conditions/requirements corresponding to a specific class.

Detailed assessment

Assessment in design

An expert review of the acoustic comfort in the building is carried out based on the information available in the design stage. The objective of the assessment is the identification of daily or seasonal conditions that may degrade the acoustic performance of the building. For example, seasonal changes will change the operating conditions of HVAC equipment, which may change the location and level of background noise in the building.

1. Location/Site. The location of the building is analyzed focusing on the presence of external sources, such as road traffic, industrial area, in the vicinity of the building. Based on the location of the building, the sound pressure level of the sources external to the building is measured. The measured sound pressure level is compared to the acoustic target values presented by the Finnish Society for Indoor Air Quality and Climate (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008).

2. Conduct a facility and building evaluation:
a. Review of weighted sound reduction of the facade and internal construction components. Based on the composition of the construction and the applied construction materials, the weighted sound reduction index between spaces (R'_w) and the weighted normalized impact sound pressure level from surrounding spaces ($L'_{n,w}$) are calculated and evaluated. The predicted sound pressure levels are compared to the acoustic target values presented by the Finnish Society for Indoor Air Quality and Climate (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008).
b. Review facility operational documentation. Document the occupancy types and operations for each space type within the facility. Review building plans, including HVAC designs. The HVAC equipment sound pressure level ($L_{A,eq}$) is predicted based on the available documentation.
c. Review of building plans and floor plans in order to evaluate the risk of distracting sounds due to the movement of people or carts.

Assessment of the background noise level is carried out along the lines of the acoustic target values presented by the Finnish Society for Indoor Air Quality and Climate (Finnish Society of Indoor Quality and Climate (FISIAQ) 2008).

		Background noise level			
		External noise	Internal noise		HVAC
		Sound pressure level of sources external to the building ($L_{A,eq}$) [dBA]	Weighted sound reduction index between spaces (R'_w) [dB]	Weighted normalized impact sound pressure level from surrounding spaces ($L'_{n,w}$) [dB]	HVAC equipment sound pressure level ($L_{A,eq}$) [dB]
A	Excellent	S1			
B		-			
C	Adequate	S2			
D	Poor	S3			
E	Bad	-			

Detailed assessment

Assessment in operation

The acoustic comfort in the spaces of the building is evaluated based on the measurement of the background sound level. The objective of the background sound level measurement is to provide a relatively simple and quick evaluation of the background noise in a room. The purpose is to assess acoustic annoyance that would affect study and work performance, as well as sleep and relaxation.

A-weighted sound pressure level (L_{eq} in dB(A)) measurements should be made in the occupied spaces. Measurements should be made using instrumentation equivalent to an integrating sound level meter equipped with and an omnidirectional condenser microphone.

Background noise shall be measured at any valid measurement point where one would typically expect to find the ears of the occupant (e.g., near the seated position in front of the desk in a private office). In addition, at least three more measurement locations must be measured in the room. The distance between any two measurement points shall be at least 1 meter. At each measurement point, record the time-average (L_{eq}) octave band and A-weighted sound pressure levels. The minimum duration of each measurement shall be 30 seconds. The sound level meter operator shall take special care to avoid taking any acoustic measurements when transient sounds (e.g., people talking, doors closing, etc.) are present.

The acoustic measurements should, if possible, be conducted with the room vacated by its normal occupants. If this is not possible, the report shall indicate the occupancy of the room and a general description of what the occupants were doing during the measurements. In addition, all non-HVAC related sound-producing equipment (computers, radios, etc.) should be turned off for the duration of the measurements.

The operating condition of the HVAC equipment or system serving the room during the measurement shall be determined and reported. If possible, the measurements shall be conducted with the system operating at full capacity (e.g. during maximum cooling for a VAV system). Measurements at two or three different operating conditions (e.g., maximum cooling, maximum heating, full economizer, etc.) are strongly encouraged, but not required. In all cases the HVAC system shall be operating in a known steady-state condition during the measurements.

If intruding noise from outdoor sources (e.g. aircraft, street traffic, lawn mowers, etc.) is of concern, then measurements should be scheduled during time periods when these sounds are at a maximum. If windows are designed to be opened for ventilation, then measurements should be performed with and without the windows open.

The results of the measurements are compared with noise criteria and acoustic target values presented in the ASHRAE's Performance Measurement Protocols for Commercial Buildings, Table 9-1 (ASHRAE 2009) which are based on the specific use of the space. A range of criteria are provided, the lowest NC/RC values represent an ideal acoustic environment, and the highest value represents the level above which the acoustic space is no acceptable for the intended use.

Acoustic performance criteria vary by room and are based on the type of activities that occupants engage in during their time spent in these spaces. The overall result is that any commercial building will typically have some spaces that are acceptable and others that are not acceptable. Any rating scheme

for the building must address this issue. A good rule-of –thumb is that if between 80% and 90% of the room background noise measurements
are found to be acceptable, then the commercial building may be considered as marginally acceptable . If more than 90% of the room background noise measurements are found to be acceptable, then the building may be considered as acceptable (ASHRAE 2009).

Table 42: Assessment in operation

		Background noise level
		A-weighted background noise level ($L_{A,eq}$) [dBA]
A	Excellent	Excellent, the measured background noise level is lower than the target values presented by ASHRAE (ASHRAE 2009)
B		-
C	Adequate	Sufficient, the measured background noise level complies with the target values presented by ASHRAE (ASHRAE 2009)
D		-
E	Bad	Bad, the measured background noise level is higher than the target values presented by ASHRAE (ASHRAE 2009)

2.5.2. Reverberation time

Simple assessment

Assessment in design

An expert review of the reverberation time in the building is carried out. The objective of the assessment is the identification of degraded acoustic performance of the building due to echo and reverberation.

1. A facility and building evaluation is conducted:
a. The echo and reverberation in a space is evaluated based on the evaluation of the acoustic requirements for the specific space. For example, if speech intelligibility is an issue in the room, the performance is evaluated based on the quality of the spoken speech across the space.
b. Based on the composition of the construction and the applied construction materials the echo and reverberation in the spaces is evaluated.

Table 43: Assessment in design

		Reverberation time
A	Excellent	Reflected sound from one location to another is avoided, e.g. the risk for possible reflected sounds is accounted for in the building design.
B	Good	Some sound may be reflected from one location to another; however this is not a significant[1] distraction.
C	Adequate	Sound may be reflected from one location to another by hard, flat surfaces, such as walls and columns that are not treated to absorb sound, and by ceiling light fixtures that have flat plastic lenses; and for some people this is a significant[1] distraction.
D	Poor	Many surfaces reflect sound from one location to another, and there is a considerable[1] risk for distraction of many occupants.
E	Bad	Many hard, flat surfaces reflect sound in the space, to a degree that most occupants find significantly distracting[1].

[1] Subjective descriptions should be defined more detailed according to the acoustic requirements of the spaces

Simple assessment

Assessment in operation

An expert review of the reverberation time in the building is carried out. The objective of the assessment is the identification of degraded acoustic performance of the building due to echo and reverberation.

1. A facility and building evaluation is conducted:
a. The echo and reverberation in a space is evaluated based on the evaluation of the acoustic requirements for the specific space. For example, if speech intelligibility is an issue in the room, the performance is evaluated based on the quality of the spoken speech across the space.
b. Based on the composition of the construction and the applied construction materials the echo and reverberation in the spaces is evaluated.

Table 44: Assessment in operation

		Reverberation time
A	Excellent	Excellent, e.g. it is easy to understand soft-spoken speech from across the room, and no echo or reverberation from loud or abrupt sounds. Reflected sound from one location to another is avoided, e.g. by adding sound absorption materials on walls and columns, by shape of space, and by shape of surfaces, including window glass
B	Good	Good, e.g. soft-spoken speech from across the room can be understood. Only slight echo or reverberation from loud or abrupt sounds; or, only slight muffling of speech and loud sounds. Although some sound is reflected from one location to another by hard, flat surfaces such as walls and columns, this is not a significant distraction because most such surfaces are treated with absorbent material or so placed to not reflect sound from one location to another.
C	Adequate	Sufficient, e.g. easy to understand normal speaking voice across the room. Sound is reflected from one location to another by hard, flat surfaces, such as walls and columns that are not treated to absorb sound, and by ceiling light fixtures that have flat plastic lenses; and for some people this is a significant distraction.
D	Poor	Poor, e.g. In some parts of the room a normal speaking voice is hard to understand, or hard to hear, due to echo or reverberation from loud or abrupt sounds. Many surfaces reflect sound from one location to another, and this is distracting to many occupants.
E	Bad	Bad, e.g. discussion is understood in adjacent spaces, and sounds from adjacent spaces are continually distracting. Many hard, flat surfaces reflect sound in the space, to a degree that most

		occupants find significantly distracting.

Note: Assessment of the reverberation time based on the table above applies to spaces where speech intelligibility is an issue. Alternative requirements may be defined more detailed according to the acoustic requirements of the spaces.

Detailed assessment
Assessment in design

The acoustic comfort in the spaces of the building is evaluated based on the simulation of the reverberation time in the spaces, for example using building simulation software, such as ODEON (www.odeon.dk) and ESP-r (Citherlet, Macdonald 2003). The objective is the evaluation of the reverberation time which could influence the speech intelligibility in the room.

The predicted reverberation times are evaluated against the specified room criteria presented by ASHRAE {(ASHRAE 2009) and ISO Standard 3382 (ISO 3382/II - 2008 2008).

Table 45: Assessment in operation

		Reverberation time
A	Excellent	Excellent, the predicted reverberation time complies with the target values presented by ASHRAE {(ASHRAE 2009) and ISO Standard 3382 (ISO 3382/II - 2008 2008)
B		-
C		-
D		-
E	Bad	Bad, the predicted reverberation time does not complies with the target values presented by ASHRAE {(ASHRAE 2009) and ISO Standard 3382 (ISO 3382/II - 2008 2008)

Detailed assessment

Assessment in operation

The acoustic comfort in the spaces of the building is evaluated based on the measurement of the reverberation time in the spaces.

Reverberation times should be measured with the measurement microphone and the noise source both located within the measurement volume of the room. Many different types of loudspeakers can be used as the noise source. The choice of loudspeaker depends on the power output and frequency range of interest. For additional information on the measurement of reverberation times the reader is referred to ASHRAE {(ASHRAE 2009) and ISO Standard 3382 (ISO 3382/II - 2008 2008). In addition, the minimum distance between the source and the measurement microphone shall be greater than 50% of the largest dimension of the room. The acoustic decay slope evaluation range shall begin 5 dB below the steady-state level and terminate at least 20, but preferably 30 dB below the steady-state level. The results shall be presented in seconds, normalized for the time for the sound to decay by 60 decibels in each frequency band.

The measured reverberation time in all octave bands from 250 Hz to 4000 Hz (rounded to the nearest 0.1 second) shall be evaluated against the specified room criteria presented by ASHRAE {(ASHRAE 2009).

Table 46: Assessment in operation

		Reverberation time
A	Excellent	Excellent, the measured reverberation time complies with the target values presented by ASHRAE {(ASHRAE 2009) and and ISO Standard 3382 (ISO 3382/II - 2008 2008)
B		-
C		-
D		-
E	Bad	Bad, the measured reverberation time does not complies with the target values presented by ASHRAE {(ASHRAE 2009) and ISO Standard 3382 (ISO 3382/II - 2008 2008)

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