MINISTRY OF EDUCATION
TE TĀHUHU O TE MĀTAURANGA

Designing Schools in New Zealand (DSNZ)

Designing Quality Learning Spaces (DQLS)

Lighting and Visual Comfort

Version 2.1, December 2020

Document history

This is a 'living document'; the table below is a record of the changes that have been made to this document.

Revision date	Version	Summary of changes
2007	1.0	• First version for general release
December 2020	2.0	• Document rewritten to align with the Ministry's Te Rautaki Rawa Kura - School Property Strategy 2030 • The holistic interaction of internal environmental quality factors is now clearly presented with effective control strategies • Document rewritten for a target audience of architects, designers and engineers involved in the design and specification of schools • Document rewritten to separate the mandatory requirements from the design guide to enhance navigation and readability • Revised performance requirements for measuring the quantity and quality of daylight • Inclusion of mandatory requirements for new builds and refurbishments • Inclusion of guidance for site planning for good daylighting • Inclusion of a verification methodologies for mandatory requirements
July 2021	2.0	• Lamp Colour Rendering Group revised to R9>50
July 2023	2.1	• Useful Daylight Illuminace (UDI) compliance criteria (percentage of hours within lux range) revised to take into account single side-lit and deep plan spaces • We clarified which spaces are excluded from the daylighting analysis and compliance requirements

Foreword

The Designing Quality Learning Spaces (DQLS) series of documents has been prepared by the Ministry of Education (the Ministry) and a panel of expert advisors, and compliance is mandatory for all projects starting the preliminary design phase after 1 January 2021.

This document was first released by the Ministry of Education in partnership with the Building Research Association of New Zealand (BRANZ) in 2007. The DQLS – Lighting has been updated and replaced with DQLS – Lighting and Visual Comfort.

Changes in this latest version have been made to align with industry best practice, the latest research, feedback received from design reviews, and responses to a wide range of technical queries.

The mandatory requirements have also been strengthened to improve lighting performance and to align with the Ministry's Te Rautaki Rawa Kura - School Property Strategy 2030, in particular the objective of providing quality learning environments to support teaching and learning and the wellbeing of everyone who use or occupy school buildings.

Although the mandatory requirements have been developed as a result of best practice and specific Ministry requirements, it is not intended that this document addresses every conceivable condition. Instead, it provides solutions where experience has indicated that problems commonly arise. The document has been structured for continual improvement to incorporate new research, technologies, developments, concepts and feedback.

This document is freely available for download from the Ministry's Property pages.

Background

The Ministry owns one of the largest property portfolios in New Zealand, with more than 18,000 buildings and over 35,000 teaching spaces distributed across more than 2,100 schools. Learning space design and upgrades are commissioned through various mechanisms – nationally via Ministry-led programmes, regionally through the Ministry's Capital Works and Infrastructure Advisory Service divisions, and locally through schools' Boards of Trustees.

The objective of this lighting document is to ensure that the design and construction of school buildings provide quality physical environments that support effective teaching and learning. The requirements are not intended to be prescriptive to the degree of restricting thinking, but it is intended that the information provided will help facilitate school design that represents the best value for expenditure, while supporting a variety of teaching and learning styles.

Acknowledgements

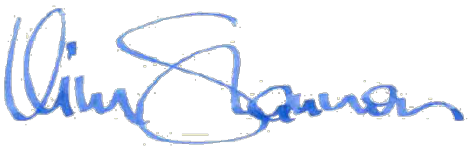
The Ministry gratefully acknowledges the following DQLS – Lighting Panel members for contributing to this document:

- David Fullbrook — eCubed
- AProf Michael Donn — Victoria University of Wellington
- Michael Warwick — MAW Design
- Renelle Gronert — Senior Manager, School Design, Ministry of Education
- Craig Cliff — Senior Policy Manager, Ministry of Education
- Aniebietabasi Ackley — Technical Advisor, School Building Performance, Ministry of Education

The Ministry would like to thank Design Review Panel (DRP) members for reviewing this document and Prendos New Zealand Limited for preparing the illustrations.

Feedback, Future Amendments

Where architects, engineers, designers, building scientists or users have feedback, they are encouraged to contact the Ministry through the School.Design@education.govt.nz mailbox to facilitate continual improvement and usability of this document. Your feedback will be reviewed and, where accepted, incorporated into future amendments.



Kim Shannon

Head of Education Infrastructure Service

Contents

Colours and Hyperlinks in this document

Every underlined word is a hyperlink
It may be a defined term that takes you to the glossary, a reference or a link to a webpage that explains a concept in more detail or gives background information. Hovering your pointer over a hyperlink will give you information about that link and clicking it will take you there.

Using this document

In this document, the use of the word ***"must"*** **and *all requirements in tables and bold text*** indicates that a requirement is absolutely mandatory.

The use of the words ***"should",*** and ***"recommendation"*** means that there may exist valid reasons or circumstances where a requirement cannot be met. In such cases the full implications must be understood and carefully weighed before choosing an alternative approach.

Introduction

Purpose and Scope

This document is part of the Ministry of Education's Designing Quality Learning Spaces (DQLS) suite of design requirements for building quality learning environments for schools. The DQLS series covers the four main internal environmental quality factors: lighting and visual comfort, acoustics, indoor air quality and thermal comfort requirements. These requirements form part of a set of documents for *Designing Schools in New Zealand - Requirements and Guidelines* (DSNZ), which is the overarching guidance for school design.

This DQLS – Lighting and Visual Comfort document has been developed to provide technical requirements to assist architects, designers, and engineers in creating quality physical learning environments that are fit for purpose, and technical guidance for property managers undertaking school projects.

The lighting requirements set out in this document apply to all 'new-build' structures including extensions, pre-fabricated, and any new contracts for modular buildings. The requirements also apply to refurbishments of existing school buildings, including significant alterations and temporary learning spaces that are used at a school for more than 28 days.

Overall purpose of the DQLS – Lighting document
• To provide lighting performance standards that are appropriate to, and consistent across, school facilities.
• Create spaces and environments that are comfortable and support the educational delivery process across different teaching styles and practices.
• Set mandatory minimum requirements that are part of achieving quality learning environments.
• Set a basis for evaluating the lighting performance of project design submissions.
• Set a basis for evaluating the lighting performance when undertaking Post Occupancy Evaluation (POEs).
• Facilitate school design that represents best value for expenditure while supporting educational outcomes.

In order to demonstrate compliance with the mandatory requirements, design teams must submit the completed IEQ Design Report with their design. Accuracy is critical as POE will be based on this report.

This document is divided into five key sections:

- Section 1 specifies the **mandatory requirements** for lighting with which design teams must be able to demonstrate compliance.
- Section 2 provides **recommendations** that designers should consider when applying the mandatory requirements.
- Section 3 gives **good practice design advice** on the use of daylighting and electric lighting and provides **design guidance** for the main areas of lighting performance.
- Sections 4 provides further lighting guidance for **specialist learning and ancillary spaces**.

Te Haratau: Lifting the quality of New Zealand learning environments

The Ministry's programme Te Haratau: lifting the quality of NZ's physical learning environments, is aimed at delivering the strategic objective of quality learning environments, as set out in Te Rautaki Rawa Kura – The School Property Strategy 2030. Te Haratau involves collecting and analysing performance data on the "quality" of all school assets for property planning and making evidence-based decisions. The Te Haratau model consists of three interrelated objectives for the delivery of quality learning environments, as set out in Table 1.

Table 1: The three main interrelated aspects of Te Haratau

TE HARATAU MODEL	
1	Fitness for Purpose - Internal environment (lighting, acoustics, thermal comfort and air quality) and usability. Data sourced through internal environment monitoring and user feedback through the School Evaluation of the Physical Environment (SEPE) tool.
2	Asset condition assessment – data relating to condition grade and remaining useful life for building and site elements is sourced through detailed condition assessments.
3	Operational Efficiency - Energy and water consumption, resilience, and maintenance costs. Data is sourced through a range of approaches.

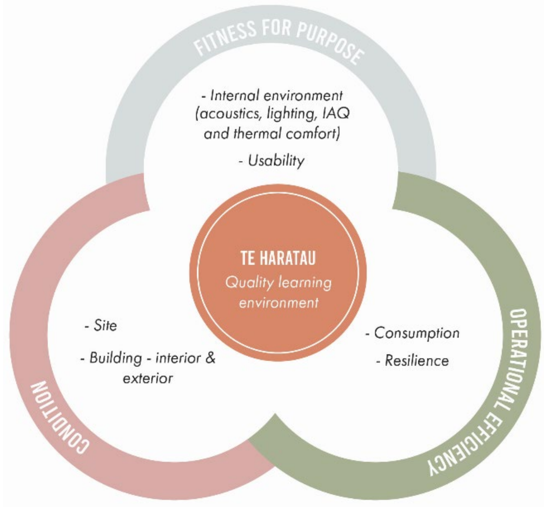


Figure 1: Te Haratau Model

The Te Haratau model will capture data across these key aspects to provide information about a school's buildings and site, and how each of these three aspects moves from the design phase into operations. The DQLS requirements provide the framework for assessing the internal environmental quality aspects of fitness for purpose. For example, when reviewing data about light levels within a learning space the acceptable threshold will be provided by DQLS (refer to **Section 1.1.3**).

Understanding Internal Environmental Quality

Internal environmental quality refers to the entire quality of a building's environment in relation to the health and wellbeing of the occupants within it. Internal environmental quality is determined by many factors, including the four Te Haratau fitness-for-purpose aspects:

Internal Environment Quality Factors	
1	**Lighting and Visual Comfort** – illuminance, luminance ratios, view, reflection, etc.
2	**Acoustic Quality** – noise from indoors, outdoors, vibrations, etc.
3	**Indoor Air Quality (IAQ)** – fresh air supply, odour, indoor air pollution, etc.
4	**Thermal Comfort** – temperature, air velocity, relative humidity, moisture, etc.

There is strong evidence that good lighting, temperature, humidity, acoustics, and indoor air quality support educational outcomes (Barrett et al., 2015; Wall, 2016; Ackley et al., 2017). For example, a United Kingdom study of 3766 students in 153 classrooms in 27 schools identified seven key design parameters that together explain 16% of the variation in students' academic progress. These design parameters were Light, Colour, Temperature, Air Quality, Ownership, Flexibility, and Complexity (Barrett et al., 2015).

Better internal environmental quality in learning spaces could support teachers/kaiako and learners/ākonga to succeed. For example, learning can be impeded if the lighting conditions cause visual discomfort, which can lead to eyestrain and headaches and can disturb the circadian rhythm. Research on biological lighting demands has revealed that the dosing of daylight is important for health purposes. The amount of light that enters the eye affects our bio-rhythm: more light supresses melatonin production, thereby making us more awake and alert.

Poor acoustics can make communication difficult and increase activity noise levels. Poorly ventilated rooms can result in unwanted thermal effects (both through temperature and humidity) and lead to high levels of carbon dioxide, which could cause drowsiness. Indoor air pollutants can be odorous and could irritate the trigeminal nerve endings in nose and eyes, causing itching and other negative reactions impeding learning.

The Ministry is committed to providing better internal environmental quality in learning spaces to achieve the objectives of the Te Rautaki Rawa Kura – The School Property Strategy 2030. Setting standards for, monitoring, and evaluating internal environmental quality are extremely important across all stages of the building process: design, construction, commissioning, operation, and renovation.

The built internal environment is considered a system with sub-systems that do matter, but the system will only function if all sub-systems (components) are optimised along with the total system, whether this is related to health, comfort, or sustainability issues. Internal environmental quality factors are one of the key sub-systems that are interrelated in a building (**Figure 2**).

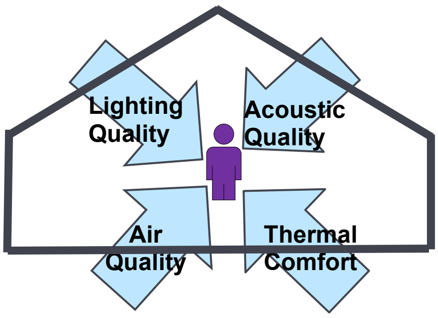


Figure 2: What is internal environment quality, Source: Bluyssen, (2009)

These factors must be considered during the design phase so that comfort is achieved. A holistic approach is essential, and no single internal environmental quality factor should be altered without assessing its effect on all the others. This is because they interact with one another e.g., achieving good daylighting must be balanced against possible uncomfortable heat gain from the sun, and the need for ventilation can increase noise levels inside.

Given the complex nature of the internal environment, design teams must ensure that the lighting requirements set out in this document are applied together with the requirements set out in the other DQLS series of documents (acoustics, and indoor air quality and thermal comfort).

This document sets out requirements and guidance that will produce acceptable lighting conditions to the majority of occupants in a learning space. Special consideration for inclusive design is given in Section 4.1.

To ensure that all new buildings and refurbishments provide comfortable environments, design teams must consider the effective control strategies in **Table 2**.

Table 2: Internal environment quality factors, parameters, and effective control strategies. Adapted from Bluyssen, (2009).

Description	Lighting Quality	Acoustic Quality	Air Quality	Thermal Quality
Parameters	• Illuminance and luminance • Reflectance(s) • Colour temperature and colour index • View and daylight	• Sound level (s) • Reverberation time • Frequency spectra • Speech intelligibility • Sound insulation	• Pollution sources • Carbon dioxide concentrations • Types of pollutants • Ventilation rate and efficiency	• Temperature (air and radiant) • Relative Humidity • Air velocity • Activity and clothing
Control	• Daylight harvesting • Luminance distribution • Electric lighting	• Acoustic design • Sound absorption • Sound insulation	• Source control • Operable windows • Ventilation systems • Maintenance • Air cleaning • Activity control	• Building design (e.g., insulation, façade, etc.) • Heating and cooling systems

Importance of Good Lighting

Lighting and visual comfort is very important to people's health and wellbeing. It affects the mood, emotion and mental alertness of teachers and students. There is clear evidence that shows that good daylight in learning spaces contributes to improved learning performance (Heschong Mahone Group, 1999; Nicklas & Bailey, 1997; Barrett et al, 2015; Ackley et al, 2017, 2020). A study by Heschong Mahone Group, (1999, 2001, 2003) compared the school records of 21,000 students from 3 school districts in 3 states in California with day-lighting conditions in over 2,000 learning spaces. They found that classrooms with good daylight had better learning performance, increased attendance and 26% higher results in reading tests and 20% in mathematics tests in one year than those with the least.

Good daylighting can support and adjust the circadian rhythms that influence people's physiological and psychological state, improve visibility, supress melatonin production which improves alertness, enhance colour rendering, and lead to energy savings.

Poorly designed daylighting can create visual discomfort and glare issues. Glare is the excessive contrast between light and dark within a building which can be caused by the inadequate distribution of daylight in a space, or by viewing the sun reflected on bright surfaces. In addition, poor daylight design can introduce undesirable solar heat gain, causing discomfort and increasing ventilation and air conditioning loads and energy use.

Good daylighting design requires understanding a building's local climate, the location, placement, orientation, usage, shading of windows and skylights relative to their solar orientation. A good daylighting system provides:

- balanced, diffuse, glare-free daylight from two or more directions
- sufficient light levels for the tasks being undertaken in the space
- operable shading devices to reduce light intensity for audio-visual programs and computer work
- windows for interest, relaxation, and communication with the outdoors
- exterior shading devices as needed to minimize solar heat gains during the warmer season.

When designing for daylight, design teams should consider measures to control potential summer overheating, provide effective ventilation, and balance daylighting with the various factors in **Figure 3**.

Figure 3: Factors to consider when designing for daylight

The quantity of light within a learning space defines the visual quality of the indoor environment, and how it impacts on the functions of the space (Ackley et al, 2020). Adequate lighting, whether by daylight or electric light means, is essential for the tasks and activities undertaken in a school and is a basic functional requirement of lighting design.

Design teams must also provide electric lights that is energy efficient, has a long life, and requires minimal maintenance. The electric light needs to work to supplement the daylight to achieve the design goals but take over completely when the daylight is inadequate.

Section 1: Mandatory Requirements

The following section quantifies the Ministry's mandatory performance requirements for daylighting and electric light in schools. These performance requirements have been set to enable the design and upgrade of schools in line with the Ministry's expectations about the way physical spaces will support a variety of teaching and learning approaches, while providing adequate levels of comfort, and ensuring an environment conducive to good health and wellbeing.

Designers will need to consider four key performance outcomes and associated control measures:

- **Daylighting** – **Section 1.1**
- **Electric Light** – **Section 1.2**
- **Surface Finishes** – **Section 1.3**
- **Site Planning for Good Daylighting** – **Section 1.4**

The Ministry's requirements and recommendations given in this DQLS document are intended to apply to all school projects, and in particular to new school buildings and specialist learning spaces. The extent to which upgrades to existing buildings can meet all requirements and recommendations will depend on the nature and scale of the upgrade. A major upgrade would be expected to meet all or most of the requirements and recommendations, whereas a minor upgrade should target specific requirements and recommendations where the works involved are practically capable of achieving them (Refer to **Section 2.4**).

In addition to daylighting and electric light, the Building Code requires emergency and escape route lighting in the event of failure of the main lighting. The requirements for this lighting are prescribed in the **Building Code Clauses F6** and **F8**, and in **AS/NZS 2293.1:2005, AS/NZS 2293.2:1995,** and **AS2293.3:2018**.

1.1 Daylighting Requirements

The designer is to demonstrate within a project's preliminary and developed design reports that the daylighting provisions within learning spaces meet the requirements and key performance criteria set out in this document and summarised in **Table 3**. Areas which may be excluded from these requirements are listed below.

Table 3: Daylighting Mandatory Requirements

<table>
<tr><th>Description</th><th>Requirements
(New Build and Refurbishments)</th></tr>
<tr><td>General Scope</td><td>• Daylighting must be the principal source of lighting in learning spaces, supplemented by electric light when daylight is insufficient to meet the specified illuminance levels (refer to Table 4 for standard maintained illuminances).</td></tr>
<tr><td>Simple Building Forms</td><td>• A design statement and supporting calculations demonstrating compliance will be acceptable for simple building forms (refer to Section 1.1.1 for the four-step daylight sequence).
• Simple building forms are generally recognised as follows:
○ A building floor depth of 14 m or less, and
○ An area-weighted majority of applicable spaces:
- less than 7 m deep and daylit from one side, and/or
- less than 14 m deep, daylit from two opposite sides, with window areas distributed approximately evenly on each side, and
○ Window/wall ratio in the range of 30-50%, and
○ The qualitative design recommendations described in Section 2.1 of this document are adhered to.
Design teams must use the Daylight Calculator Tool to demonstrate compliance with the four-step daylight sequence.</td></tr>
<tr><td>Complex Building Forms</td><td>• For more complex building forms outside the above simple building criteria, Climate Based Daylight Modelling (CBDM) must be carried out at the preliminary and developed design stages, in accordance with the daylight modelling requirements and guidelines set out in Section 1.1.2 below.
• CBDM results must be presented using the format provided in the IEQ Design Report template.
• The Useful Daylight Illuminance (UDI) target for learning spaces is 300 lux to 2000 lux for at least 60% of school hours, across at least 50% of the applicable floor area.
• The 'applicable floor area' of the building is the sum of the floor areas of applicable learning spaces, net of any excluded areas.</td></tr>
<tr><td>Excluded Spaces & Areas</td><td>• The following spaces are excluded from the daylighting analysis and compliance requirements:
- ancillary spaces, such as toilets, storage, and circulation areas
- auditoria, performing arts spaces, music recording studios.
• The following spaces are excluded from the daylighting compliance requirements, but must be included in the daylighting analysis and IEQ Design Report:</td></tr>
</table>

	- **breakout spaces** - **administrative spaces, such as offices, teachers' resource spaces, and meeting rooms** - **maker spaces, wet spaces, and presentation spaces** - **specialist learning spaces (e.g., multi-purpose halls, technology spaces, and libraries). Refer to [Section 4](#) for daylighting guidance for these spaces.** • **Where it is known that desks or working areas will not be directly against walls, then a 500 mm perimeter zone can be excluded from the calculation area in each space.** • **Within open-plan learning spaces, areas intended for circulation rather than sedentary learning may be excluded. These should be clearly demarcated in the daylighting report.**
Non-Compliant Designs	• **Where building geometry and site constraints make compliance with these daylighting requirements unpracticable, best endeavours should be used to provide good daylighting. The daylighting report should demonstrate that daylighting has been optimised and outline the constraints which justify non-compliance.**

Refer to Section 2.4 for design considerations relevant to refurbishments.

1.1.1 Simple Building Forms - Four-step Daylighting Design Sequence

The design statement must follow the four-step daylighting design sequence (Reinhart & Lo Verso, 2010) for simple building forms, and must use the **Daylight Calculator Tool**.

1) **Zoning:** divide the applicable spaces into daylit zones. Each zone should be characterised by a common set of expected activity types. For each zone, calculate the effective sky angles (**Figure 4**), θ (in degrees), and use a target average daylight factor of 2% for all potential daylight zones.

2) **Daylight feasibility test:** using 0.87 glazing transmittance value, determine the minimum required window-to-wall ratio (WWR) for each zone from step (1) according to the following equation:

$$WWR = \frac{0.088\ x\ Daylight\ Factor}{Glazing\ Transmittance}\ x\ \frac{90°}{Effective\ Sky\ Angle} \qquad \textbf{Equation 1}$$

Note that the minimum WWR given by Equation 1 excludes mullions and frames; only zones with a minimum WWR ≤ 80% will be realistic candidates for daylighting. If the zone WWR calculation suggests a value > 80% then the design will need to be revised.

3) **Room proportions:** for each zone with minimum WWR ≤ 80%, select surface reflectances of 0.2 (floor) and 0.6 (walls) and 0.75 (ceilings), space widths, and window-head-heights (WHH). Use Equation 2, below, to determine the depth of the daylit area in each zone:

$$\text{Depth of daylit area} < \text{Minimum} \begin{cases} \frac{2}{1-Mean\ surface\ Reflectance} / \left(\frac{1}{Space\ Width}\right) + \left(\frac{1}{WHH}\right) \ldots\ldots.A \\ (WHH - Working\ Plane\ Height)\ x\ tan(\theta) \ldots\ldots\ldots..B \\ 2.0\ x\ WHH\ (if\ a\ shading\ device\ is\ required) \ldots\ldots\ldots C1 \\ 2.5\ x\ WHH\ (if\ no\ shading\ device\ is\ required) \ldots\ldots.C2 \end{cases} \qquad \textbf{Equation 2}$$

θ = Effective Sky Angle

According to Equation 2, the depth of the daylit area will be less than the lowest value given by any of the three relevant expressions (A, B and C1 or C2).

Selection of space widths, and window-head-heights will be an iterative process until suitable daylit depths are achieved for all zones.

4) **Glazing area:** calculate the Total Interior Surface Area (TISA), from floor, wall and ceiling areas based on the daylit depth calculated by Equation 2 in 3 above (i.e. do not include areas outside the daylit depth when calculating TISA. Calculate the required glazing area using Equation 3, below:

$$\text{Required glazing area} = \frac{(Daylight\ Factor)\ x\ 2\ x\ TISA\ x\ (1-Mean\ Surface\ Reflectance)}{(Glazing\ Transmittance)\ x\ (Effective\ Sky\ Angle)} \qquad \textbf{Equation 3}$$

Note that this daylighting design sequence is intended to provide for adequate daylighting under generic New Zealand conditions. It does not allow for regional variations in outdoor illuminance. The target daylight factor of 2% is intended to yield approximately 300 lux at the working plane under standard clear sky conditions. Higher target daylight factors may be used, with caution, where lower-than-typical outdoor illuminance values are expected; refer to **NZS 6703:1984, Section 5**, for guidance.

The above daylighting design sequence does not allow for control of glare. Careful consideration should be given to the orientation and location of windows, and provision of shading devices, in order to minimise direct sunlight and control glare; refer to **Section 3.8**, below, for more information. **The design statement submitted to demonstrate compliance with the four-step daylighting design sequence must also include consideration of shading and glare control options and must make specific recommendations to minimise glare and excessive heat gain where appropriate. Note that the use of blinds to control glare is not enough.**

Effective Sky angle calculation: For all walls with openings an effective sky angle will need to be calculated. Use the equation below to do so and **Figure 4** for reference.

$$\theta = 90° - \arctan\left(\frac{X}{D + Glass\ Setback}\right) - \arctan\left(\frac{Glass\ Setback}{0.5 * WH}\right)$$

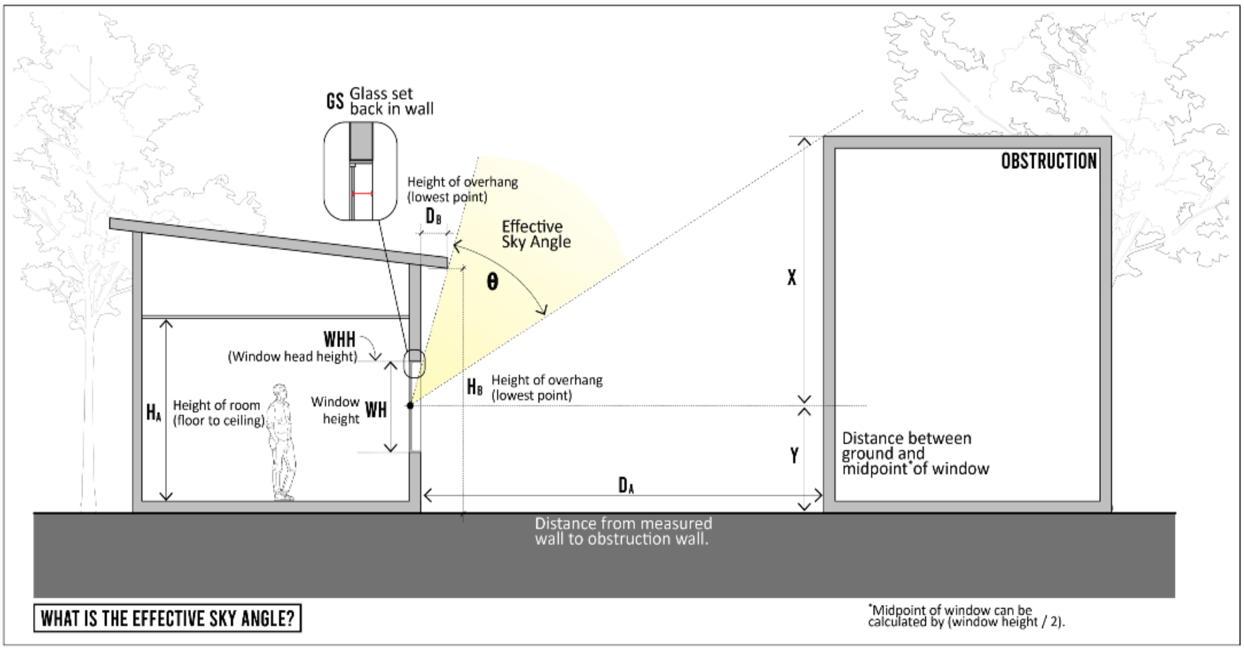


Figure 4: Effective Sky Angle Calculation (refer to Section 3.7)

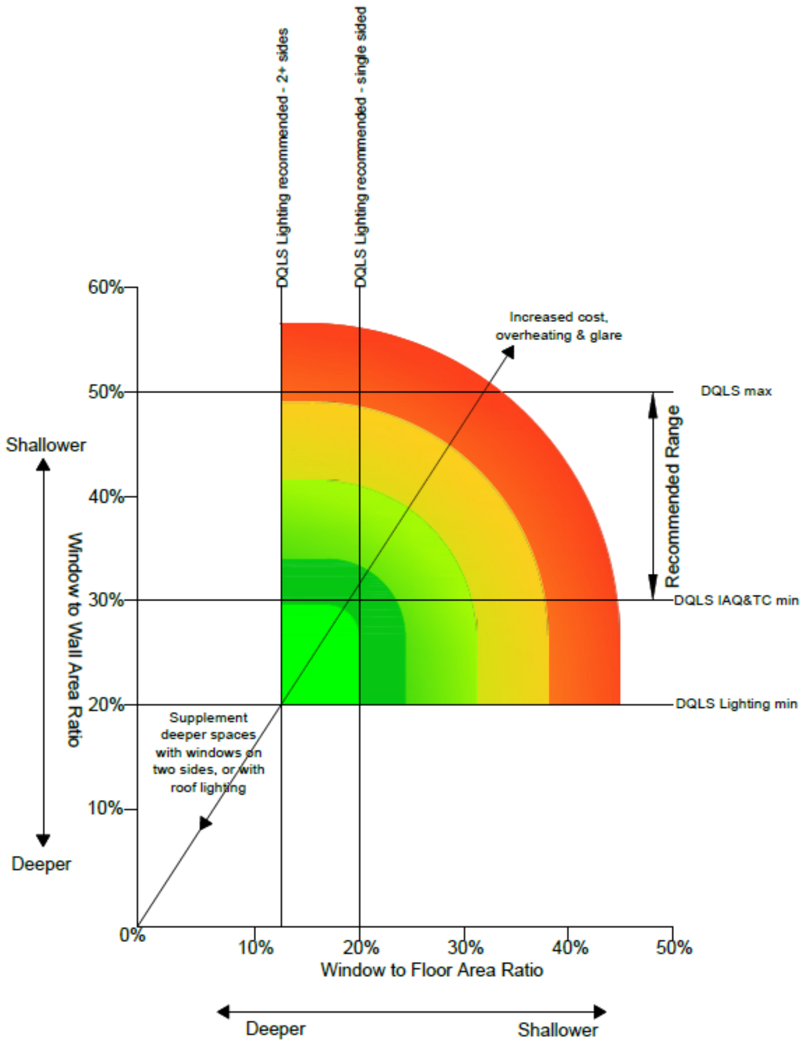


Figure 5: The relationship between 'window area to floor area' ratio and 'window to wall area' ratio (refer to Section 3.5 for more guidance on WWR).

1.1.2 Complex Building Forms - Daylight Modelling Requirements and Guidelines

Climate Based Daylight Modelling (CBDM) must be carried out in accordance with the following requirements and guidelines:

- **When undertaking UDI analysis, the calculation grids should relate to the use of the space and - where known - the furniture layout.** If a space is flexible, then the calculation grid should reflect that. Grid spacing must allow for 5 – 10 grid intervals along each grid axis (25 - 100 reference points per daylighting zone). Where it is known that desks or working areas will not be directly against walls, then a 500 mm perimeter zone in each room can be eliminated from the calculation area
- **Daylight modelling software must have been validated in accordance with CIE Report 171:2006 - Test Cases to Assess the Accuracy of Lighting Computer Programs (CIE, 2006).** (See also Maamari *et al.,* 2006, for examples of the application of the CIE test cases to modelling programs)

The accuracy of the model plays a significant role in the accuracy of the results. A number of key modelling requirements are listed below. The values used for these parameters must be detailed in the modelling report.

- **Wall thickness:** this must be modelled, including any window ledge or overhang
- **Window detail:** the transmittance of the glazing is important for the accuracy of the model. Equally important is the modelling of the window frame. It is not sufficient to allow an arbitrary light loss factor. The depth, height and reflectance of the window frame is important
- **Internal details:** items such as acoustic panels, ductwork, downstands, window reveals, and light shelves need to be included in the modelling as they will affect the distribution of light. If blinds are included in the modelling analysis, then UDI performance must be reported both with and without blinds included in the analysis. The practicality of using the blinds as modelled must be assessed
- **Reflectance values:** must match the design and be supported with data from the paint supplier or carpet manufacturer etc. Where a combination of vinyl and carpet is used the floor model should reflect the locations and areas of different materials. At the early design stage when furniture layouts and floor reflectances may not be known, a floor reflectance of 0.2 can be used and the room should be modelled without any furniture to enable an understanding of the distribution of daylight through the space. At detailed design stage the actual room layouts and reflectances must be used to validate the design
- **External obstructions:** external obstructions that may intermittently block sunlight and daylight should be modelled. Similarly, accurate modelling of building orientation is very important
- **Weather data:** Annual standardised weather data by region for New Zealand should be downloaded from Energy Plus Website. In the Energy Plus website, use the weather data file with the description “NIWA” e.g., Auckland-Auckland AK 931190 (NIWA). This is because the NIWA data is derived from 30 years of recorded information, and it is intended to be typical of New Zealand’s weather.
- **Analysis parameters:**
    - **Hours of operation:** 9:00 am until 3:00 pm. Full year data including weekends and holidays should be used; only the summer holiday shall be excluded. For modelling purposes, the academic year shall run from 1st February – 20th December
    - **Time Step:** In order to reduce computation time while maintaining modelling accuracy, an hourly time-step over the full analysis period shall be used (see Sullivan & Donn, 2018)
    - **Grid Location:** Working plane height (varies – refer discussion below)

1.1.3 Rationale for Climate Based Daylight Modelling (CBDM) and Key Performance Criteria

Historically, daylight factors and a uniform overcast sky have been used to determine the quantity of daylight light available within a room. This conservative approach was suited to places in the northern hemisphere where these factors were developed which have a greater proportion of overcast skies. They were also suited to quick and imprecise estimates of the quantity of daylight. They relied on other calculations to estimate the likely qualitative properties such as glare. By manipulation of the daylighting design parameters, the aim was to deliver a certain percentage of diffuse light (normally 2.0 - 2.5%) into the space, and to achieve a certain degree of illuminance uniformity. This approach does not, however, consider the effects of direct sunlight or of varying illuminance over time. Building designs which maximise daylight factors have resulted in over-sized glazing, with detrimental effects in terms of thermal control and glare (Tsagrassoulis, Kontadakis, and Roetzel, 2015, Mardaljevic, Brembilla and Drosou, 2016).

Climate Based Daylight Modelling (CBDM) is better suited to the New Zealand climate and provides information about the daylight distribution within a space throughout the year. CBDM uses realistic sun and sky conditions derived from standardised weather data to predict the quality and quantity of daylight distribution within a space (Mardaljevic, 2000; Reinhart & Herkel, 2000). This data should inform design decisions at the preliminary design stage.

Figure 6: Image showing lighting visualisation.

Refer to the '*Rationale for Daylighting Requirements Addendum'* document for example school block results for daylighting performance metrics and compliance requirements.

Working Plane

Teaching is based around a wide variety of activities and ways of using spaces. Furniture should not be considered fixed, as it may be rearranged between classes, and furniture arrangements will be adapted many times during the building lifespan. Student group sizes and positions will also vary greatly, from working at desks, to working on the floor, to a variety of types of seating.

For daylight measurements, it may not always be easy to identify the working plane, particularly in a large open plan learning space. There may be multiple working planes in a space – for example, close to floor level if students may be sitting or lying on the floor while working, as well as at desk level and at the level of other furniture such as couches or stools. Designers need to consider the likely uses of the space when identifying working planes and selecting orientations for daylighting measurements; **assumption should be clearly stated in the modelling report**.

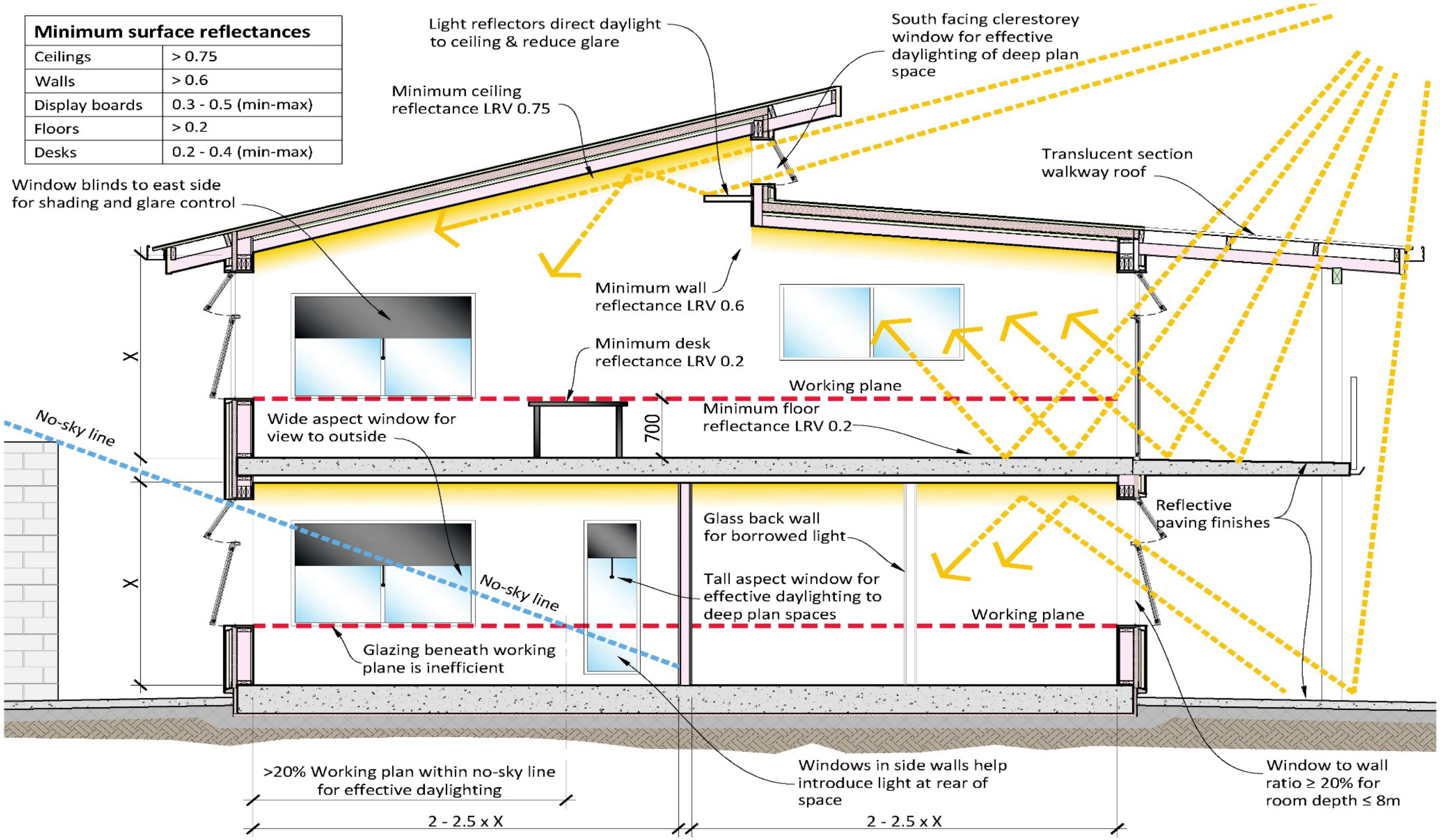
Key Performance Criteria - Useful Daylight Illuminance:

- UDI is defined as the annual occurrence of illuminances across the work-plane that are within a range considered 'useful' by occupants; this range may vary depending on the activity.
- For example, it is common to set the useful minimum daylight level as the point where electric light is no longer necessary for a particular task. Thus, UDI counts as potentially useful each hour that daylight provides light in excess of the lower bound of the range. However, if the illuminance is higher than the target range (too high for doing the task) then each hour where this occurs is not useful. A UDI value is reported for each position in the room and indicates the percentage of the working year that the daylighting is within the range deemed useful.
- A full CBDM analysis produces a UDI value for each point in a room. A space UDI reports what percentage of the space floor area achieves a UDI target, and a building UDI reports the percentage of the building's applicable floor area achieving the target.
- **The UDI target is 300 lux to 2000 lux for 60% of school hours, across at least 50% of the building's applicable floor area.**
- Refer to Table 3, above, for spaces and areas which must comply with the UDI requirements.
- Refer also to Table 3 for spaces which need not comply with the UDI requirements, but which are subject to daylighting analysis and reporting.
- Where building geometry and site constraints prevent compliance with the above UDI parameters, justification must be provided in the daylighting IEQ design report at each design stage.
- These targets ensure good quality daylight across at least 50% of the general learning space area.
- The daylighting report shall clearly show which spaces meet the UDI criteria, which spaces fail due to insufficient daylighting, and which spaces fail due to overprovision.
- The daylighting report shall also show the percentage of the building's total applicable floor area which complies with the UDI target range.
- The daylighting report shall clearly describe, for each applicable learning space (where students spend most of their time), the daylighting solutions (shading, glazing type, window geometry and distibution, etc.) that have been considered as part of the optimisation process. The report shall identify which solutions are recommended as providing the best daylighting outcomes, taking into consideration other design constraints.
- The daylighting report shall tabulate the window-to-wall ratio (WWR) for each applicable space. This shall be calculated to exclude window frames but include mullions. Glazed doors shall also be included in the WWR calculation.
- Within open-plan learning spaces, areas intended for circulation rather than sedentary learning may be excluded. These should be clearly demarcated in the daylighting report.
- Where it is known that desks or working areas will not be directly against walls, then a 500 mm perimeter exclusion can be eliminated from the calculation area in each room. Where applied, these should be clearly demarcated in the daylighting report.

Key Performance Criteria – Built Verification:

- As part of post occupancy evaluations, the Ministry will monitor lighting levels within a selection of spaces using Internal Environmental Monitoring (IEM) devices.
- These devices will provide an indication of the overall lighting levels (not specific to daylight or electric light) over time. For the purposes of assessing spaces, the general rule will be that when lighting levels are below **300 lux or above 2000 lux**, this may indicate lighting issues that need further investigations.

Figure 7, below, illustrates daylighting strategies that designers should consider (refer to Section 3.9 for more daylighting principles).



Minimum surface reflectances	
Ceilings	> 0.75
Walls	> 0.6
Display boards	0.3 - 0.5 (min-max)
Floors	> 0.2
Desks	0.2 - 0.4 (min-max)

Figure 7: Summary of daylighting strategies

1.2 Electric Lighting Requirements

The minimum requirements for electric lighting in terms of standard maintained illuminances, uniformity ratio, limiting glare index, lamp appearance group, and lamp colour rendering group, are given in Table 4 below.

Table 4: Electric lighting performance requirements

Type of Space	Standard Maintained Illuminance Lux	Uniformity Ratio	Limiting Glare Index	Lamp Colour Rendering Group	Lamp Colour Temperature Group	Comments
General Learning Spaces	300	0.7	19	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	
Specialist Learning Spaces requiring close and detailed work (e.g. art & craft rooms)	300	0.7	19	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	With task lighting to 500 Lux
Science Learning Spaces	300	0.7	19	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	
Music rooms	300	0.7	19	$R_A > 80$ $R_9 > 50$		
Multi-Purpose Halls: − General use − Social use −Examinations − Theatre use (non-exam mode)	160 80 300 240	0.7	19	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	
Gymnasiums	300	0.7	22	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	
Libraries Stack Areas	300 240	0.7	19	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	200 Lux on vertical plane
Workshops/Technology Spaces	300	0.7	19	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	With task lighting
Offices	300	0.8	19	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	
Circulation Spaces, Corridors, Stairs & Lobbies	80-120	0.5	25	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	
Waiting Areas	175-240	0.5	22	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	
Reception Areas	240-300	0.5	22	$R_A > 80$ $R_9 > 50$	Intermediate 4000K	

The definitions of each of the terms in Table 4 are as described in **AS/NZS 1680 (Part 1 – General, and Part 2.3 – Educational and Training Facilities)**.

Many of the rooms in educational buildings are used flexibly for a variety of purposes, without fixed workspaces. This is particularly true of multi-purpose halls. **Lighting arrangements must reflect this, and provision must be made for controls/switching to satisfy the required flexibility. Task lighting and locally dimmable lighting is preferable to higher general illuminance levels.**

Electric lighting must meet the performance requirements given in **Table 4 above**. **Additionally, new buildings must comply with the following requirements:**

- **Luminaires must be 100% based on LED lamp technology**
- **LED luminaires must comply with AS/NZS 60598 and must be in accordance with the following:**
  - CRI of R_A > 80
  - Driver power factor of ≥ 0.9
  - LED chip binning of ≤ 3 McAdams
  - LED luminaires must have a maintained output of 70% after 50,000 hours
- **LED luminaires shall have prismatic or opalescent style diffusers**
- **Choice of a luminaire must be based on a holistic consideration of the following criteria:**
  - Luminaire application - general, accent, up/downlight, emergency, internal/external and security
  - Luminaire construction and materials, IP rating, weight and seismic restraint requirements
  - Type and ease of installation – recessed/surface/suspended
  - Performance - photometric and luminous efficacy
  - Maintenance and durability
  - Standards/safety/EMC compliance
  - Cost
  - Warranty provisions

1.2.1 Emergency Lighting

Emergency lighting must comply with AS/NZS 2293.1, AS/NZS 2293.2, AS/NZS 2293.3, the NZ Building Code, and the specific Fire Engineer's report for the building. A specific emergency lighting report shall be prepared to support compliance with Clauses F6 and F8 of the NZ Building Code.

Self-contained single point systems shall include:

- Emergency lighting batteries with a minimum ten (10) year life
- Luminaires with sealed rechargeable battery cells of sufficient capacity for not less than half an hour of emergency lighting after mains failure
- Battery charger with full wave rectifier and automatic 2 rate output
- High frequency fluorescent ballast, and miniature fluorescent lamp or LED driver and LED module
- Devices to switch the lamp on when mains voltage fails, and off when battery voltage fails
- LED lamp to indicate battery charge condition, and test push button to interrupt mains supply

- Alternatively, one luminaire may incorporate battery cells of sufficient capacity to operate two luminaires with the second connected as a slave

Testing Facility:

Provide a test facility on the front of each distribution board that tests emergency lighting systems to AS/NZS 2293.1, energising emergency lights and exit signs and then automatically resetting after a pre-set time

Photoluminescent emergency lighting and signage systems:

Exit Sign and Escape Route products must meet the exit sign requirements of New Zealand Building Code Clause F8 Signs and the emergency lighting requirements of Clause F6 Visibility in Escape Routes.

Photoluminescent products shall only be used in areas where there is sufficient daylighting to charge the products.

1.2.2 Security Lighting

All new schools must have a security system, and all new facilities and building up-grades that cost over $200,000 must install a security system (see Security Design in Schools, Ministry of Education, 2018). Lighting forms an integral component of any security system.

If the floor area for the project is over 1000 m^2, a security design report must be carried out to:

- Identify local security issues.
- Outline how the design will deal with these issues, with reference to **Crime Prevention Through Environmental Design (CPTED; available on the Ministry of Justice website).**

Figure 8 below illustrate a summary of electric lighting strategies that designers should consider (refer to Section 3.10 for more electric lighting principles).

Minimum surface reflectances	
Ceilings	> 0.75
Walls	> 0.6
Display boards	0.3 - 0.5 (min-max)
Floors	> 0.2
Desks	0.2 - 0.4 (min-max)

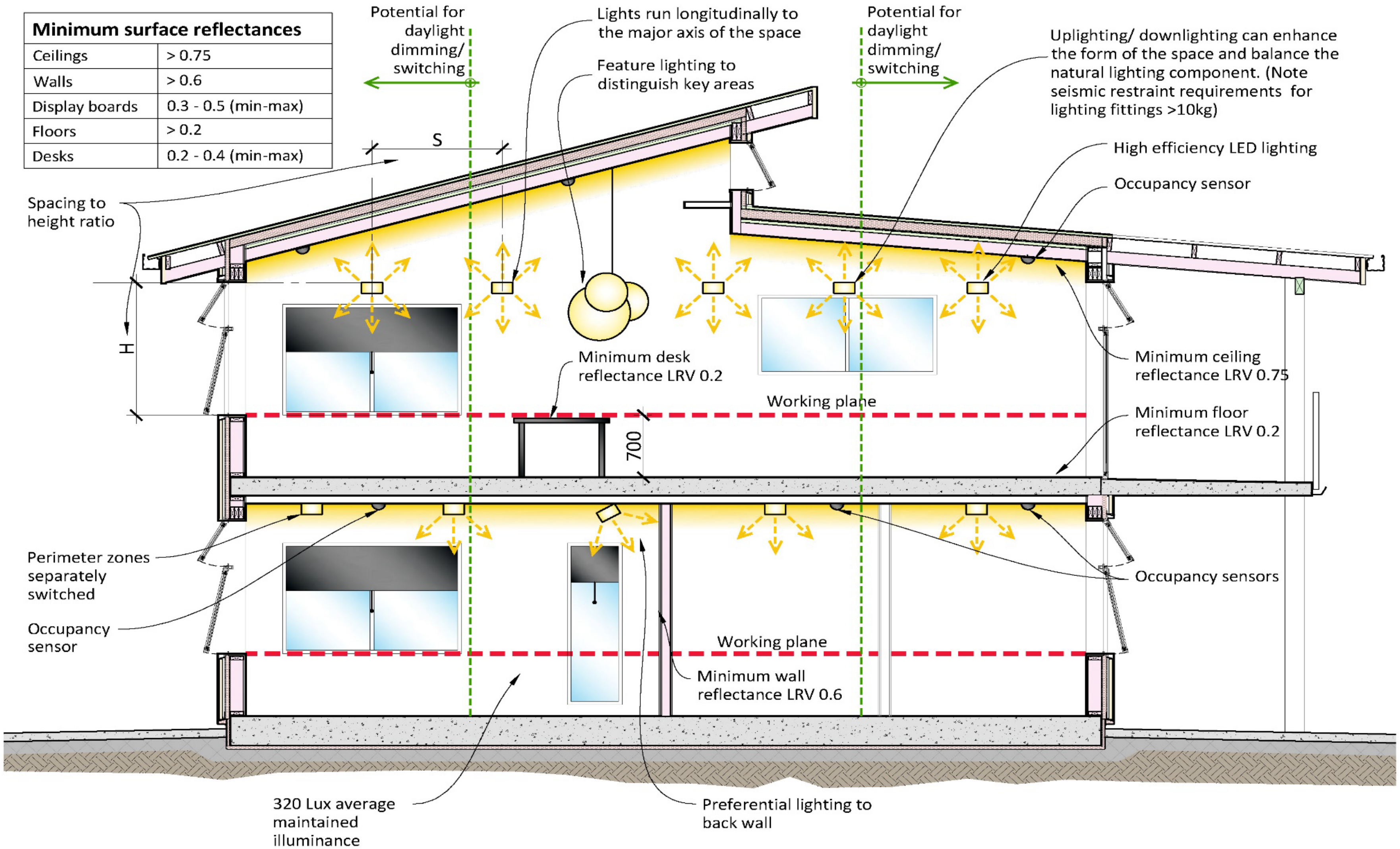


Figure 8: Summary of electric lighting strategies

1.3 Surface Finishes Requirements

The appearance of a space is largely controlled by the distribution of light within it. The minimum surface light reflectance values (LRVs) given in **Table 5**, below, should be used to create spaces with adequate brightness.

Table 5: Minimum light reflectance values for selected surface types.

Surface Type	LRV
Ceilings	>0.75
Walls	>0.6
Display Boards	0.3-0.5
Floors	>0.2
Desks	0.2-0.4

1.4 Site Planning for Good Daylighting

Master planning the layout of school buildings on a site or modifying the layout to accommodate roll growth, presents opportunities to achieve good daylighting within buildings and the open spaces between them.

Access to daylight can help to make buildings more energy efficient by reducing the use of electric lighting, heating and cooling.

Design considerations that enhance daylighting at the master planning stage of a building include:

- Building forms – narrow versus deep plan, single storey versus two storey (refer to **Table 8**)
- Building orientation - to maximise daylight, without exposing the interior to excess solar gain or glare
- Separation distances between buildings to minimize overshadowing
- The framing of specific views from buildings or from the site
- Using light coloured hard landscaping close to buildings and under covered walkways

These considerations must form part of an overall environmental analysis of the site, including wind, ventilation and acoustics. The form and relative position of buildings may have implications for wind flow, acoustics, and sunlight distribution. Figures 9 and **10**, below, illustrate some of the shading implications of building form, orientation and layout. Shading depth is a function of building height and is also influenced by site latitude. During site planning, consideration must be given to shading of both buildings and external activity areas, especially outdoor learning spaces.

Modern architectural software allows designers to rigorously explore the daylighting benefits of a range of site plans at concept stage.

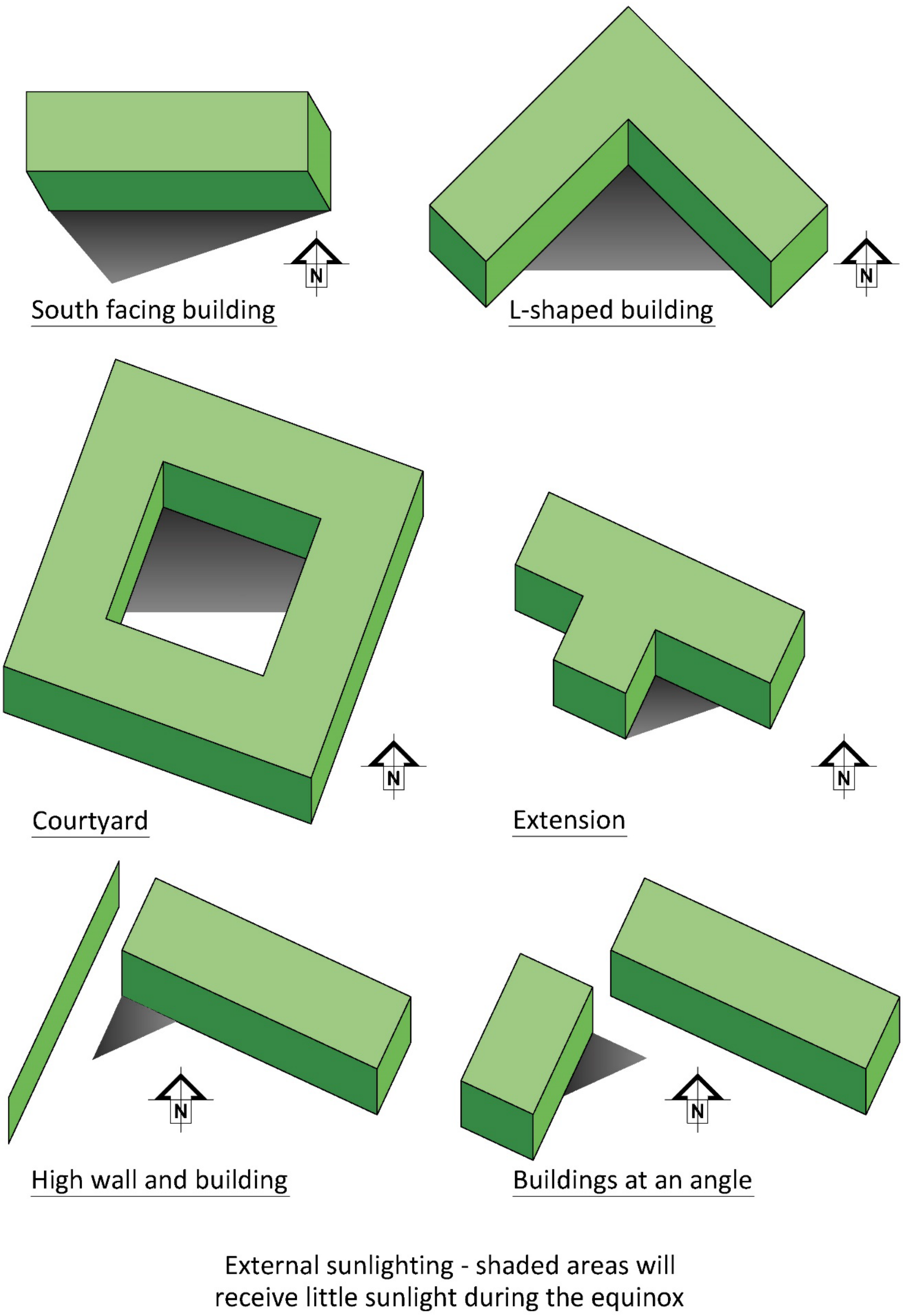


Figure 9: The Effect of Building Form and Orientation on Exterior Sunlight

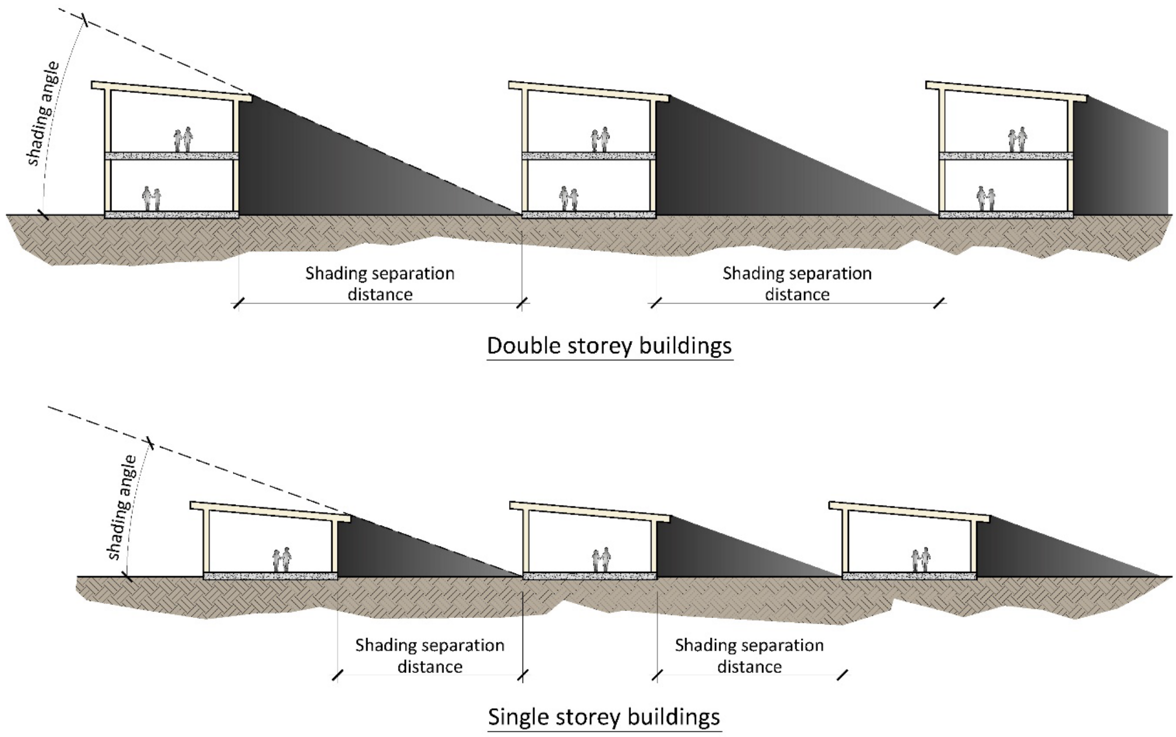


Figure 10: The Effect of Building Form and Orientation on Exterior Sunlight

Section 2: Lighting Recommendations

Learning spaces should be designed with the assistance of a lighting engineer. Lighting engineers are professionals with the knowledge and experience required to design learning spaces. This section provides recommendations that designers should consider when applying the mandatory requirements above. Section 2 of this document provides advice about designing to optimise daylighting and electric lighting.

2.1 Daylighting Recommendations

The following daylighting recommendations should be considered:

- Spaces that require higher lighting levels could be zoned to the North orientation, while spaces with high heat loads (e.g., computer rooms) could be zoned to the South orientation
- Where possible, it is preferable to place windows in more than one wall to improve the way light is experienced within a room
- In deeper single storey or upper storey spaces, the balance of daylight can be improved by the introduction of a carefully designed clerestory window or skylight which excludes direct sunlight on the working plane

Design characteristics that reduce glare include:

- Orientation of the building
- Fixed external sunshades, louvres, light shelving
- Internal blinds
- Splayed window reveals
- Painting the window wall in a light colour and avoiding dark colours near the window
- Rooms at the perimeter of the building should have glazed partitions to allow the use of borrowed light in interior spaces

2.2 Electric Lighting Recommendations

The following electric lighting recommendations should be considered:

- In single sided rooms with depths greater than 7.5 m, the walls remote from the windows should be lit preferentially and separately from the general task lighting, and should be switched separately, to balance supplementary electric lighting use and appearance with daylighting
- In deep spaces beyond 7.5m from a window wall, the ceiling should be preferentially lit with suspended up/down lighting to balance supplementary electric lighting use and appearance with daylight
- Add character and interest to flexible learning spaces by introducing some directional light to provide modelling and variety to special areas by use of spotlights, feature pendants or wall washing. These areas shall also be switched separately
- Whiteboards and presentation/display walls should be lit preferentially by dedicated (separately switched) ceiling mounted luminaires shielded from direct view and positioned above and in front of the whiteboard such that veiling reflections are avoided
- **All luminaires should use LED lamp technology**

- Luminaires should generally have a light output ratio of >0.7
- Lamp efficiency should generally be greater than 100 Lumens/lamp watt
- The maximum energy density from the lighting in any particular space should not exceed $8W/m^2$
- For calculation in design, a light loss factor (LLF) of 0.8 should be used
- Lamps and luminaires need to be regularly cleaned to minimize the deterioration of their light output. Consider maintenance when selecting the lighting equipment, luminaires or luminaire locations. Luminaires which require special arrangements for cleaning and re-lamping should be avoided.
- Special attention is required when positioning luminaires where ceiling sweep fans are used, in order to avoid flicker/stroboscopic effects
- Where not controlled by occupancy controllers, all luminaires should be time switch controlled, or should be switched locally with the master switch linked to the security system
- Luminaires in intermittently used spaces including Learning Spaces should be provided with occupancy control with local on/off/auto switches
- Luminaires within 5m of the perimeter of a space with side lighting should be separately switched, ideally with daylight dimming
- Luminaires should be designed in a flexible way that promotes adjustment (dimming) in response to changes in daylight levels
- Selected luminaires should be provided with dimming e.g., in learning spaces, drama studios, multipurpose halls, and in feature presentation areas of Learning Spaces

2.3 Surface Finishes Recommendations

In larger learning spaces, dull uniformity should be avoided by the judicious choice of reflectance and colour to ensure that some areas have a different character than others. There is also advantage to be gained in preferentially lighting certain focal areas of the learning space, such as book corners and display walls.

- Glossy ceiling and wall surfaces should be avoided to minimize confusing reflections and glare
- Avoid using dark surfaces immediately adjacent to windows
- Ceilings with exposed concrete surfaces intended to provide thermal mass in schools should be painted matt white as this provides good light reflectance

Floor finishes:

- When selecting floor finishes it is necessary to achieve a balance between the benefit of daylight and the operational needs of cleaning and maintenance
- Floor reflectance of between 20% - 40% should be provided in all learning spaces. Floor finishes should have a surface reflectance lower than 40% to avoid scuff marks. A floor reflectance value of 20% is generally used as standard in lighting calculations to assess unfurnished rooms; when furniture is installed, it generally has a higher surface reflectance than 20%, and so compensates for the low floor reflectance value used in standard calculations

Furniture and window surrounds:

- Gloss factor is different from reflectance and should not be confused. A highly reflective material with a matt or diffuse finish is beneficial in delivering light within an internal space. However, high gloss (specular) surfaces are likely to give rise to discomfort glare
- Direct daylight can be reflected from specular surfaces such as window sills with a high level of intensity and direction towards the internal occupants. This should be avoided

2.4 Refurbishment Recommendations

This section covers design considerations relevant to upgrading existing learning environments. It explains how the Ministry's mandatory requirements set out in Section 1 apply to upgrade projects and includes a range of potential strategies and design solutions.

Daylight and electric lighting design must endeavour to meet the Ministry's mandatory requirements as specified in Section 1, as well as any relevant requirements contained in other DQLS documents.

As with new building projects, major upgrades require an integrated approach to a number of aspects of building design and performance. This applies to upgraded spaces with different post-completion occupancy, spatial layouts, and activity patterns.

In general terms, daylight and electric lighting strategies for upgrade projects are much the same as for new buildings. There is generally room for some improvement in lighting provision as part of any upgrade. However, for new buildings, specifying daylight and electric lighting provisions automatically falls within the project scope. In contrast, it may not be immediately apparent whether an upgrade project will necessitate modification of the existing daylight and electric lighting arrangements.

One aim of this section is to offer guidance in determining whether daylight and electric lighting requirements should fall within an upgrade project brief. This discussion will centre on changes to key parameters, including building envelope, layout, occupancy level, activity type, and equipment age; the section will also consider how any proposed changes will affect the daylighting and electric lighting provisions for the spaces concerned.

Figure 11: A flexible learning space in an upgraded building in use

2.4.1 Changes to building structure, occupancy and usage patterns

In general, daylight and electric lighting requirements may change due to alterations in the use of the space, or in the external structure of the space. Designers should consider the implications for daylight and electric lighting of an upgrade project.

Three questions should be investigated:

1. **Will the expected use of the space (occupancy levels, activity types) change?**
2. **Will the upgrade involve significant modification of the building envelope?**
3. **Does the existing space perform poorly with respect to Ministry daylighting and electric lighting requirements?**

If the answer to any of these questions is yes, then further investigation of the daylight and electric lighting implications are warranted.

If there are significant changes to layout, occupancy levels, activity types and/or there are significant problems with the existing lighting provisions, then the daylight and electric lighting requirements set out in Section 1 should be followed as far as is reasonably practicable.

Walls, windows, floors, ceilings, roofs, doors and partitions all form part of the envelope of a space. Any change to these building elements should be investigated to determine its effect on daylighting and electric lighting of the spaces.

2.4.2 Daylighting design for refurbishments

As part of major upgrades, designers should consider the following:

- whether existing daylighting provisions meet the **Ministry's minimum requirements**
- what opportunities the project brief offers for **improving daylighting**
- whether to **increase or decrease the area of existing windows, or whether to eliminate or add windows**
- how to optimise the **use of passive design** within the bounds of the project scope
- how to **maximise the life cycle and economic performance** of any new system

2.4.3 Electric lighting design for refurbishments

Designers should consider:

- whether the existing lighting levels meet the **performance requirements** of Section 1
- the **age and condition of the luminaires,** and whether they can still be sourced and replaced with similar luminaires
- the extent of the upgrade and the impact it will have on existing lighting arrangements
- consider **repositioning or expanding** existing lighting arrangements
- consider a **full lighting replacement** for extensive upgrades where existing luminaires are in poor condition, or fail to meet the performance requirements of **Section 1**

Section 3: Lighting Design Guidance

This section covers the basic design considerations, potential strategies and design solutions relevant to good lighting design. The section is intended to provide guidance for building lighting design prior to any analysis being carried out in accordance with the mandatory requirements of **Section 1**.

3.1 Integrated design approach

With traditional design processes, when just 10% of a project's cost has been expended, 70-80% of the life-time costs and consequences of the building will have been effectively locked in. An integrated whole building design process develops an overall building design by 'work-shopping' a range of design options and solutions that offer positive outcomes across all design disciplines – architectural, structural, services, acoustics, fire *etc*.

Integrated Design brings together the various specialist disciplines that contribute to the overall design process of a building or project (**Figure 12**). For new school projects, collaboration between specialist design disciplines should ideally occur early in the design process, at the Master planning and Preliminary Design stages. Integrated design seeks to exploit available synergies between different design disciplines, and to avoid conflicts between the various design strategies developed by each discipline. Integrated design plays a key role in maximising indoor environmental quality and energy efficiency across the range of relevant building services.

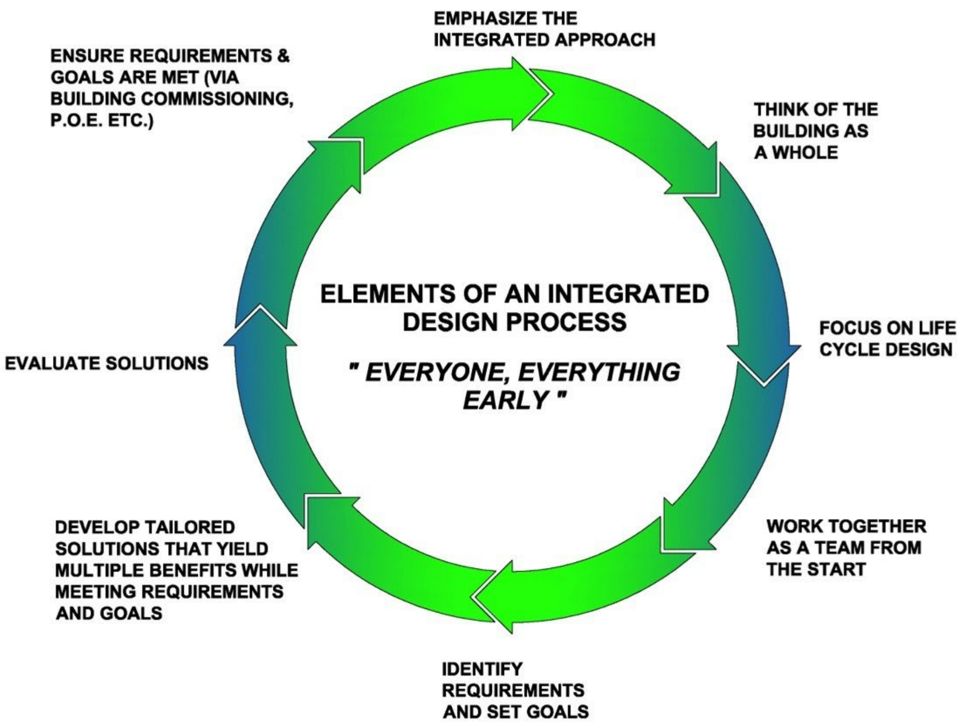


Figure 12: Integrated Design Process

Further guidance can be found in the Ministry for the Environment's Integrated Whole Building Design Guidelines.

Passive Design seeks to adopt design strategies that take advantage of local environmental and climatic conditions. A principal aim of passive design is often to minimise the building's energy use.

Passive design strategies may be employed across the range of specialist design disciplines, including lighting, acoustics, heating/cooling, and ventilation. Passive design strategies frequently involve more than one specialist design discipline – a passive temperature control strategy, for example, may have implications for lighting, ventilation, and structural design. Good passive design usually requires an integrated design process, as described above, that brings together all of the specialist disciplines that contribute to the overall design of a building or project.

Important elements of passive design include building location, form and orientation, internal layout and finishes, window design, external shading of the building, and passive ventilation design. Each of these elements should complement the others in order to achieve good daylighting, comfortable temperatures, good indoor air quality, good acoustics, and a high degree of energy efficiency.

Building design features can either support or challenge the achievement of passive design goals. Building design features that particularly affect passive lighting control are highlighted in **Table 6** below.

Table 6: Key design features affecting the success of passive lighting control.

Success Factors	Problem Issues
Site layout planned for daylight.	Site layout detrimental for daylighting design.
Shallow plan building design or deep plan buildings with side lighting and rooflights	Deep plan building design
Windows in multiple walls	Windows in one wall only
High ceilings	Low ceilings
Well designed and distributed windows	Poorly designed and distributed windows
Light internal finishes	Dark internal finishes
Flexibility of light switching & dimming to specific areas (allows greater reliance on daylighting)	Lighting grouped & switched together across dissimilar zones (lack of flexibility)

3.2 The Components of Interior Daylight and Electric Light

The illuminance level of a space is determined by three components (**Figure 13**):

- The **Direct Sky Component,** which is received directly at a point in the room with line of sight to the brightness of the sky. At some point in the room the sky will not be visible, and this is called the 'no skyline'. The direct sky component is significantly influenced by the size and configuration of the glazing and by the geometry of the room. This component is generally dominant close to the windows
- The **Internally Reflected Component** is dependent on the reflectances of the surfaces in the room (walls, floor, ceiling and furniture). It is a dominant source of illumination at points remote from the windows. A high proportion of internally reflected light indicates a greater degree of lighting uniformity within the space
- The **Externally Reflected Component,** which is received indirectly at a point in the room by reflection of light from external surfaces (surrounding buildings or ground surfaces immediately adjacent to the exterior of the glazing). This component is dependent on the reflectances of the surfaces external to the building and in the field of view. This is a tertiary source of illumination close to the windows

For good daylighting it is important to maximise the contribution of all 3 components, but also to balance their contributions such that the space appears to be well lit with good uniformity and without harsh contrasts and glare. Where adequate daylighting is not possible, daylight should be supplemented with electric lighting. Again, the balance between the two is important and electric lighting can be used to preferentially light surfaces such as walls and ceilings to improve the uniformity of lighting and appearance throughout the space.

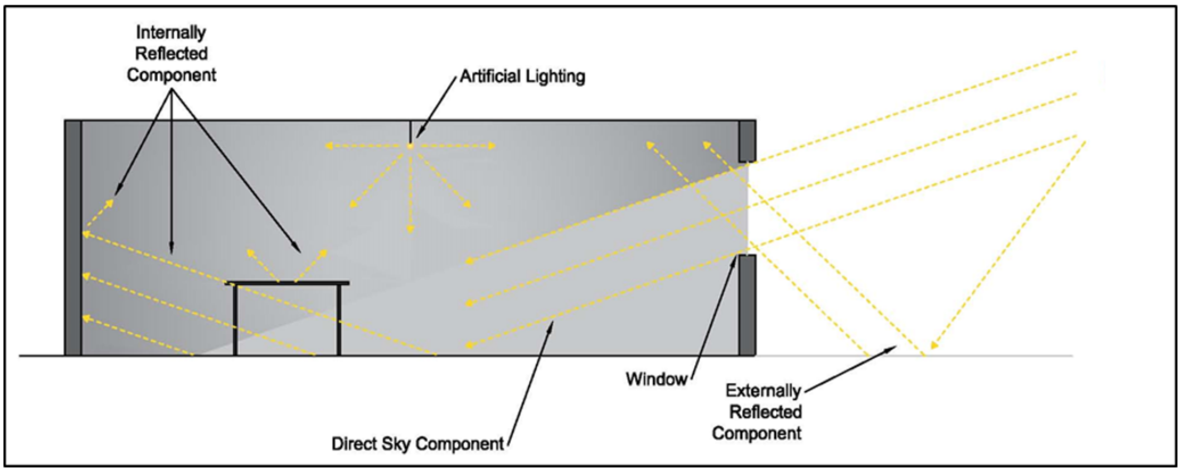


Figure 13: The Components of daylight and Electric Light

3.3 Orientation

Solar access and solar control are important aspects of school design.

Orienting a building on an east-west axis, with most glazing facing north and south, has traditionally been the aim in school design. An east-west orientation allows for easier solar control by means of overhead eaves, screens or shade structures due to the higher inclination of the sun. North facing buildings are generally the most favourable as this allows for adjacent outdoor areas to receive winter sun and creates bright, warming environments that can support outdoor learning and play. The southerly facing spaces in an east-west aligned building receive very little, if any, sunlight during normal school hours. Depending on the intended use and particular design of the southerly-facing spaces, this may allow for uniform daylighting with minimal glare, or it may be disadvantageous if the spaces would benefit from some direct sunlight. Consideration should be given to the intended uses of spaces when selecting their orientation.

In situations with deeper floor plans, say in excess of 12-14 m width, there may be merits to inclining the axis away from a due east-west axis for the building so that all areas of the learning space will receive some sunlight throughout the day.

An ideal orientation generally lies between +/- 30˚ North (**Figure 14**).

Where feasible through site planning, a due north-south axis with large elevations of east and west facing glass should be avoided in order to control and prevent associated glare and solar gain issues.

Poor orientation can be mitigated with good shading, although this adds cost and complexity to the building form

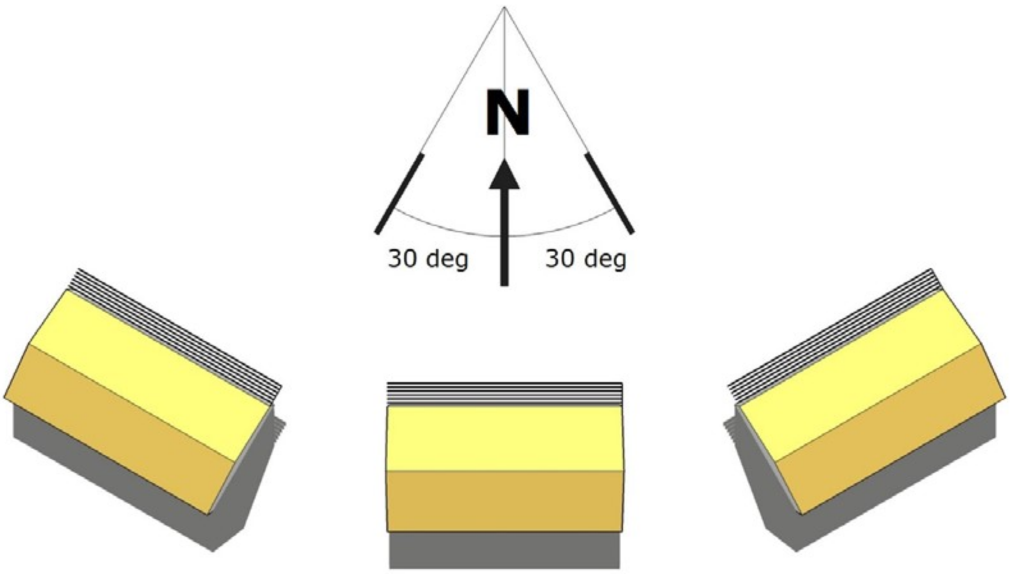


Figure 14: Building Orientation shading to help manage solar gain.

3.4 Building form

The form of a building can impact on the daylight distribution within the spaces, hence the following should be considered:

- Deeper spaces are characterised by poor daylight uniformity, which leads to the use of electric lighting in areas furthest from the window. Generally, narrow building forms allow greater utilization of daylighting and natural ventilation
- Single storey buildings also allow the roof design to be utilized more fully in deeper plan spaces
- As building forms become deeper, more complex and more sub-divided internally, reliance on daylighting becomes increasingly challenging
- In planning school buildings consider the depth of the floor plate and its implications for teaching and learning, as well as for daylight and natural ventilation
- Buildings of around 12-14 metres depth will allow more building envelope per square metre of floor area, with greater opportunities for light and ventilation to penetrate the building, even when multi storey. They can relate well to outdoor learning areas but do not allow for as much internal connectivity between learning areas
- Buildings in excess of 12-14 metres depth increase the possibilities of educational connectivity, particularly for maximizing cross curricular learning. The reduced building envelope per square metre of floor area may therefore require overhead daylighting. Clerestory windows or roof lights should therefore be considered. For larger learning spaces, increased building heights and volumes can also help to improve the potential for daylighting. The ratio of height to depth is an important factor in daylight design. Increased areas of taller glazing can assist in deeper plan spaces, as will providing windows in more than one wall

Atrium Design Considerations

Atria in schools are not common, as they are costly, but there will be occasions (on difficult sites and more complex building forms) where they may have a place, as a means of introducing daylight.

Some general considerations in the design of atria are as follows:

- The atrium shape and axes should follow the shape of the building to maximise the extent of spaces benefiting from the daylight it introduces
- The well index should be kept as low as possible
- Increasing the floor-to-floor heights, particularly at the lowest floor, in deep form buildings with atria to increase daylight penetration from the perimeter and atrium
- If an atrium is to be fully daylit, its height should be less than 2.5 times its width
- Use high reflectance walls within the atrium and maximise the area of reflective surfaces at the upper parts of atrium to increase reflected light at the lower floors.
- Keep windows within the atrium free from obstruction
- Maximise the view of the sky from spaces adjoining the atrium by using tall windows, or potentially by sloping atrium walls
- Increase light transmission of any glazing adjoining the atrium
- Maximise glazing and openings at the lower levels of the building opening to the atrium
- The design of the atrium roof in relation to local climate and daylight availability should introduce more indirect light in warmer parts of New Zealand, and more direct light in cooler parts. Shade direct sunlight on any adjoining learning spaces (such as glare or solar gain), particularly for the upper floors of the atrium building

3.5 Window Area to Floor Area Ratio and Window to Wall Ratio

Although light is a key design parameter, window size alone is not significantly correlated with learning outcomes. Only when orientation, risk of glare, and overheating are taken into consideration can students benefit from optimum glazing size.

A number of rules of thumb relating to daylighting design have been developed over time; these should be used with caution (Ibrahim & Hayman, 2005), as many were created for climates dissimilar to our own, and can result in overlit spaces. However, these rules of thumb can provide helpful shortcuts as part of the analysis of daylighting requirements given in **Section 1.1.**

3.5.1 Window Area to Floor Area Ratio

This ratio has historically been used in a variety of overseas building regulations as a means of specifying minimum glazing area for spaces. For example, 20% window area to floor area has been proposed by various authors (Robson, 1888, 1972; Waldram, 1914; Hopkinson, 1963) for health, comfort and effective teaching of children. Similarly, for schools in New York a ratio of 17-25% has been used (Price, 1914).

The area of glazing necessary to achieve the required quantity of daylight depends upon the arrangement of the glazing. When side-lighting in one wall only is employed, it is difficult without very high ceilings to achieve the necessary quantities of daylight with a glazed area of less than 20% of the floor area. If side lighting is in two or more walls the area could potentially be reduced to 12.5%, and if the side lighting is supplemented by top lighting the area could potentially be reduced to 10%. Below 10% it is unlikely that a satisfactory view outside will be provided.

3.5.2 Window to Wall Area Ratio

This is a commonly used environmental ratio which appears in the companion DQLS publication, ['Indoor Air Quality and Thermal Control'] to limit glazing area for thermal reasons, i.e. control of heat loss and heat gain. It is also used in daylighting design for ensuring the adequate provision of view, and as an alternative to the 'window area to floor area' ratio for ensuring adequate daylighting. For buildings in general, window wall ratios typically range from 30 - 50% (other than in curtain wall type buildings). The window to wall ratio for school buildings tends to be towards the lower end of this range, ie. 30-35% primarily due to cost and the simpler construction methods and forms used for school buildings.

Table 7, below, indicates the minimum glazed areas below which research (IES, 1972; Ne'eman & Hopkinson, 1970) has shown that windows do not provide sufficient view.

Table 7: Threshold window wall sizes conducive to occupant satisfaction

Depth of Room (distance from the window wall)	Window-to-Wall Ratio
<8m	20%
8-11m	25%
11-14m	30%
>14m	35%

- When determining the window to wall ratio for the purposes of calculating an appropriate glazing area, it should be noted that glazing beneath the working plane will not contribute significantly towards daylight illumination; glazing beneath the working plane should therefore be minimized.
- **Figure 5**, above, brings together these criteria into a visual form that provides a quick first check on window area provisions for a typical learning space.
- Most modern learning environments tend to be 11-14 m in depth, and so a window to wall ratio of 30-35% is generally the minimum for adequate daylighting.

3.6 Room Depth

Room depth is another important determinant in the effectiveness of daylight design. This has been expressed in a number of ways in daylighting publications – including window head height to room depth ratio and limiting depth.

3.6.1 Window Head Height to Room Depth Ratio

Window head height has been used in a number of 'rules of thumb' to help determine the maximum room depth that will promote good daylighting. Maximum room depth to window head height ratios from a number of studies are provided below:

- Maximum room depth is 2 to 2.5 times window head height for continuous fenestration and curtain wall construction where window heads are close to the ceiling (Kaufmann, 1975)

- 2.5 times window head height for continuous or near continuous windows under overcast skies and 3 to 3.5 times under a clear sky (AIA, 1982)
- 2 times for continuous clear glazed and curtain walling (Rea, 1993)
- 2.5 with a daylight factor of 2% (Standards Australia, 1994)
- 2 to 2.5 times window head height as a general rule (Dekay & Brown, 2013)
- 1.5- or 2.5 times window head height with a north-facing (southern hemisphere) light shelf (O'Connor, 1997)

These rules of thumb apply to unilateral or single-sided daylighting unless otherwise specified. A widely proposed variant of these rules (e.g., Yeang, 1999) recommends a maximum floor depth of twice the ceiling height.

These rules may provide useful guidance during early design stages. However, the iterative five-step process set out in **Section 1.1**, above, should be used to determine the window head height, glazing areas, and room depth required to ensure adequate daylighting.

3.6.2 Limiting Room Depth

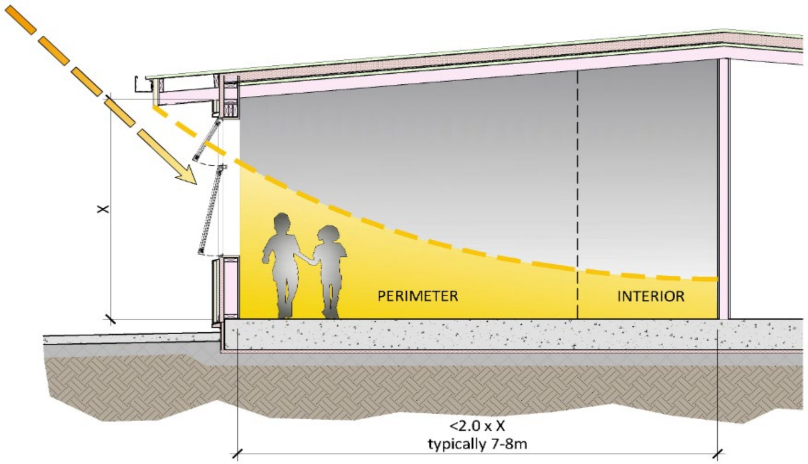
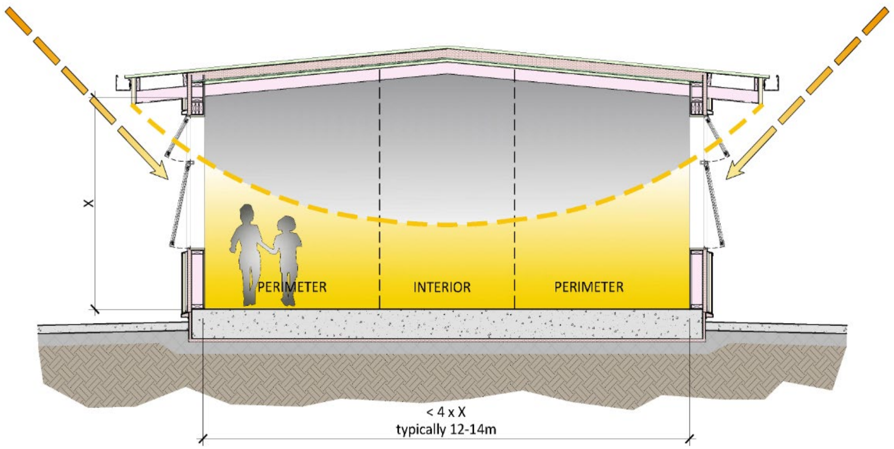
Daylighting rules of thumb specifying absolute room depth also have a long history. Again, these are usually stated without additional limitations, although room geometry, surface reflectances, window orientation, window transmissivity, and site latitude all affect daylight penetration. The rules of thumb provided below apply to unilateral daylighting:

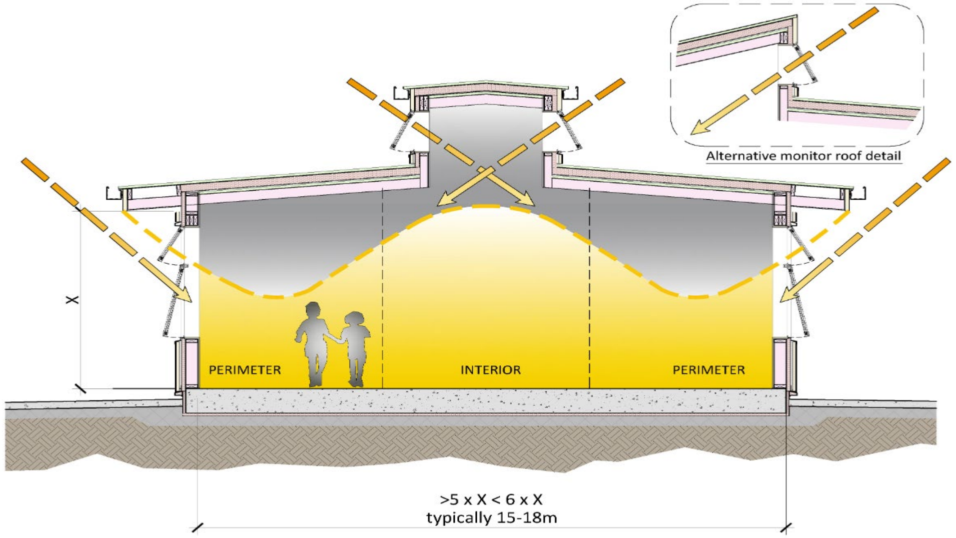
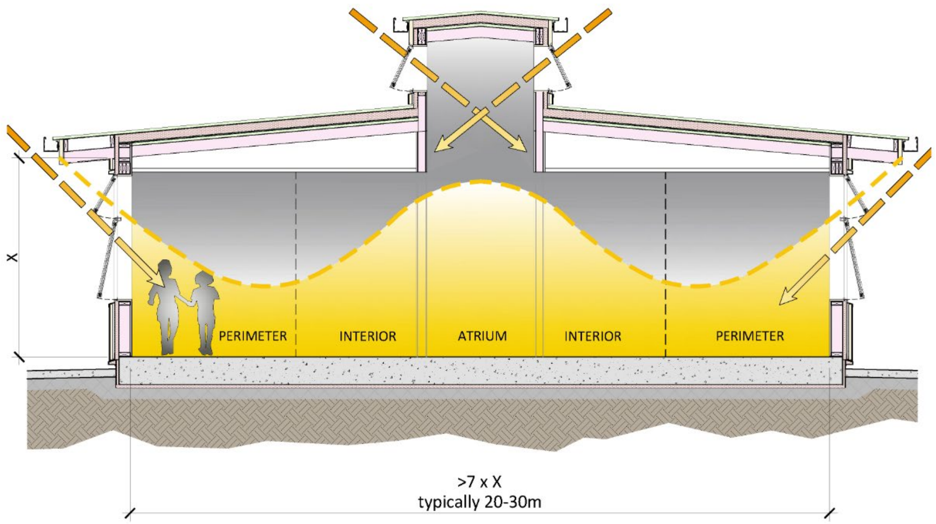
- Maximum floor depth of approximately 8 metres and a ceiling height of 2.7 metres for adequate daylight and ventilation in reference to 1930's New York skyscrapers (Willis, 1995)
- Six metres for buildings with window to window to wall area of between 15 and 20% (e.g. Yeang 1999, Ibrahim and Hayman, 2005)
- Five metres for windows or roof lights illuminating a room from one side (Ruck, 1995)
- Fully daylit to 4.5 metres (Manning, 1965) and partially lit to 9 metres (Lechner, 2001)
- Full and effective daylighting at 3.6 metres (Manasseh and Cunliffe, 1962)

The above rules may provide useful guidance during early design stages. However, the depth of the daylit area in a space shall be calculated using the iterative five-step process set out in **Section 1.1**, above.

Table 8 brings together room depth criteria into a visual form that provides a quick first check on the depth of spaces and the approach to daylight design. The daylight analysis required by **Section 1.1** can then be used to refine the design further.

Table 8: Building Form and Daylighting

School building forms		Building type	Lighting strategy	Advantages & disadvantages
1 Shallow plan single side windows		**Traditional classroom** **Primary/ Secondary**	**Predominantly day lit**	• Simple learning space • Larger surface area of external wall/ glazing • Low energy use/ passively controlled • Side windows at rear of room can assist
2 Shallow plan windows in opposing/ adjacent walls		**Smaller building learning spaces** **Primary**	**Predominantly day lit**	• Allows larger learning spaces to be accommodated • Low energy use • May need electric lighting to be on in centre of room • Zone lighting for perimeter and interior lighting switching/ control

School building forms		Building type	Lighting strategy	Advantages & disadvantages
3 Medium plan		**Larger learning spaces** **Primary/ Secondary**	**Predominantly day lit**	• Allows larger learning spaces to be accommodated • Low energy use • May need electric lighting to be on in centre of room • Zone lighting for perimeter and interior lighting switching/ control
4 Deep plan		**Larger learning spaces** **Secondary**	**Balance of daylight and electric daylight**	• Allows for a range of smaller and larger learning spaces closely adjoined to the central circulation spine or atrium for 2 storey forms • Building form and internal subdivision affects natural lighting • Can potentially be naturally lit if the learning spaces are open to the atrium/ circulation space but may require electric lighting to maintain acceptable year round lighting • Natural light may be compromised to some extent

3.7 Position of the No Sky-Line

If a significant area of the working plane (normally more than 20%) lies beyond the no sky-line (i.e. it receives no direct skylight) then the distribution of daylight in the room will look poor, and supplementary electric lighting will be required. This should be considered at the design stage; switching and preferential lighting of surfaces should be designed accordingly.

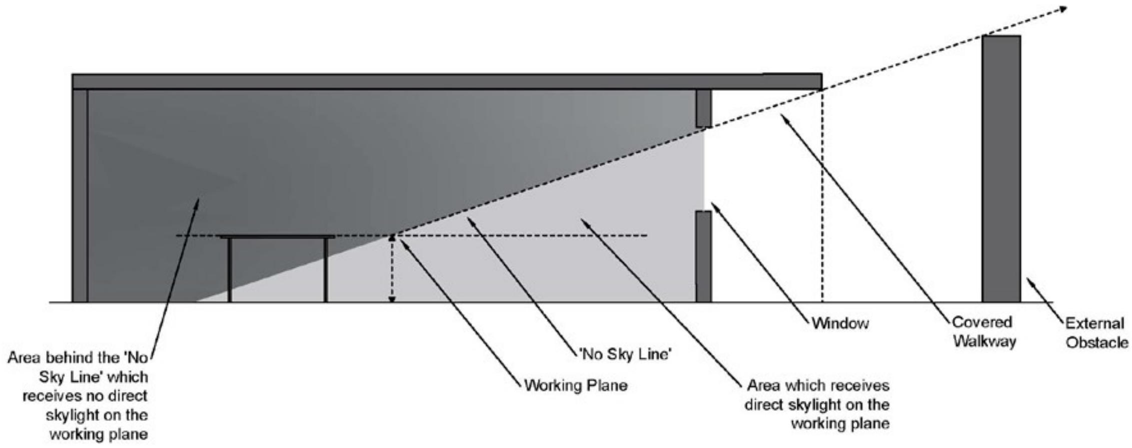


Figure 15: Position of the 'No Sky-Line' in a room

3.8 Window Design

Good design should incorporate a mix that ensures that the appearance of the building from the exterior and the delivery of good quality daylight are balanced. A better approach is to prioritise users of the space, and to investigate window design opportunities that provide a view to the outside, and which provide good daylight penetration.

3.8.1 Window Placement

A number of considerations besides optimal daylighting design may inform placement of windows. Other considerations may include placement so that staff and students can enjoy specific views, or to allow good supervision of outdoor learning areas. Hence:

- Windows can also be positioned to optimise the even distribution of daylight as an illumination source. This will generally require that the windows be reasonably evenly distributed in the available window walls
- In deeper single storey or upper storey spaces the balance of daylight can be improved by the introduction of windows to the rear and side, or by introducing carefully designed clerestory windows or skylights which exclude direct sunlight on the working plane
- Window area below the working plane is less useful than above the working plane
- Horizontal rooflights in the plane of the roof (as compared to clerestory glazing) are generally problematic and should be avoided, other than in covered walkways

3.8.2 Window aspect ratio

The preferred shape of windows may depend on whether a window is being considered primarily for view, or for illumination. Shorter wide aspect ratio windows tend to be good for views, whereas narrower and taller aspect ratio windows are more helpful for daylight penetration. Wide aspect ratio windows may be appropriate overlooking outdoor learning areas, while taller aspect ratio windows would maximise light penetration into the room interior and might be positioned to the rear or sides of learning spaces.

It may be more important to provide a view to the exterior in shallow learning spaces, and to prioritise illumination in deeper learning spaces. Alternatively, a low-level wide aspect window with solar shading may be used to provide a view to the exterior, with a high-level window above to provide daylight penetration into the space.

3.8.3 Glazing Type

A wide selection of glazing is available, variously designed to maximise acoustic insulation, minimise transmitted solar gain, maximise thermal insulation, or some combination thereof. A useful rating value for light transmission through glazing is its visible light transmission (VLT).

There is a preference in schools for the use of clear (or at most, lightly tinted) glass with a VLT > 70% (in conjunction with shading devices where necessary). **Reflective or heavily tinted glass should be avoided.**

Additional shading can be provided in a variety of architectural ways, such as by overhangs, louvres, brise soleil, fins and covered walkways.

3.8.4 Shading

The use of sunshades should be considered as appropriate to the orientation of each façade and the extent of the glazing. These may consist of simple overhangs for north facing orientations, or fins or outriggers for orientations facing east and west.

Shading by itself is seldom fully effective at all times of the day and year, and internal blinds should therefore also be provided where required to control glare and direct sunlight. The interaction between internal blinds and ventilation openings needs to be carefully considered. Window design should allow the deployment of blinds without obstructing ventilation openings.

The achievement of daylighting goals will have implications for the thermal design strategy employed; passive lighting and passive thermal control are closely allied, and the two need to be carefully considered and jointly optimised.

Figure 16: Combination of sunscreens and overhangs provide a good level of solar shading and daylighting

Figure 17: Use of external sunshade screen to manage heat gain and glare.

3.8.5 Reflectors

Reflectors can help balance daylight distribution within a space and minimize the need for blinds to control glare. The most common reflecting device is a light shelf. This is either used at the perimeter for side lighting or associated with clerestories at high level. A light shelf is a horizontal or near horizontal baffle which provides shade below it and reflects light into the building from its top surface. Light shelves reduce light levels to the front of the room and redirect light onto the ceiling for a more balanced daylit appearance.

In perimeter daylighting applications light shelves are fitted some way up a window, dividing the window into two parts - a view window below the shelf and a clerestory/daylighting window above the shelf. Ideally light shelves should be at a height of just over 2.0m above floor level, and they should have a semi-specular finish (ensuring they have self-cleaning surfaces (rain) if outdoors and can be readily cleaned inside). Light shelves can be internal, external, or both. In addition to redistributing light, they can also provide a more pleasant environment by reducing glare close to the window line.

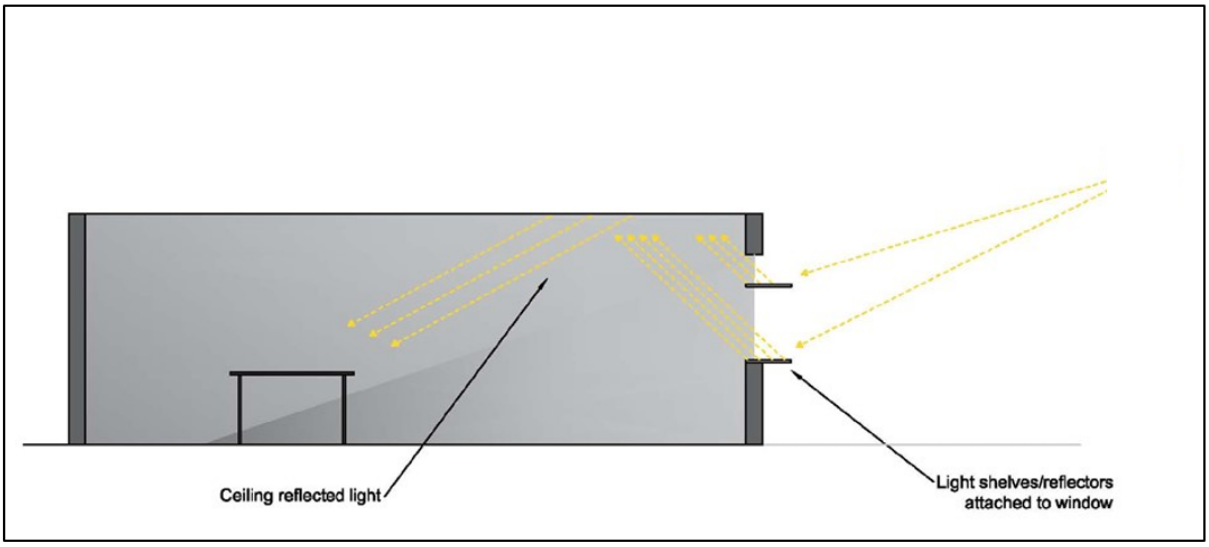


Figure 18: Daylight Reflectors

Prismatic or laser-cut glazing tuned to particular sun angles for specific orientations have been used in the top sections of windows and in clerestories in some Australian schools with high sunshine hours. These deflect daylight towards the back of the room. They are less effective in cloudy locations as they tend to reduce daylight levels (Santos, 2009).

3.9 Daylighting Strategies

3.9.1 General

Daylighting shall meet the performance requirements of Section 1.1.

Daylighting can be provided solely by side windows. This strategy is typically used for smaller rooms up to 6-8 m deep, or for larger rooms up to 12-14 m deep if windows are provided in two or more sides.

Spaces deeper than 12-14 m should also consider vertical clerestory/lightwell rooflighting where feasible.

3.9.2 Side Lighting Principles

The main advantage of side lighting is that it provides both daylight and a view to the outside.

Windows with heads close to the ceiling give higher levels of light towards the back of a space compared to similarly sized windows set lower into the wall.

Being horizontal, the light from side windows provides strong modelling of peoples' faces and of solid objects. If it is too strong, the effect may be harsh.

When windows are placed in multiple walls in a space, the resulting shadows and modelling effect will be softened. Too much glazing in multiple walls can, however, make the daylight too diffuse and the modelling effect too flat and lacking interest.

Figure 19: Side Lighting Design Principles – tall windows in more than one wall, with borrowed light via glazed walls to break out/study space

3.9.3 Roof-Lighting Principles

Rooflights provide a measure of contact with, and awareness of, the outside environment - particularly with regard to changes in weather. However, they are less effective in this respect than windows in side-walls.

In combination with side-windows, rooflights can modify the overall flow of light so that shadows are softened and walls that do not receive direct light from side-windows are brightened. For this reason, rooflights are particularly helpful in relatively deep-plan spaces.

Carefully designed rooflights also provide a more even distribution of light than side-lighting.

The nearer the slope of glazing is to the horizontal, the more light it will transmit. However, it will also transmit more sunlight (as opposed to diffuse daylight), which is undesirable with respect to solar heat gain and glare. For maximum solar control, roof glazing should be vertical and should face due south. Vertical roof glazing is generally referred to as clerestory glazing. However, to produce the same level of daylight, a south-facing rooflight will require at least 3 times as much glazed area as would a nearly horizontal rooflight. Horizontal rooflights have the disadvantages of being more difficult to weatherproof, and more difficult to use as part of a natural ventilation strategy. They should therefore generally be avoided.

Clerestory glazing with orientations other than due south require careful consideration. Over-hangs, shading fins, or a combination of both may be required to limit direct sun penetration at all times of the year.

Figure 20: The effect of balancing overhead and side lighting in deeper spaces

Figure 21: A very deep plan space with high ceiling, central clerestory rooflights, and suspended luminaires with up/down lighting components.

Figure 22: High ceiling and central clerestory rooflight.

Figure 23: Extensive natural roof light system with more limited side lighting maintains good daylight levels, but with reduced outside awareness

3.10 Electric Lighting

A well designed and flexible general lighting layout will normally provide uniform horizontal illuminance over the whole of the working area. It will provide sufficient light for the tasks to be carried out anywhere within the room. The pattern of lights can be varied, but it is generally better to align luminaires parallel to the major axis of the space. This arrangement is also complementary to the flow of daylight from side windows, particularly if daylight dimming or switching is considered, as described in **Section 2.2**. Diagonal and 'herring-bone' patterns can cause a disturbing visual effect and should be avoided, other than potentially as a specific lighting highlight feature.

Even lighting is achieved by spacing the luminaires correctly: spacing guidance is given by the luminaire supplier in the form of a recommended spacing to height ratio (s/hm). Provided the ratio has not been exceeded, the uniformity of horizontal illuminance over the whole of the working area should not vary by more than 0.7 - 1.0 (this is known as the uniformity ratio). This assumes that there are no vertical obstructions within the working area.

Disadvantages to this type of regular lighting layout include:

- The lighting may be monotonous and flat.
- The lighting may lack a sense of flow, although normally this is provided in daylight hours by daylight from side windows.
- There may be inadequate light on the ceiling.

These disadvantages can to some extent be mitigated by preferential local lighting to feature areas or feature walls where display material may be hung. Preferential lighting of walls and ceilings remote from side-lit windows can be helpful in balancing daylighting and electric lighting.

3.11 General exterior and security lighting

General exterior lighting

General exterior lighting for afterhours school use should provide an adequate and safe level of light for staff, students and visitors in car parks, walkways, courtyards, entries and other frequently used areas. The period after normal school hours when electric external lighting is required will vary throughout the year. Automated controls are best set using a time clock with seasonal adjustment; an after-hours override button with adjustable timer should be provided for unplanned use.

Control of external lighting using photocells only, which turn lights on when it gets dark and off again in daylight, is not recommended. Photocells may be appropriate if used in conjunction with a time clock.

External lighting controlled solely by photocells may waste energy by keeping lights on for an excessive period of time, and neighbours can become accustomed to the school being 'lit up' and may not notice when security lighting is triggered. It is recommended that after normal school hours, external lighting revert to security lighting.

Good general exterior lighting:

- should provide even illuminance across a public area
- should light up those parts of the building that can be seen from public areas, including exterior doorways and parking areas

- should not create blind spots and shadows
- should not use in-ground luminaires due to cost and reliability

External lighting design considerations include:

- positioning of luminaires so that they don't cast shadows in dark corners
- use of luminaires that cast a light pattern over a broad horizontal area, rather than a tall vertical area
- use of light-coloured surfaces that reflect light more efficiently than dark-coloured surfaces
- use of 'dark sky' luminaires which direct light down to where it is needed are generally recommended

Security Lighting

Security lighting only turns on if someone enters the school after hours. It is specifically designed to provide natural surveillance, to work well with CCTV systems, and to discourage unwanted visitors.

It is best practice not to have security lights on all night; they should instead be triggered by motion sensor switches (such as passive infrared sensors). By activating suddenly, security lights should:

- surprise intruders and discourage them from going further
- send a message to trespassers that they have entered a private area and can now be seen
- signal to neighbours and passers-by that someone may be trespassing

To make security lighting most effective:

- use passive infrared sensors to activate lighting when there is a human presence
- mount security lighting sufficiently high so that it cannot be vandalised or stolen
- ensure that motion-sensor detector heads are inaccessible, so that intruders cannot tilt the sensor to stop it from detecting their presence
- design security lighting to complement the use of any CCTV cameras; if an area cannot be overlooked or observed at night, then lighting will only help an intruder to see what they are doing, rather than deter them. In this case, other security measures such as actively monitored CCTV, or patrols of the area by security staff, will be required
- higher lighting levels may be required for more vulnerable areas as identified by a CPTED report
- use luminaires that provide adequate light and colour rendering for an offender to be identified by CCTV; LED lamps provide a white light that makes it easier to identify colours

Additional guidance on security system design may be found on the Ministry of Education's website.

3.12 Lighting Control Strategies

Lighting control for schools can be relatively simple, and should consist at a minimum of one of the following strategies:

1. Time switched control of lights with On/Off/Auto override switches in each space. Zones can be set up for separate areas e.g., learning spaces, administration spaces, multi-purpose hall, and gymnasium
2. A better arrangement would use occupancy sensing in each principal space, again with a local On/Off/Auto override switch. This has the advantage over time-switched controls of lighting the room only when it is occupied
3. Time switches and occupancy control can also be combined to provide simple daylight control of perimeter zones (< 4.5 m from the window wall) in well daylit areas. This can be used to automatically switch off the lighting at the perimeter between the hours of e.g. 10:00 am to 3:00 pm, with local manual override facilities for when daylight is inadequate on dark days. This arrangement has the advantage of reducing the amount of electric lighting used when the space is occupied
4. A more sophisticated and costly option is to dim the lighting at the perimeter in response to daylight levels. This overcomes the need for a manual override facility and provides for a more graduated integration of daylighting and electric lighting across the space
5. The most sophisticated lighting system includes occupancy control and full dimming capability of all luminaires. This enables daylight dimming at the perimeter, maintenance dimming by reducing the higher illuminance levels available when luminaires/lamps are new, and reduced lighting levels for activities' such as cleaning

For new schools, strategy 3 is recommended and for upgrades, strategy 2 or 3 is recommended.

Section 4: Specialist Learning Spaces

Specialist spaces usually require special lighting arrangements to meet their particular design characteristics and activities.

For each specialist space, the following issues will be considered in turn:

- **Daylight Design**
- **Electric Lighting Design**

In general, the requirements and recommendations contained in **Section 1** and **2** will apply to general and specialist learning spaces. However, specialist spaces may have additional requirements, such as local and flexible task and dimmable lighting, stage lighting, or black-out and grey-out shade devices.

Specialist spaces such as gymnasiums, multi-purpose halls and theatres may require complex and elaborate lighting, and specialised controls.

Designers must:

- consider that **stage lighting and specialist lighting are significant investments** for schools
- arrange with the appropriate service contractor to provide proper **training to school staff** to ensure that they are **able to maintain and operate the lighting** and control systems
- arrange for a **service manual** to be supplied to the school

4.1 Special needs facilities

Lighting designers should consider the needs of students with a wide range of impairments, including visual, hearing, physical, behavioural, and learning disabilities. **NZS 4121:2001 – Design for Access and Mobility** provides general guidance. The particular lighting needs of students with visual or other impairments can be varied. It is difficult, therefore, to make general lighting design prescriptions that would accommodate all special needs.

Due to the diversity of impairments to be expected among the typical school roll, general school buildings are best served by good general lighting design in accordance with the Ministry's requirements and recommendations set out in **Section 1** and elsewhere in this document, and in accordance with the design guidance contained in **NZS 4121:2001**. Other resources such as Design Guidelines for the Visual Environment (National Institute of Building Sciences, 2015) may also provide useful general design guidance.

This section is primarily concerned with lighting design features particular to special needs facilities, rather than with impairment-friendly lighting design advice for general school buildings.

Design guidance for special needs facilities

Special needs facilities may include Sensory Resource Centres catering to students with hearing or vision impairments, or Special School satellite units. Design guidance particular to special needs facilities is summarised below:

Lighting Flexibility:

Special needs facilities provide an opportunity to tailor lighting design to the specific requirements of individual students. The particular lighting requirements of students with visual or other impairments can be varied. Designed flexibility is therefore important to accommodating a wide range of individual needs.

For many visually impaired individuals increased general illuminance improves their visual performance, however, increased illuminance may be detrimental for others. **Task lighting and locally dimmable lighting is preferable to higher general illuminance levels.**

Individuals with certain impairments, such as autism, may be particularly sensitive to lamp colour temperature. Some individuals show a marked preference for 'cold' light, and others for 'warm' light. **Task lighting should be available in a range of colour temperatures.**

Controls for lighting, window blinds, screens *etc.* should be accessible and operable by the student themselves. Controls should be located within reach of students while they are working.

Glare Minimisation:

Heightened sensitivity to glare is common for people with visual impairment. Particular care should be taken to shield light sources from view. In the case of flexible task lighting, this may require movable partitions between task areas in special needs facilities. Window blinds and movable screens should be used to control glare from windows and from internal light sources.

Contrast Maximisation:

Visual contrast helps to demarcate and identify building elements, furniture, *etc*. Visual contrast is a function of the colour, reflectance and texture of the surfaces themselves, and also a function of the colour rendering index of the light source.

Doors, door frames, and door furniture should be chosen with colours and textures that contrast strongly with each other and with the surrounding wall.

Handrails should be chosen with colours and textures that contrast strongly with the background wall.

Walls should contrast strongly with both floors and ceilings; corners should be marked by a change in wall finish or by a contrasting nosing.

Floor finishes should be chosen to give a floor cavity reflectance at the higher end of the range given in **Section 1.3**, above, (towards 40%).

Types of visual impairment

Designers should consider a range of visual impairments, including:

- **Tunnel vision** narrows the field of vision to a central area, with loss of peripheral vision. This may hinder mobility and peripheral awareness, while supporting fine task work and reading
- **Loss of central vision,** with retained peripheral vision. This is frequently caused by macular degeneration. This may hinder fine task work, without substantial impairment of mobility. Additional task lighting is typically not required by people with a restricted field of vision, although they may be particularly sensitive to glare

- **Loss of colour vision**, with retained ability to distinguish shades and textures. Where colour is used as a visual cue, complementary use of other cues such as texture or contrast may assist in making the cue more accessible
- **General blurring of vision or low acuity**, which may require the person to be in close proximity to objects in order to see them best. Glare can be particularly troublesome – light contrasts that may not be problematic for a typical person may cause disabling glare for a visually impaired person. In some cases, brighter task lighting may help a person with low acuity; in other cases, it may hinder them
- Some **behavioural conditions** can be triggered or exacerbated by bright or flickering light. Flickering light can cause seizures in some epilepsy sufferers (including some blind epilepsy sufferers); people with autism can be hypersensitive to flickering light and to luminaires that emit noise; bright glare, especially when intermittent (flickering) can cause migraines or other reactions in photosensitive people

Design guidance specific to different types of visual impairment is summarised in **Table 9**, below:

Table 9: Specific lighting design measures for occupants with special visual needs.

Impairment	Beneficial Lighting Design Features	Detrimental Lighting Design Features
Tunnel Vision	Strongly contrasting edges, stair nosings, handrails, handles, doors etc.	Glare
	Flexible task lighting	
Loss of Central Vision	Strongly contrasting edges, stair nosings, handrails, handles, doors etc.	Glare
Loss of Colour Vision	Use of contrasting textures/reflectances to distinguish surfaces	Use of homogenous textures/reflectances on adjacent surfaces
Hypersensitivity to Light	Locally dimmable lighting	Inflexible lighting arrangements
	Provide a range of lamp colour temperatures	
Stroboscopic Sensitivity		Cheap/poor quality LEDs; ceiling or other fans coincident with strong light sources

4.2 Halls and Multi-Purpose Spaces

Many schools have a large hall which is used for a variety of activities such as assemblies, theatrical productions, musical recitals, gymnastics, teaching, examinations, and lectures. Such facilities might also be used out of hours by the local community and may even be a source of revenue for the school as a venue. Each of these different activities has its own range of lighting requirements.

In general, the greater the variety of likely activities, the greater the flexibility and versatility required of the lighting design. It may be difficult to predict all the activities the hall will be regularly used for, but provision of a flexible lighting system in terms of lighting level, effect and switching, should allow for the most common activities. The lighting designer should seek a good understanding of the anticipated uses to which the space will be put, including the dimensions and likely positions of permanent or movable stages, platforms, sports paraphernalia (netball nets, goals etc.) and other indoor furniture. It may be possible to exclude the likelihood of certain activities if these are already provided with a dedicated specialist space – for example a dedicated performing arts centre, or gymnasium.

The proposed lighting design should be flexible, durable, and easy to manage, operate and maintain. **Figures 24 and 25** shows electric lighting and natural lighting in events centre.

Figure 24: Performing Arts Centre

Figure 25: Events Centre

4.2.1 Daylighting Design

- To the extent allowed by the acoustic and thermal design requirements of the space, daylighting should form part of the lighting design. Some activities, such as assemblies or recreation activities, may require minimal electric lighting if good daylighting is provided
- Robust and user-friendly shade devices should be provided to control glare and to provide grey-out. Where internal blinds are provided in a space that will be used for indoor sports, blinds should be able to withstand impact from balls and other projectiles
- Surfaces should be selected to maximise the distribution and uniformity of daylighting, while minimising glare. Light-coloured matt surfaces are generally recommended
- If it is expected that the hall will be used for performing arts (drama, dance, music) or for film projection, then blackout capability will also be required

4.2.2 Electric Lighting Design

In general, these spaces are flexible and multi-functional. The lighting design should provide suitable lighting for common activities and should also have the flexibility to cater for additional equipment and specialised lighting to be hired by the school for particular activities. The lighting designers should allow for adjustable stage lighting rail systems to support any additional lighting equipment for these occasions.

Lighting designers should inform the structural engineer when overhead lights and specialised gear are to be used in the space, identifying:

- **Number, type, and location**
- **weight**
- **configuration**

General ambient lighting should be appropriately zoned and separately switched so that maximum use can be made of available daylighting without compromising overall lighting standards. Ambient lighting sufficient to meet the requirements of the most demanding expected activity should be provided – refer to the requirements in **Table 4**, above. A **lighting control management system** should be provided. It should be easily accessible and centrally located - where possible, in close proximity to the activity (e.g., stage).

The controls should be grouped, well labelled, and easy to manage and operate. The system should allow for:

- the permanent lights in the space
- any specialised lighting and related equipment that is to be used intermittently
- ambient lighting for performances, etc
- any overlaps in the lighting requirement for different activities
- daylighting controls such as motorised blinds and daylight sensors

Lighting designers should consider:

- access requirements to all luminaires and equipment for cleaning and maintenance
- luminaire fittings that are long life (LED) and are easy to clean and maintain

Guidance for some common activities with more complex requirements is provided in **Tables 9 – 11**. Seek specialist lighting advice if a broad range of activities is anticipated, particularly those with complex requirements such as performing arts.

Examinations:

If the space is to be used for examinations, ambient lighting to 300 lux at the working plane shall be provided (as per **Table 4**, above). This should be appropriately zoned, and separately switched to allow for maximum flexibility.

Assemblies, Lectures, Speeches etc.:

At assemblies, lectures and similar events, it may be desirable to preferentially illuminate a stage, dais or lectern, for which purpose spotlights should be provided. These should be selected and positioned to clearly illuminate the speaker(s) – particularly their face – without casting shadows or causing glare for audience and speaker. Preferential dais lighting should illuminate the whole dais, with additional illumination for the speaker provided such that neither glare nor shadows affect the other individuals present on the dais. Stage lighting and general ambient hall lighting should be dimmable and separately switched to provide maximum flexibility.

Table 10 Design guidance for common activities in halls and multi-purpose spaces – Assemblies, Lectures, Speeches etc.:

Design Consideration	Daylighting Guidance	Electric Lighting Guidance
Illumination of a stage, dais, or lectern: locate spotlights to clearly illuminate the speaker (particularly their face) without casting shadows or causing glare for the audience and speaker.	Control glare - provide blinds to any windows behind the stage or dais.	Use dedicated spotlights or use stage lights if provided. Spotlighting to be separately switched to allow for flexibility and glare control depending on activity.
Allow for a number of people on the dais while a person addresses an audience.	Control glare	Allow for illumination of the whole dais, with additional spotlighting for the speaker. Ensure that glare and shadows do not affect people on the dais. Lighting should be dimmable and separately switched.
Allow for a number of people on the dais for panel discussions/debates.	Control glare	Allow for even illumination of the whole dais. Ensure that glare and shadows do not affect people on the dais. Lighting should be dimmable and separately switched.
Use daylighting as much as possible.	Allow windows for general ambient lighting; control glare - provide blinds to windows & skylights; use overhangs & interior baffles to control direct sunlight.	Provide daylight sensors to luminaires and integrate into the lighting management system.

Sports and Physical Activities:

Specialist lighting for sports activities will generally only be necessary at secondary school level. Expert advice should be sought for complex lighting designs, particularly for larger secondary school facilities and where a space is to be used as a competition venue. Useful sports lighting advice is provided in Artificial Sports Lighting – Updated Guidance for 2012 (Sport England, 2012). See also Section 4.3 Gymnasiums, below.

If activities involving balls or other projectiles are anticipated, light fittings should have impact resistant protection, designed to ensure that balls etc. cannot become trapped.

Table 11: Design guidance for common activities in halls and multi-purpose spaces – Sports and Physical Activities

Design Consideration	Daylighting Guidance	Electric Lighting Guidance
Lighting should either be impact resistant or protected by grilles.	Windows & skylights are to withstand the direct impact of a football at full force and when impacted shall not produce sharp, heavy or dangerous fragments, especially if mounted at high level. Use window grilles that do not trap shuttle-cocks and balls.	Light fittings are to withstand the direct impact of a football at full force and when impacted shall not produce sharp, heavy or dangerous fragments, especially if mounted above. Use light protection grilles that do not trap shuttle-cocks and balls.
Participants & spectators should not be affected by glare	Identify problematic window and rooflight positions through use of a daylight modelling tool. Control glare with user-friendly shade devices.	Shade bright lamps from direct view; consider the varied view-lines of both participants and spectators.
Specialised activities such as gymnastics may have specific and varied lighting requirements, & may involve participants in elevated positions (e.g. performing from a pommel horse or balance beam)	Consider the view lines and position of both participants & spectators; control glare - provide blinds to windows & skylights; use overhangs & interior baffles to control direct sunlight.	Lighting should be flexible to allow for different disciplines and equipment configurations, e.g. a gymnast on a balance beam 1.25m above the floor performs moves 2m or more above it. Bars and rings require an elevated view; use purpose lighting to suit.

Performing Arts:

The provision of specialist lighting for activities such as drama, music and dance productions may be beyond the available Ministry budget, and may be provided instead either by school fundraising, or by hiring lighting equipment as needed. If it is expected that lighting equipment (and other stage equipment) will be hired for such activities, then adequate electrical outlets and access for rigging should be provided in defined locations.

Stage lighting requirements in a primary school may be fairly modest and intuitive; those in a secondary school may be elaborate and involve complex controls. Stage lighting is a specialised field, and expert advice should be sought in the design of more elaborate stage lighting particularly for larger secondary school facilities.

A wide range of specialised stage lighting is available, capable of being adjusted in terms of brightness, colour, focus angle, lateral position (follow spots), and direction. Modern ‘intelligent’ stage lighting (automated lighting/moving heads) can be programmed to achieve a range of lighting effects that would formerly have been achieved by several different lighting units. These may offer a cost effective way of providing a range of lighting options for simple stage productions.

The utility and versatility of elaborate stage lighting designs are limited by the competence of the operator, and this needs to be considered before committing to a system that may be too elaborate to use. Schools considering significant investments in stage lighting should ensure that competent stage lighting designers and stage lighting technicians will be available. It should not be assumed that non-specialist teachers will be able to acquire stage lighting expertise without specialised training. Aside from technical stage design considerations, there are a range of safety issues associated with rigging suspended/motorized lighting trusses/battens, and only competent personnel should undertake such tasks.

If it is expected that the hall will be used for performing arts (drama, dance, music) or for film projection, then blackout capability will most likely be required and blinds should be provided accordingly.

Table 12: Design guidance for common activities in halls and multi-purpose spaces – Performing Arts

Design Consideration	Daylighting Guidance	Electric Lighting Guidance
Allow black-out for theatrical and music performances	Allow for user-friendly black-out blinds to windows & skylights	Specific egress and emergency issues
Specialist lighting may be hired for particular events.		The lighting control management system, power supply sizing, & electrical outlets should allow for temporary lighting equipment.
Adjustable lighting for both stage and audience		Ability to dim and set the colour for a number of specialist stage and house luminaires
Stage lighting design can be highly specialised & involve substantial capital expenditure.		Seek specialist design advice for complex stage lighting requirements.
Stage lighting can require complex controls, particularly in secondary schools.		Ensure provision is made for proper training of staff.
Installation & adjustment of stage lighting rigs can involve working at height, heavy loads, & other hazards		Ensure provision is made for proper training of staff.

4.3 Gymnasiums

Gymnasiums are used for a wide range of sports activities, with goals, nets, etc. located in different areas within the space. It is important that light distribution is uniform throughout the space - gymnasiums require good illumination at floor level and at all planes through which a ball or other projectile might pass. This is usually best achieved through a mix of daylighting and electric lighting.

Figure 26: Auckland Grammar School gym sports centre. High level translucent glazing with sloped ceiling to minimise glare. Limited low level windows for view; glare risk mitigated by non-reflective external surface.

4.3.1 Daylighting Design

- Gymnasiums have extensive wall and roof areas, with an unobstructed interior space. Glare from windows and skylights must be controlled as they can be a distraction for spectators and participants. Gym users require a global view of the space to follow the trajectory of a ball or other object, or when using a variety of sporting equipment such as trampolines, gymnastic bars etc. Designers should consider
- **High level windows and skylights** to provide daylight into the gym in conjunction with shade devices or translucent/ diffusing glazing to control glare. Consider whether these shade devices will be used on a regular basis, whether their controls are user friendly, whether they should be automated, and whether they should have a default position
- Daylight modelling may be required to predict which windows or skylights will pose a glare risk during activities. Daily and seasonal changes in the sun-path should be taken into account; provision should be made to adjust shades where necessary
- **Low level windows** are less likely to transmit glare from direct sunlight. However, they can cause glare from reflective surfaces around the gym perimeter; they should be located so as to minimise glare
- **Non-reflective external surfaces** such as grass, vegetation, dark or matt building surfaces, and asphalt can minimize reflective glare from outside
- **Reflective external surfaces** that should be avoided include white or reflective wall surfaces, glazing on neighbouring buildings, and light ground coloured surfaces. These should be identified and included as part of the building design parameters

- Identify possible implications of **future external developments,** and whether these should be included in the daylighting design
- **Window parameters** such as:
    - size
    - location
    - impact resistance
    - thermal performance
    - uniform distribution of both daylighting and electric light

Figure 27: Glare risk from low-level windows with reflective external surface.

4.3.2 Electric Lighting Design

Gymnasium lighting should:

- have **impact-resistant protection** that is designed to prevent balls etc. becoming trapped
- be able to **withstand direct impact** from a football launched at full force
- **not produce sharp, heavy or dangerous fragments when impacted**, especially if located overhead
- **be accessible** for maintenance and adjustment to suit different activities
- use light fittings that are **long life**

Gymnasiums may often be used for activities such as examinations or performing arts, and by the local community for diverse activities. If the space is used on a regular basis for such activities, purpose lighting should be provided accordingly (temperature control and ventilation design may also need to be adjusted; careful consideration should therefore be given to whether the costs of equipping the space for disparate activities outweigh the benefits). The required light level for examinations and similar activities is 300 lux measured at the work plane – refer to Table 4, above, for other uses.

Lighting for these activities should be separately switched where it does not form part of the general lighting design for typical gymnasium activities. Additional zoning and separate switching of the general gymnasium lighting may be required for performance arts and other uses, together with provision of electrical sockets for any additional temporary lighting rigs.

4.4 Libraries

Lighting designers should consider:

- the range of expected activities, such as group learning, storytelling, individual study, and sunlit reading spaces, each with different lighting requirements
- creating cohesive and attractively lit spaces
- reflectance values of materials, furniture, floor and wall coverings
- the form, volume, orientation, use and size of the library, as these vary significantly between schools
- whether the library functions as a separate building, or as part of a social hub for students
- any learning spaces that are integrated within the library space

Different lighting requirements may include general ambient lighting, lighting for bookcases (sufficient to clearly illuminate all books on tall and narrowly spaced bookcases), task lighting for reading areas, librarian desks and check-out counters, accent lighting for display areas, and more indirect lighting in computer areas. A high ceiling in a library assists in creating ambience, and allows for high-level or tall aspect ratio windows, which assist with daylighting.

Figure 28: Library: a mix of side lighting, clerestory lighting and suspended luminaires.

4.4.1 Daylighting Design

- Wall, floor and ceiling reflectances should be selected to **optimise use of available daylighting**. Windows may contribute towards ambient space lighting and may provide pleasant daylit spaces along the perimeter of the space for reading. Where daylighting is intended to provide a primary lighting source, supplementary electric lighting should be provided for use during overcast weather. This should be switched separately from general ambient lighting

- Where daylighting is used, **book stacks should be protected from UV light** by positioning them away from direct sunlight, and away from high levels of daylight and UV light
- The **risk of glare** should be assessed, including from working surfaces such as study desks and computer areas. Where necessary, fixed or adjustable shade devices should be used. Adjustable shades should be robust and user-friendly
- Computer laboratories and IT hubs associated with libraries may have high IT equipment loads in addition to the normal learning space thermal loads. Glazing design in these areas should **take into consideration the cumulative effect of solar heat gain and IT thermal loads**. Desks and computer screens should be orientated to minimise glare

4.4.2 Electric Lighting Design

Opportunities to minimise energy use should be investigated, including separate switching of peripheral lighting, and the use of occupancy sensors in less frequented areas of the library.

Due to its distribution characteristics, overhead ambient lighting in stack areas needs careful consideration as it will generally fail to illuminate the lower shelves. This is generally less of a problem in school libraries as the shelving tends to be sparser and the heights lower. However, orientation of the lights in relation to the stacks still requires careful consideration. This may be overcome through the use of directional luminaires and light-coloured floor surfaces. Tilting lower shelves slightly to expose the book spines to overhead illumination would also make it easier for library users to examine books without kneeling. Illumination of 200 lux on the vertical plane just above floor level is adequate, so long as the light source is sufficiently diffuse to avoid shading of overhead lights by the library user.

The layout within the library may change over time, and lighting designers should therefore consider:

- movable bookcase lighting, such as task lighting fixed to the top of the bookcase
- movable ceiling-mounted lighting
- other design measures to minimise rearrangement costs

If movable or bookcase-mounted lighting is not feasible, designers should consider orientating the overhead aisle lighting to be perpendicular to the bookshelves. However, there are drawbacks to this approach, such as:

- Uneven distribution of lighting
- Lighting over bookcases, rather than in between the aisles, will create a shadowing effect from bookcases and library users
- Less amenable to localised switching

The **recommended illumination for computer and reading areas is 300 lux across the work plane**, with additional task lighting for dedicated work desks where necessary (up to a maximum of 500 lux). In the case of computer areas, sources of glare and veiling reflections should be identified and minimised.

4.5 Music facilities

Music facilities range from small solo practice rooms to large rehearsal and performance spaces designed to accommodate multiple performers and an audience.

The principal factor constraining passive design for music facilities is the need for good acoustic performance. This requirement may limit reliance on daylighting, as acoustic insulation requirements may preclude the use of extensive glazing. The DQLS – Acoustics document should be consulted to identify acoustic requirements and how they may affect daylighting options. The lighting designer should coordinate with the acoustic consultant.

4.5.1 Daylighting design

- Where possible, daylight should be included in the design of music spaces – particularly for one-on one practice rooms and for spaces which do not require high levels of acoustic isolation. Acoustically insulated glazing may be appropriate. However, acoustic requirements should take precedence over daylighting in the design of music spaces. Practice spaces should have observation windows for supervision purposes

4.5.2 Electric Lighting Design

- Performance spaces, practice rooms, and studios may be subject to after-hours use; building-wide lighting-control systems should make allowance for after-hours use. Lighting should be controlled by timer-switches or occupancy sensors, particularly in the case of practice rooms. General ambient lighting should be dimmable in all music performance spaces. Where appropriate, additional task lighting should be provided for sheet-music stands, keyboard instruments, sound desks, *etc*

4.6 Science Spaces

Science spaces may have variable ambient and task lighting requirements, depending on occupancy and activity. In primary schools, science activities will generally take place in general learning spaces, and standard ambient and task lighting will usually suffice.

Secondary schools have dedicated science labs, and activities will include making detailed observations and taking accurate measurements. Hazardous equipment and materials may also be used, requiring the hazardous environment rating of ambient lighting and any additional task lighting. Where naked flame and hazardous equipment is used, the risks from glare are amplified, requiring that internal shades should be provided.

Figure 29: A secondary school science laboratory

4.6.1 Daylighting Design

Daylighting may be required for a number of science activities - particularly in biology labs, but potentially also in physics and chemistry experiments. This may include growing plants or exposing experiments to daylight. A suitable workspace adjacent to a window should be available.

Daylighting should be included in the lighting design of the space in a similar way to more general learning spaces. Lighting designers should, however, be particularly careful to eliminate sources of glare. Internal blinds should be provided. Their use should be controlled by teachers, who should be aware of the risks posed by visual glare when manipulating hazardous materials. There may be specific requirements for black-out in certain science areas for light experiments.

4.6.2 Electric Lighting Design

- Activities in specialist science labs may include making detailed observations and taking accurate measurements, requiring a high level of ambient and task lighting. **Illuminance of at least 300 lux should be provided to the working plane in science spaces where practical work is conducted, with a maximum Unified Glare Rating (UGR) of 19**
- **Some processes need to be terminated or otherwise made safe prior to the emergency evacuation of a space. This may include securing hazardous materials or shutting down dangerous equipment – particularly if it poses a risk or impediment to the evacuation. In such cases, emergency task lighting should be provided to specific areas and items of equipment. Any such requirements should be brought to the attention of the lighting designer and the fire engineer.** It may be necessary to plan escape routes such that they avoid hazardous areas, and to provide emergency evacuation route lighting that minimises the risk posed by hazards
- Depending on the size and geometry of the space, peripheral lighting in areas which receive daylighting should be separately switched so that it can be turned off when not needed
- Educational displays are a common feature of many science spaces (e.g., anatomical models, botanical and zoological specimens, instruments etc.) Accent lighting may be appropriate for such displays. The anticipated location of such displays should be brought to the attention of the lighting designer
- Some science spaces may include fixed equipment such as fume cupboards or demonstration apparatus. Depending on the nature of the equipment, additional task or accent lighting may be required. The anticipated location and method of use of such equipment should be brought to the attention of the lighting designer

4.7 Workshop and Technology Spaces

Workshop and technology spaces have a range of work benches at varying heights (seated desks, standing work benches, and assorted machinery). The anticipated location and working height of these areas should be available to the lighting designer so that appropriate ambient and task lighting can be provided as necessary. Special emergency lighting provisions may be required around hazardous equipment, and evacuation procedures and routes may need to take into account the location of hazardous equipment.

Coordination between the fire engineer, services engineer and the lighting designer is required.

4.7.1 Daylighting Design

- Where possible, daylighting should contribute to the lighting design of workshop and technology spaces. Traditionally, workshops used overhead south lights, and this remains a good strategy where site and building planning permit. Where hazardous equipment is used, the risks from glare are amplified. If daylighting may pose a glare-risk, internal shades should be provided, and teachers should be diligent in enforcing their use

- Where daylighting may meet part of the ambient lighting requirement, peripheral ambient lighting should be separately switched so that it may be turned off when not needed

4.7.2 Electric Lighting Design

- **The use of occupancy-controlled lighting is not recommended where hazardous equipment is used**, as the sudden loss of illumination while machinery is in operation may create a serious risk of injury
- **The risks from glare are amplified when hazardous equipment is being used. Electric ambient lighting should be provided sufficient to deliver illuminance of at least 300 lux at the working plane, with a maximum UGR of 19. Good colour rendering is important. Where dust or moisture are generated, light fittings should have a minimum rating of IP44**
- Workshops may release dust and other debris into the air (although this should be minimised by dust extract hoods). This may necessitate regular cleaning of light fittings; they should be positioned for ease of access and should be protected by robust diffusers and grilles where necessary. It is important that an appropriate cleaning schedule which includes luminaires be established, and that the schedule be properly enforced
- Task lighting should be provided in addition to the general ambient lighting. This should be suitable for the particular item of equipment, bearing in mind different tasks that users may need to carry out around it, and the directionality of the lighting required to illuminate these tasks. More than one directional luminaire may be required. Where task lighting is fixed directly to machinery, it should be supplied on extra low voltage and should not obstruct the safe operation of the equipment. All task lights should be positioned so as to minimise glare for other spaces users, and so that they do not obstruct clearance areas around equipment or interfere with the safe use of machinery
- Display areas for completed work *etc*. are a common feature of technology spaces; accent lighting may be appropriate for such displays. The anticipated location of display areas should be brought to the attention of the lighting designer

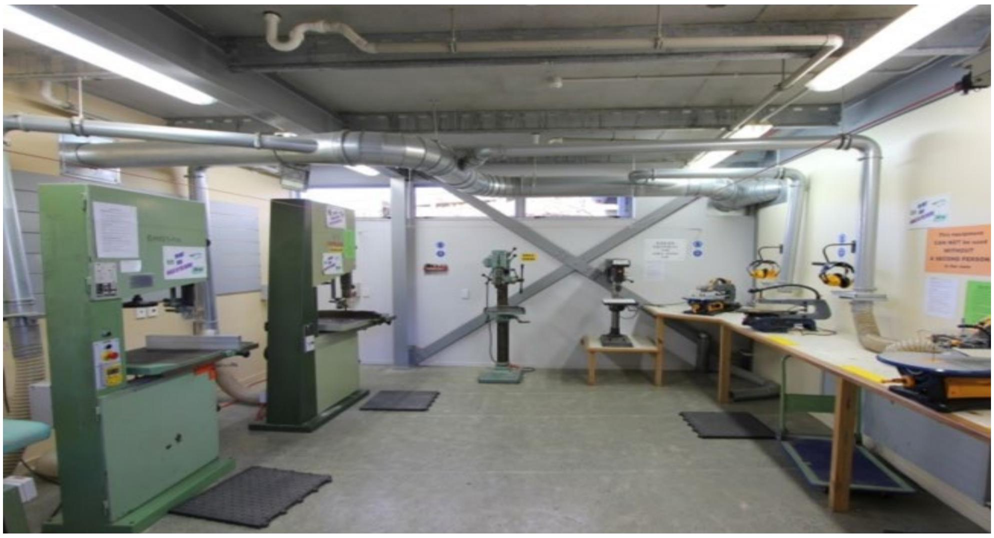


Figure 30: A secondary school workshop space

4.8 Toilets

The Ministry Toilet Reference Design Guide specific requirements.

Glossary

Description	Definition
Annual sunlight exposure (ASE)	A measure of the direct sunlight received by a space, expressed as the percentage floor area receiving above a specified lux for more than a specified number of occupied hours per year. ASE 1000/250h measures the percentage floor area that receives at least 1000 lux for at least 250 occupied hours per year. ASE was developed by the Illuminating Engineering Society of North America as an indicator of the extent to which a space receives excessive direct sunlight.
Borrowed light	Light supplied to an internal space through an adjacent room.
Clerestory window	A window located high on a wall, usually at a change in roof level.
Climate Based Daylight Modelling (CBDM)	Daylighting analysis that uses meteorological datasets, building geometry, and window orientation to predict annual and seasonal irradiance, illuminance, radiance, luminance, etc. for a particular space. Unlike simple numeric daylighting analysis, which typically assumes a static overcast sky and which targets daylight values averaged across a whole space, CBDM considers both direct and diffuse daylight components. CBDM is able to map predicted daylighting values for all positions within the space across the whole year. It provides greater detail about light distribution and intensity, allowing for more realistic daylighting assessments, and enabling designers to achieve more uniform daylighting outcomes.
Colour rendering	The effect of a light source on the colour appearance of an object, in comparison with a reference illuminant; often stated in terms of a 'colour rendering index' (CRI). A commonly used CRI is the CIE Ra value, with a maximum value or Ra = 100 signifying the most faithful colour rendering. High CRI values are typically achieved by incandescent/halogen bulbs and by high-CRI LED lamps. It should be noted that a high CRI does not guarantee a high colour fidelity. The yellow light of an incandescent bulb can achieve a high CRI due to the definition of CRI; care should be taken in the interpretation of CRI values.
Daylight factor	The ratio between the daylight illuminance measured on a horizontal plane at a point inside a space, and the daylight illuminance from an unobstructed and overcast cast sky measured on a horizontal plane outside. Daylight Factor is only relevant for diffuse light from a cloudy sky and so cannot help identify problems due to direct sunlight; nor can it distinguish between the different orientations of windows.
Daylight glare probability (DGP)	Expresses the probability that an occupant will be dissatisfied with the visual environment due to glare. The metric is also sensitive to high ambient lighting levels. DGP measurements are particular to specific orientations, which must be carefully selected based on expected occupant positions and orientations. In a flexible learning space, this may require that multiple measurements be taken. Measurements are then processed through specifically developed software.
Direct glare	Discomfort or vision impairment caused by bright objects in the field of vision.
Indirect glare	Discomfort or vision impairment caused by light from bright objects reflecting off secondary surfaces in the field of vision.
Diffuse lighting	Lighting having a distribution of luminous intensity such that the fraction of emitted luminous flux reaching the surface directly (i.e. without being reflected by other surfaces first) is between 90-100%. Cf. 'direct lighting'.
Direct lighting	Lighting having a distribution of luminous intensity such that the fraction of emitted luminous flux reaching the surface directly (i.e. without being reflected by other surfaces first) is between 40-60%. Cf. 'diffuse lighting' and 'directional lighting'.

Directional lighting	Lighting in which the light incident on a surface arrives predominantly from a particular direction. Directional lighting is typically used to accentuate particular objects or features, to emphasise surface textures, and to generate shadows and patterns of contrast. Misuse of directional lighting may create glare or generate undesirable shadows and contrasts.
Disability glare	Glare that impedes one's ability to carry out detailed work, without necessarily causing discomfort.
Discomfort glare	Glare that causes discomfort without necessarily impeding one's ability to carry out detailed work.
Discomfort Glare Probability (DGP)	A specific measure of the probability that occupants will be affected by discomfort glare. The DGP calculation takes into account the contrast ratios within the field of vision, as well as empirical assessments of typical subjective reactions to glare. A DGP value > 4.5 indicates intolerable glare; DGP < 0.3 indicates imperceptible glare. DGP values pertain to a specified view direction.
Glare index	A numerical index for the evaluation of discomfort glare.
Glazing system	The glass and framing of windows and doors; these may be specified to achieve a variety of lighting, temperature control, ventilation, and acoustic outcomes. The glazing system may be an integral part of a lighting, heating, ventilation, or acoustic design strategy.
Gloss factor	Gloss is an optical property of surfaces. It describes their ability to reflect light in a specular (mirror-like) manner. Gloss should be distinguished from reflectance, which refers to the proportion of incident light reflected from a surface – whether in a specular or diffuse manner. High gloss (specular) surfaces are likely to give rise to discomfort glare. Standards for measuring gloss differ by jurisdiction and by material; ISO-2813 and AS-1580 provide equivalent standardised measurement conditions for paints.
Illuminance	A measure of the luminous flux falling on a surface from all directions, expressed per unit surface area. The SI units of illuminance are lux (lx) or lumens per square metre.
Light output ratio	A measure of the efficiency of a luminaire, given by the ratio of its light output to the light output from the lamp(s) that it houses. It is hence a measure of how much of the light emitted by the lamp(s) is lost within the luminaire fitting.
Luminance	A measure of luminous intensity of light travelling in a given direction, expressed per unit area. 'Luminous intensity' is a measure of light power per unit solid angle; 'luminance' expresses this per unit area on which the light falls. The SI unit of luminance is the candela per square metre (cd/m^2).
Light reflectance value (LRV)	A measure of the visible light reflected from a surface
Luminaire	A light fitting
Luminous flux density	A measure of the total light output from a source, weighted according to the wavelength sensitivity of a standardised human eye. Unlike 'luminous intensity', luminous flux is not expressed per unit angle. If the focus angle of a lamp with fixed luminous output is halved, its luminous flux density will remain unchanged (the total light output does not change), but its luminous intensity in the direction defined by the focus angle will double. The SI unit of luminous flux is the lumen (lm).
Luminous intensity	A measure of the power emitted by a light source per unit solid angle, weighted according to the wavelength sensitivity of a standardised human eye. The SI unit of luminous intensity is the candela (cd). If the focus angle of a lamp with fixed

	luminous output is halved, its luminous intensity will double.
Maintained illuminance	The minimum illumination which should be maintained in a space or on a working plane throughout operational hours (or at all times, where no operational hours are specified). It is the minimum illuminance at which maintenance operations such as cleaning of room surfaces, glazing, and luminaires, and the replacement of lamps, should take place to ensure adequate illumination of the space.
Reflectance	The ratio of light reflected from a surface, against the light falling on it.
Splayed window reveal	A window reveal is a surface connecting the edge of the window to the adjacent wall; it may be perpendicular to the window face or angled (splayed).
Task lighting	Lighting that provides a high level of localised light for a visually demanding task.
Ultraviolet light (UV)	An invisible component of sunlight, corresponding to wavelengths of between 30 PHz – 750 THz, exposure to which may cause damage to eyes, skin and various materials (particularly some plastics, pigments and dyes).
Unified Glare Rating (UGR)	A parameter calculated from the luminance values of the luminaires in a space, and from the background luminance. The calculation provides a rating from 10 – 30, which can be used to express the statistical perception of glare among a sample of observers. A UGR value <10 indicates that any glare is insignificant; a UGR approaching 30 indicates strong glare. A UGR value of 19 indicates that ~35% of observers would be disturbed by the glare. UGR values are frequently quoted for luminaires, based on standard reference conditions. These conditions may not pertain in the actual space where the luminaire is to be deployed, but UGR values may be used to make comparisons between luminaires so long as the values are quoted with respect to the same reference conditions.
Useful Daylight Illuminance (UDI)	The annual occurrence of illuminance across a work plane that is within a useful range. The range deemed 'useful' may be task specific. Three sub-categories are commonly used: • UDI-a (for lux values x - y): the proportion of time during which daylighting falls within the useful range bounded by x & y lux values. • UDI-e (for lux values >y): the proportion of time during which daylighting exceeds the useful range, and during which blinds or shades would be required in order to avoid glare. • UDI-s (for lux values <x): the proportion of time during which daylighting would fail to meet the useful threshold, and during which electric light would be required.
Well index	The well index is a way to describe the geometry of rectilinear atria with a number; it expresses the relationship between the light admitting area open to the sky, and the surfaces of the atrium well. $WI = \frac{H \: x \: (W+L)}{2 \: x \: W \: x \: L}$ A high well index value indicates an atrium space that is deep and narrow, resulting in low levels of daylight at the base of the atrium. Conversely, a low well index indicates a space that is shallow and wide in proportion to its height. As most atrium-type school buildings are only likely to be 2 to 3 storeys high, a low well index should be easily achievable.
Working plane	The height at which a task is carried out, and hence at which illuminance values for task- or general-lighting should be determined.

Tables

Figures

References

Ackley, A., Donn, M., & Thomas, G. (2020). Measuring Lighting in a National School Property Portfolio. Architectural Science Review, 1-14. https://doi.org/10.1080/00038628.2020.1806780

Ackley, A., Donn, M., & Thomas, G. (2018). Measuring the Daylight Performance of Classrooms: Can a One Point Sensor Measurement Predict the Daylight Distribution within a Space? 52nd International Conference of the Architectural Science Association, pp. 43–52, Australia.

Ackley, A., Donn, M., and Thomas, G. (2017). The Influence of Indoor Environmental Quality in Schools, 51st International Conference of the Architectural Science Association (ANZAScA)), pp. 625– 634, Wellington.

AIA. (1982). Architect's Handbook of Energy Practice: Daylighting, American Institute of Architects, New York

Barrett, P., Zhang, Y., Davies, F., and Barrett, L. (2015). Clever Classrooms – Summary report of the HEAD Project. University of Salford, Manchester.

Barrett, P., Zhang, Y., Moffat, J., and Kobbacy, K. (2013). A holistic, multi-level analysis identifying the impact of classroom design on pupils' learning. *Building and Environment*; 59: 678-689.

Bluyssen, P.M. (2009). *The Indoor Environment Handbook: How to make buildings healthy and comfortable, Earthscan, London, UK*

CIE. (2006). Test Cases to Assess the Accuracy of Lighting Computer Programs. CIE Report 171:2206. http://www.cie.co.at/publications/test-cases-assess-accuracy-lighting-computer-programs, accessed August 2018.

Costanzo, V., Evola, G., and Marletta, L. (2017). A review of daylighting strategies in schools: state of the art and expected future trends. *Buildings*; 7,41.

DeKay, M., & Brown, G.Z. (2013). Sun, Wind and Light: Architectural Design Strategies. John Wiley & Sons, New York.

Earthman, G. (2004). Prioritization of 31 criteria for school building adequacy. American Civil Liberties Union Foundation of Maryland, Baltimore, MD.

Eitland, E., Klingensmith, L., MacNaughton, P., Laurent, J.C., Spengler, J., Bernstein, A., and Allen, J.G. Schools for Health – Foundations for Student Success. Harvard T.H. Chan School of Public Health. https://forhealth.org/Harvard.Schools_For_Health.Foundations_for_Student_Success.pdf, accessed September 2018.

Heschong, L., Wright, R., and Okura S. (2002). Daylighting impacts on human performance in school. *Journal of the Illuminating Engineering Society;* Summer: 101-114.

Heschong Mahone Group, Inc. (2003). Windows and classrooms: a study of student performance and the indoor environment. Technical Report, California Energy Commission.

Hopkinson, R.G. (1963). Architectural Physics: Lighting, HMSO: London.

Hopkinson, R.G. (1969). The Lighting of Buildings, Faber & Faber, London.

Ibrahim, N.L. & Hayman, S. (2005). Daylight Design Rules of Thumb, *Conference on Sustainable Building South East Asia*, 11-13 April 2005, Malaysia.

IES. (1972). Daytime Lighting in Buildings: Technical Report No. 4, Illuminating Engineering Society, London.

Kaufmann, J. (ed). (1975). IES Lighting Handbook, Illuminating Engineering Society, New York.

Küller, R. and Lindsten, C. (1992). Health and behaviour of children in classrooms with and without windows. Journal of Environmental Psychology, 12(4), 305–317.

Lechner. N. (2001). Heating, Cooling, Lighting: Design Methods for Architects, John Wiley & Sons, New York.

Li, D., and Sullivan, W. (2016). Impact of views to school landscapes on recovery from stress and mental fatigue. *Landscape and Urban Planning*; 148: 149-158.

Maamari, F., Fontoynont, M. & Adra, N. (2006). Application of the CIE test cases to assess the accuracy of lighting computer programs. *Energy and Buildings* 38: 869–877.

Mardaljevic, John, Brembilla, E., & Drosou, N. (2016). Real-World Validation of Climate-Based Daylight Metrics: Mission Impossible? CIBSe Technical Symposium, 1–12

Manasseh, L. & Cunliffe, R. (1962). Office Buildings, Batsford, London.

Manning, P. (ed). (1965). Office Design: A Study of Environment, Pilkington Research Unit, University of Liverpool.

Ministry of Education. (2018). *Security Design in Schools.* https://education.govt.nz/school/property/state-schools/design-standards/security-design/, accessed August 2019.

National Institute of Building Sciences. (2015). *Design Guidelines for the Visual Environment*. https://cdn.ymaws.com/www.nibs.org/resource/resmgr/LVDC/LVDP_Guidelines_052815.pdf, accessed August 2019.

Ne'eman, E. and Hopkinson, R. (1970). Critical minimum acceptable window size: a study of window design and provision of a view. *Lighting Research and Technology* 2, 1: 17-24.

Nicklas, M.H. and Bailey, G.B. (1997). Student Performance in Daylit Schools. National Clearinghouse for Educational Facilities.

O'Connor, J. (1997). Tips for Daylighting with Windows: The Integrated Approach, LBL, Berkeley.

Price, G.M. (1914). The Modern Factory: Safety, Sanitation and Welfare, John Wiley & Sons, New York.

Rea, M. (ed). (1993). Lighting Handbook, 8th edition, IESNA, New York.

Robson, E.R. (1888). The Planning of Schools, *The Builder*, February 1888.

Robson, E.R. (1972). School Architecture: being Practical Remarks on the Planning, Designing, Building and Furnishing of School Houses. Leicester University Press, Leicester.

Ruffles, P. (2005). Lighting Guide 7: Office Lighting. The Society of Light and Lighting, London.

Ruck, N. (1995). BDP Environment Design Guide, Australian Institute of Architects, Canberra.

Santos, S.D.P. (2009). *Advanced Daylighting Systems: Comparative Study of Prismatic Panels, LaserCut Panels and Channel Panels. Extended Abstract of the dissertation to obtain the Master Degree in Architecture*, Instituto Superior Técnico – Universidade Técnica de Lisboa. https://fenix.tecnico.ulisboa.pt/downloadFile/395139483932/Resumo-alargado-aluno-53255.pdf, accessed August 2018.

Society of Light and Lighting, (2012). Lighting for People Who Are Visually Impaired, Factfile 8. http://www.cibse.org/getmedia/a69b8cdf-3e8f-4962-925e-e8c0e8a9ff02/Lighting, accessed August 2019.

Sport England. (2012). Artificial Sports Lighting – Updated Guidance for 2012. https://www.sportengland.org/facilities-planning/design-and-cost-guidance/artificial-sportsfacilities/, accessed August 2019.

Standards Australia. (1994). AS1680.1-1994 Interior Lighting Part 1: General principles & recommendations, Standards Australia: Sydney.

Standards New Zealand. (2016). NZS4223.3:2016 Glazing in Buildings Part 3: Human impact safety requirements, Standards New Zealand: Wellington.

Sullivan, J., and Donn, M. (2018). Some simple methods for reducing daylight simulation time. *Architectural Science Review*.

Woolner, P., Hall, E., Higgins, S., McCaughey, C., and Wall, K. (2007). A sound foundation? What we know about the impact of environments on learning and the implications for Building Schools for the Future. *Oxford Review of Education*; 33,1: 47-70.

Waldram, P.J. (1914). Some problems in daylight illumination with special reference to school planning, *The Illuminating Engin*eer; 7,1:15-27.

Wall, G. (2016). *The impact of physical design on student outcomes. Available from: Ministry of Education, New Zealand.*

Wu, P.C., Tsai, C., Wu, H., Yang, Y., and Kuo, H. (2013). Outdoor activity during class recess reduces myopia onset and progression in school children. *Ophthalmology*, 120(5), 1080–1085.

Willis, C. (1995). Form Follows Finance: Skyscrapers and Skylines in New York and Chicago, Princeton Architectural Press, New York.

Yeang, K. (1999). The Green Skyscraper: The Basis for Designing Sustainable Intensive Buildings, Prestel Verlag, Munich.

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Ministry of Education
Mātauranga House, 33 Bowen Street
PO Box 1666, Thorndon 6140
Wellington, New Zealand

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