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Publication details:
Reading between the lines: making sense of consultant reports - Understanding the environmental sciences essential to development applications

Event details:
NEERG Seminar: Reading between the lines: making sense of consultant reports - Understanding the environmental sciences essential to development applications
Sydney, Australia

Publication Date:
2006

DOI:
https://doi.org/10.26190/unsworks/609

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NEERG Seminar Thursday 31 August 2006, Powerhouse Museum

Daylight & Solar Access

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1.0 Introduction

1.1 Objectives

The Residential Flat Design Code in its section .Building Amenity.Daylight Access begins:

> Daylight consists of skylight - diffuse light from the sky - and sunlight - direct beam radiation from the sun. It changes with the time of day, season, and weather conditions. This variability contributes to pleasant environments in which to live and work. Within an apartment, daylighting reduces reliance on artificial light, improving energy efficiency and residential amenity.

1.2 Definitions:

Sunlight: Direct beam from sun; extremely bright.
Daylight: Diffuse light from all other parts of the sky, and reflected from other surfaces.

2.0 Sun access and overshadowing

2.1 Mandated solar access

Residential

For residential dwellings sunlight is regulated for amenity and energy considerations. It is considered beneficial to be assured of a specified minimum of solar access for both interiors and for private outdoor space.

Non-residential

In working interiors sunlight is generally thought to be undesirable both summer and winter in the Sydney climate. This is because any contribution to amenity or heating energy budgets is likely to be outweighed by excess heat loads, discomfort for a worker at a workstation which may be in a sunpatch, disability and discomfort glare for the predominant visual tasks, and degradation of most materials commonly found in commercial interiors due to the effects of the high UV component of sunlight.

Solar access to commercial uses is not mandated.

Public open space

Overshadowing of public open space is a concern for many local authorities. In the most general sense, they are concerned with maintaining amenity for outdoor dining and passive recreation in winter.

Where they address overshadowing of public open space at all, some Councils have very loose limits on the maximum duration of additional shadow. Some built-up areas have well spelt out periods for the protection of sun to footpaths, typically for lunch-time. The City of Sydney applies fixed height planes to development that may impact on its principal public parks and squares, while North Sydney City Council applies a ‘composite shadow line’ based on the existing buildings, as a way of limiting the height of new development in its central area.

2.2 Solar access controls

Most local government authorities mandate minimum solar access by provisions in their Residential Development Control Plans, and sometimes with reference to a more general code for energy efficiency. These DCP provisions are generally aligned with one of two model codes, being the *NSW Department of Planning* Residential Development Controls of 1990, and the Australian Model Code for Residential Development (AMCORD 95).

DCP controls generally address minimum solar access to be protected for potentially affected neighbours. To slightly confuse the issue, they are often titled 'overshadowing' controls. By extension, though often not explicit in DCPs, the same standards are applied to dwellings within a proposed multi-unit development.

Sun access for dwellings within a multi-unit development which is subject to SEPP65 is also mandated by the RFDC, confusingly perhaps in the section on Daylight cited above.

The generic form of the controls is:

- Minimum duration of sun to glazing of living spaces. Varies from 2-4 hours depending on LGA, and on whether a relaxed standard is allowed for closely built up areas.
- Minimum duration of sun to portion of private outdoor space. Generally similar duration requirement to that for glazing. Portion of such space is sometimes specified, typically 50%.
- When the minimum sun access must be achieved. Generally between 9am and 3pm on June 21. Some DCPs call up the Equinox (March/September 21) if existing conditions do not allow compliance with the mid-winter date.

2.3 Demonstrating compliance for solar access

2.3.1 The Shadow Diagram

For demonstrating compliance of proposed designs with minimum projected solar access, the ubiquitous requirement is submission of Shadow Diagrams. Such diagrams are always specified as plan projections for mid-winter, with some Councils also requiring Equinox and possibly Summer projections. Most commonly, the diagrams required are for 9am, 12 noon and 3pm.

Some Councils explicitly require documentation of projected shadows at the same times on potentially affected building elevations.

More rarely, a Council may be more cautious, and require the same shadow diagrams on an hourly basis. In the case of the elevational shadows, this can begin to answer questions of actual sun access durations, or durations of loss for affected neighbours. But for reasons explained below, it isn't usually especially helpful in plan.

2.3.2 Why are shadow diagrams always wrong?

Shadow projections on an hourly or less frequent basis, almost always only in plan, are a very poor basis for establishing compliance with minimum guaranteed solar access:

- Shadow diagrams are onerous and time consuming to construct.
- Plan projections rarely contain much of the relevant information, such as slope, etc. because the 3D geometry is difficult to visualise.
- Detailed answers to questions of solar access to 'points of interest' (such as windows) in vertical planes of different orientations and heights, are difficult or impossible to infer from plan projections. See Figure 1.

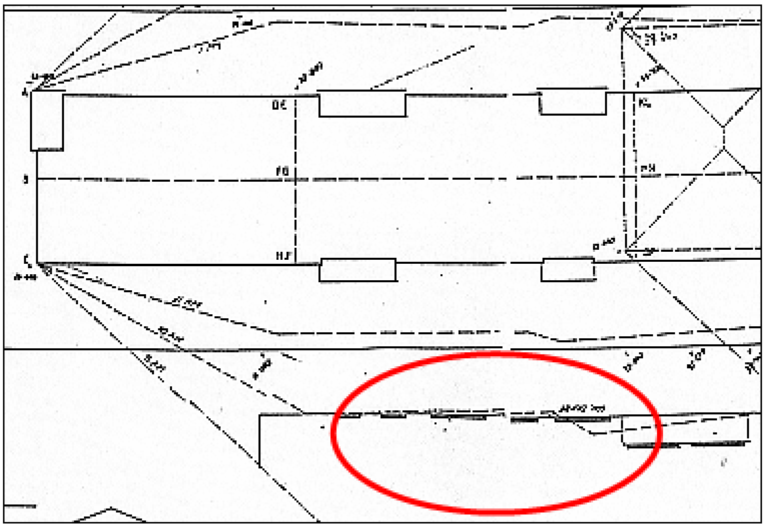

Figure 1: Plan shadows
How do you tell whether the windows are overshadowed?

In addition, shadow diagrams are prone to error and abuse through several mechanisms:

- Wrong orientation. The prime source of this error is the use of Magnetic North from survey plans. All solar projection relates to True North. In critical situations, typically involving narrow separation of buildings, this error can easily make the difference between apparently complying design, and severe and unacceptable overshadowing.
- Misreading of sun position information. The standard graphic source of apparent sun position data is unfamiliar and often misread by infrequent users.
- Failure of the projection. In other words, someone didn't know how to cast shadows.
- Approximate or distorted shadow lengths. This may be deliberate, or the result of incompetence. Even competent shadow casts may result in such distortion (usually in the applicant's favour), because the reference plane onto which the shadows are cast is arbitrary and elevated above natural ground level.
- Missing detail. Most commonly shadows of vegetation and other obstructions. Though the reasons for such omissions may be various, they invariably affect the judgement of comparative degrees of overshadowing.

So why are such Shadow Diagrams required by Councils, and obligingly provided by applicants? Because they are intuitive to look at — they look vaguely like the shadows that may eventuate. All alternative means of analysing and presenting the solar access data are less intuitive abstractions.

Yet, put simply, a shadow diagram cannot answer the key question: *how much sun does a particular point in space receive?*

2.3.3 Preferred analysis tools

There are a number of representations of solar access and overshadowing, which emphasize the representation of sunlit periods, rather than shaded conditions, and do so with much greater precision than shadow diagrams.

Computer based

Computers may be used to produce 2D and 3D views of rendered shadows, if the 3D model of the building and potentially affected surfaces have been entered. These may be animated, etc. and even accurately rendered.

The preferred output from a comprehensive computer model is views of the building and its environs from the direction of the sun. Such views clearly and unambiguously distinguish sunlit from shaded surfaces — only sunlit surfaces can be seen. See Figure 2.

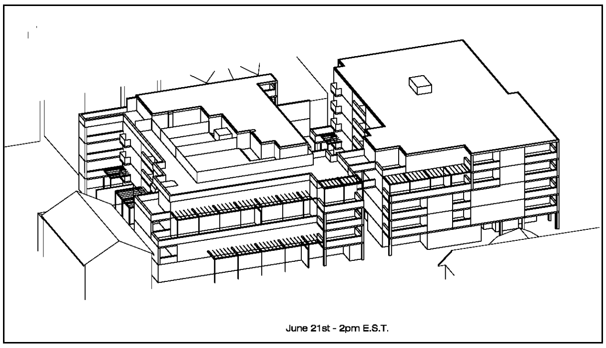

Figure 2 View from the direction of the sun
Note that only sunlit surfaces are visible

Council officers may treat submitted 3D shadowed views with some suspicion, because they can’t directly check the relevant sun position angles. The best way to deal with this is to review the model together, such that location, orientation, time and date settings are transparent.

Manual analysis

Vertical and Horizontal Shadow Angles

Part of the problem with conventional simple shadow casting, is that it utilises solar geometry related to the azimuth and altitude angles of the sun at given times and dates. If sun positions could be plotted directly in relation to the drawings prepared by architects as part of the building documentation, it would be much easier to investigate solar access and overshadowing in sections.

Of course, this translation of solar geometry is precisely the point of the so-called Vertical and Horizontal Shadow Angles, derived by 3D trigonometry from the azimuth and altitude angles and the building orientation. The relationship is illustrated in Figure 3.

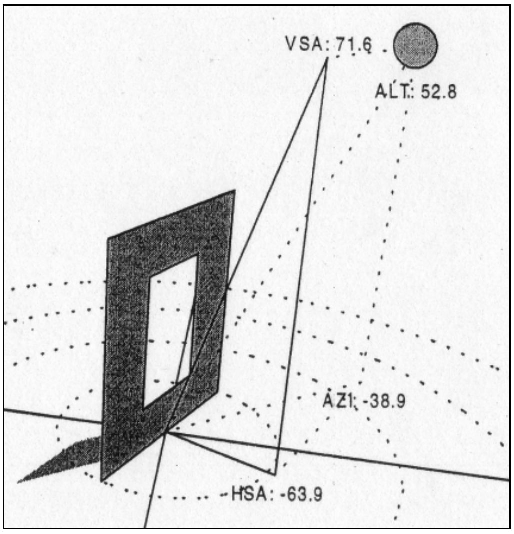

Figure 3: The basis of Horizontal and Vertical Shadow Angles

This is seriously confusing to most designers and Council officers, as a consequence of which most attempts to use it in evidencing compliance are dramatically incorrect. Where competently handled, the technique can precisely and usefully illustrate key overshadowing relationships in section or elevation, as shown in Figure 4.

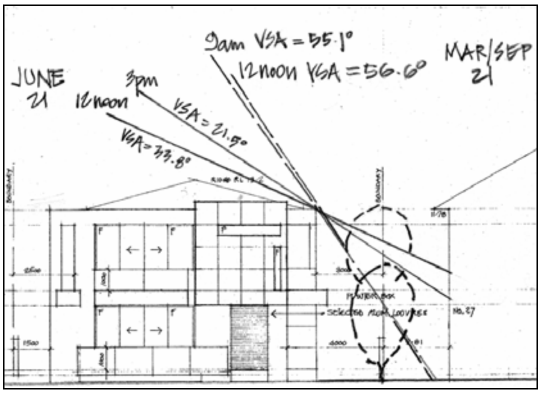

Figure 4: VSA illustrating overshadowing of neighbour

Sunlight Indicators

Effectively a derivation of the previous technique, but most suitable where only key dates of the year are of primary interest. Pre-printed Sunlight Indicator templates may be used as transparencies superimposed on the hard copies of conventional architectural drawings. Relying only on relative levels, they yield impressively accurate schedules of shaded and sunlit times for individual points in space.

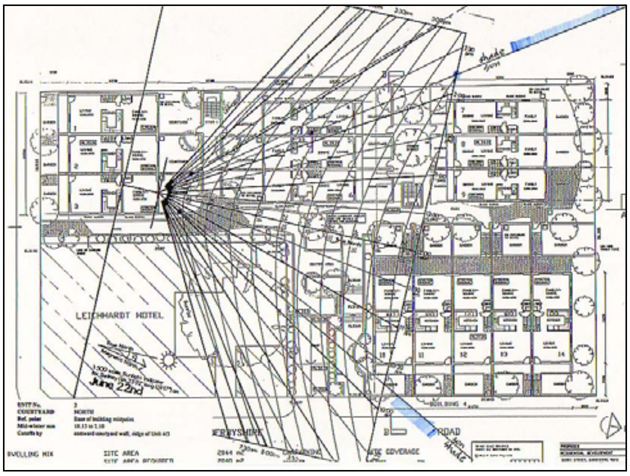

Figure 5 Sunlight Indicator for Sydney, June 22 superimposed on plan.

Sunlight indicators are by far the quickest and most effective way for Council staff to carry out compliance checking. The output fro this technique is a schedule such as illustrated in Figure 6.

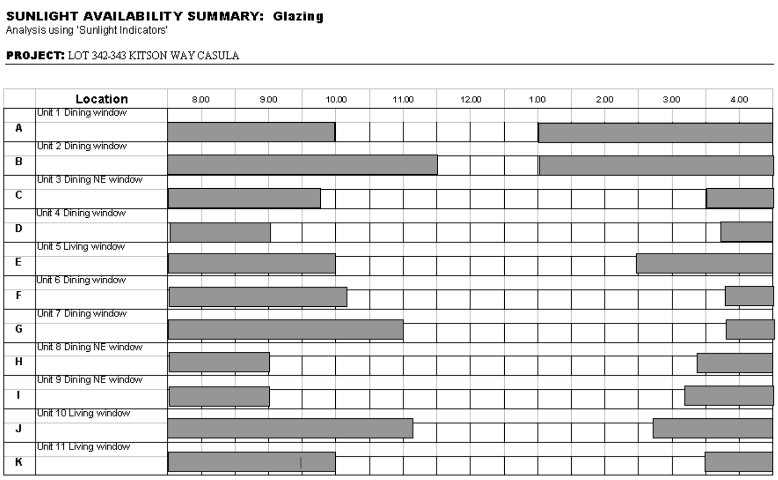

Figure 6: Report of Sunlight Indicator analysis

Model studies
Where physical models are produced for other purposes, they may be examined for solar access and overshadowing by use of a simple sundial attached to the model. The accuracy of the shadows is dependent on the distance of the light source, and the alignment between model and sundial.

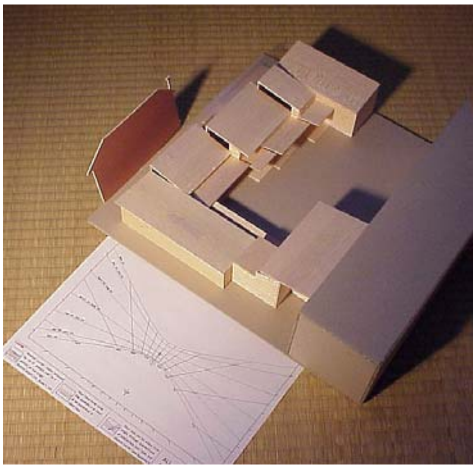

Figure 7 Model with polar sundial

Model studies may be recorded by photography, and minuted. They are particularly well suited to pre-application conferencing.

2.3.4 FACTORS TO BE CONSIDERED IN ASSESSING OR REPORTING COMPLIANCE

What sunlight counts?

The concept of 'effective sunlight' has been considered by the Land and Environment Court of NSW. It would also be reasonable to infer that the Court was motivated by a history of seeing a lot of contentious and self-serving characterisations of the last sliver of sunlight, the last tiny corner of sunpatch on a window, the last minute of fleeting sun, as part of a minimum sun access in mid-winter. A total waste of the Court's time, and not at all in the spirit of assuring the performance to which DCPs and the RFDC Guidelines seek to address themselves.

In addition, consideration must also be given to the allowed 'bracket' of time embedded in the controls, 9am to 3pm.

Parsonage

The Principle embodied in Parsonage v Ku-ring-gai [2004] NSWLEC 347 has become increasingly influential in constraining sun that may be considered as complying. In brief, the sunpatch on glazing should be a minimum proportion of its area, and any sun falling at an acute angle to the glazing is to be ignored. For outdoor space, the sunpatch should be at ground level.

Both applicants and Council officers need to be mindful of when these strictures in Parsonage are potentially problematic:

- *Minimum proportion of glazing is given as 50%.* Clearly, this is untenable, unless there is a concept of an appropriate area of glazing. The rule may therefore be contested.
- *Sun at angles not to be considered is specified as any less than 22.5° to the glass in plan.* If it were to be truly useful in assuring adequate sun penetration of the glass, this rule would have to be expressed in 3D. However, that introduces a level of almost unmanageable complexity in reporting, and is therefore ignored by everyone. Other than asking why it is the angle specified is that from the DoP Sunlight Indicators report of 1978, rather than the slightly more liberal 15° specified by Phillips in Sunshine and Shade in Australia, this rule should be taken very seriously.

- *Sun falling on the ground, rat*her than on any other arbitrary plane, is a fairly sensible constraint, except in courtyards and terraces of minimum dimensions. Here, privacy walls required by other controls may well make achieving 50% of the area sunlit for minimum time impossible. Yet in such courtyards, the most likely performance requirement is to be able to sit in the sun — which is quite easily achieved. In my experience, this rule may therefore be contested in some circumstances.

9am – 3pm

This constraint was first articulated by Walter Bunning in 1944, and related clearly to the preferred north orientation for windows. The limited bracket of time is itself based on the two main considerations:

- the likelihood of *low sun angles* being blocked by topography remote from the site, and
- the notional usefulness of the received solar radiation as an energy source.

In certain situations, such as east or west facing glazing with unobstructed sun as might be expected on the seaboard or on hill tops in Sydney, sunshine before or after these times is clearly 'effective' sun. Given that both DCPs and the RFDC are performance based controls, such effective sun should be considered to satisfy the control.

Self shading

Increasingly designers find that, even for well oriented buildings, the minimum dimensions for private outdoor space for apartments create overhangs and vertical sun control devices that limit the ability to achieve complying sun patches at the glazing line.

Given that SEPP BASIX requires that no other control regulate energy or thermal comfort, both DCPs and the RFDC can now only be read for their assessment of amenity. In some circumstances, there is some merit in considering a single sun access compliance characterisation, integrating interior and veranda performance. When applied to 'wintergarden' style terraces, this will generally be acceptable, and may well be considered reasonable in other configurations.

3.0 Daylighting

Australian Standards in the AS1680 series set out both principles and recommended standards of lighting. But they are aimed more at the appropriate design of artificial lighting, and intended to apply only to work related environments. In as much as the standards relate to the effective performance of tasks, the recommended lighting levels (*maintenance illuminance*) set out in the various parts of AS/NZ1680.2 are also of relevance to daylighting design in those working environments.

3.1 Daylighting Benefits

There are good reasons to encourage good daylighting for interiors. Daylighting differs from artificial lighting in a number of ways:

- Spectral content of daylight covers a wider frequency range, giving better colour rendering;
- Daylight is diffuse, arriving from large regions of the sky dome. Artificial light is usually very directional;
- Daylight levels vary in both the short and long term, contributing to 'arousal' for comfort and productivity;
- Effect on visual comfort and well being;
- Influence energy use. If considered at the design stage, the use of daylight allows for a significant reduction in electricity used for lighting;
- Efficiency of daylight is considerably higher than electric alternatives: daylight introduces less heat per lumen into a building.

3.2 Daylighting compliance

But regardless of its known benefits, no Standard is available in Australia for a proper quantitative assessment of daylighting, and in residential settings even the illuminance level recommendations for relevant tasks must be treated with caution.

Experts preparing daylighting studies to satisfy regulators' concerns with respect to daylighting in dwellings have in the past relied on a brief set of recommendations reproduced in a number of authoritative British texts of from 1966 to 1977. It is important to note that these citations are *not* to a British Standard. The recommendations may be summarised as follows:

> Recommended minimum Daylight Factors for no less than 50% of the floor area to be 2% for kitchens, 1% for living rooms and 0.5% for bedrooms.

3.3 Daylighting prediction

These days, daylight levels and even appearance of interiors may be predicted with relative precision and detail by use of appropriate simulation software. The industry standard software Radiance is available free of charge from the Lawrence Berkley Laboratories in the US.

There are some (but very few) other photometrically reliable software packages — most apparently similar software being derived from rendering (illustration) and gaming applications. Simulation based daylighting analysis is effective and justified where undertaken to optimise energy efficiency for a commercial building, but is rarely performed for design or compliance reporting for residential interiors.

In my experience, experts required to provide quantitative evidence in an adversarial setting on behalf of applicants have tended to rely on a simplified 'hand calculation' method. I will describe it in some detail because it is important to understand its limitations in the situations in which daylighting compliance is likely to be disputed.

3.4 The definition of a Daylight Factor

Hand calculation methods for daylight generally do not attempt to directly calculate illuminance at surfaces. Instead, they estimate a 'daylight factor'.

The Daylight Factor (DF) is a very common and easy to understand measure for expressing the daylight availability in a room. It describes the ratio of inside illuminance over outside illuminance, expressed in %. The higher the DF the more natural light is available in the room.

Daylight Factors always relate to an overcast sky. Furthermore, they relate to what is known as a 'standard CIE overcast sky', which is one with a standardised distribution of intensity at an 'average' for that latitude. See Figure 8.

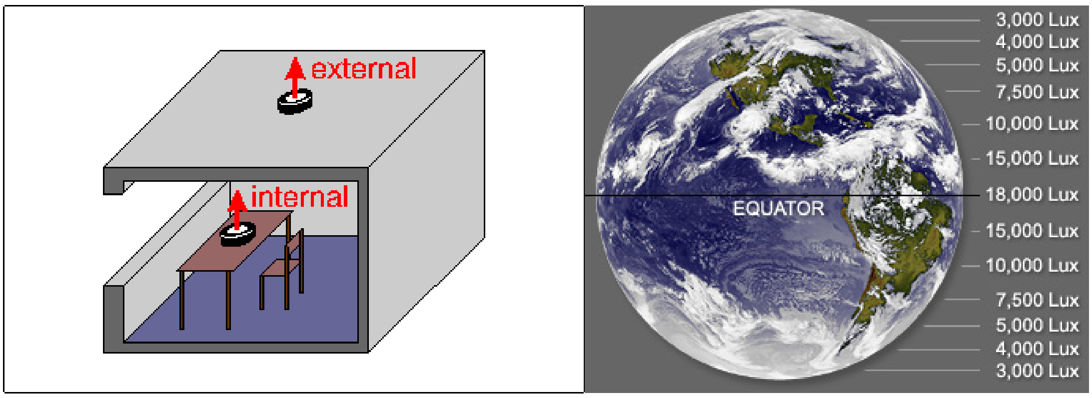

Figure 8: Daylight Factor and Standard Overcast Skies

The DF can be expressed in two different ways: for a fixed point (e.g at the desk) and as an average. The latter is the arithmetic mean of the sum of point measurements taken at a height of 0.85m in a grid covering the whole floor area of the room. Many countries have developed their own definition of an average daylight factor, and although they are all similar to one another, they are not quite the same. Again, the details of the prescribed formulae are beyond the scope of this paper, the more especially as Australia does not require adherence to any particular version.

Rooms with an average DF of 2% give us a feeling of daylight. However, it is only when the DF rises above 5% that we perceive it as well daylit.

3.5 The 'Split Flux' method

The so called 'Split Flux' method for calculating the DF was developed by the British Research Establishment in the 1960s. The basis of the method is illustrated in Figure 9.

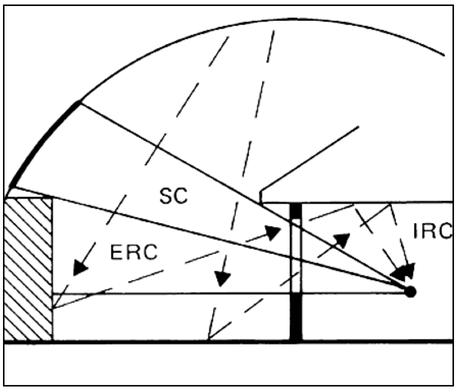

Figure 9: The Components of daylight

The BRE Split Flux method calculates a Daylight Factor in an interior, by adding the contributions from three components (hence the name). The relevant components are:

- Sky Component (SC)
- Externally Reflected (ERC)
- Internally Reflected (IRC)

3.5.1 SKY COMPONENT

Calculated by a number of possible graphic techniques (typically the Pilkington Pepperpot diagram or the Waldram Diagram), by use of the BRE 'protractors', or by the BRE Tables.

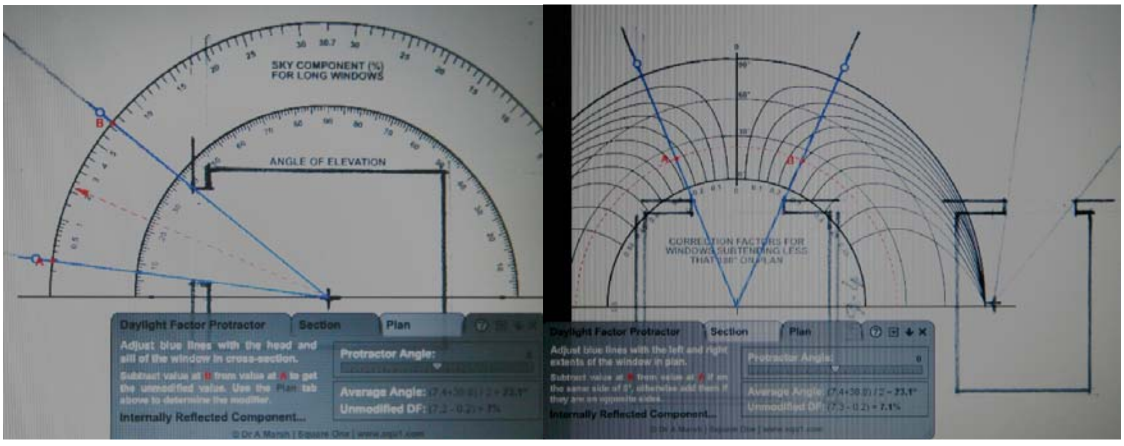

Figure 10: Using the BRE protractor

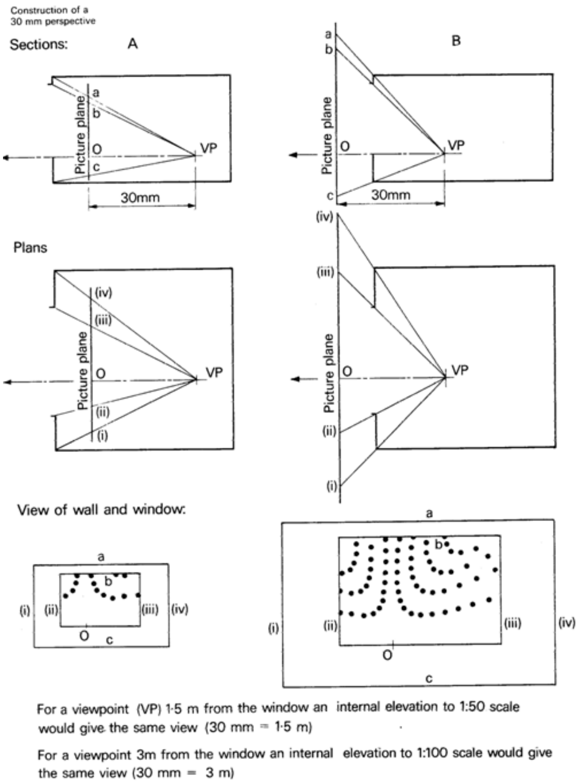

Figure 11: Using the Pepperpot Diagram

Ratio W/D = Effective width of window to one side of normal: distance from window	Ratio H/D = Height of window above working plane: distance from window																												
0	0·1	0·2	0·3	0·4	0·5	0·6	0·7	0·8	0·9	1·0	1·1	1·2	1·3	1·4	1·5	1·6	1·7	1·8	1·9	2·0	2·2	2·4	2·6	2·8	3·0	3·5	4·0	5·0	∞
0·1	0	0	0·1	0·1	0·2	0·2	0·3	0·4	0·5	0·6	0·6	0·7	0·8	0·8	0·9	0·9	0·9	1·0	1·0	1·0	1·1	1·1	1·1	1·1	1·2	1·2	1·2	1·2	1·3
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0·3	0	0·1	0·2	0·3	0·5	0·7	1·0	1·2	1·5	1·7	1·9	2·1	2·3	2·4	2·6	2·7	2·8	2·9	3·0	3·1	3·2	3·3	3·4	3·4	3·5	3·6	3·6	3·7	3·7
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0·8	0·1	0·2	0·4	0·7	1·1	1·6	2·1	2·6	3·1	3·6	4·1	4·5	4·9	5·2	5·6	5·8	6·1	6·3	6·5	6·7	7·0	7·3	7·5	7·6	7·8	8·0	8·2	8·3	8·4
1·0	0·1	0·2	0·4	0·8	1·2	1·7	2·2	2·7	3·3	3·8	4·3	4·8	5·2	5·6	5·9	6·2	6·5	6·7	6·9	7·1	7·4	7·7	7·9	8·1	8·2	8·5	8·7	8·8	9·0
1·2	0·1	0·2	0·4	0·8	1·3	1·8	2·3	2·9	3·4	4·0	4·6	5·0	5·5	5·9	6·2	6·5	6·8	7·1	7·3	7·5	7·9	8·1	8·4	8·6	8·7	9·0	9·2	9·4	9·6
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1·8	0·1	0·2	0·5	0·9	1·4	2·0	2·6	3·3	3·9	4·6	5·3	5·9	6·4	7·0	7·4	7·8	8·2	8·5	8·8	9·1	9·6	10·0	10·2	10·5	10·7	11·1	11·4	11·7	12·2
1·9	0·1	0·2	0·5	1·0	1·4	2·0	2·6	3·3	4·0	4·7	5·4	6·0	6·6	7·2	7·6	8·1	8·5	8·8	9·2	9·5	10·0	10·4	10·8	11·1	11·3	11·8	12·0	12·3	12·6
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6·0	0·1	0·2	0·5	1·0	1·5	2·1	2·8	3·4	4·2	5·0	5·7	6·3	6·9	7·6	8·1	8·6	9·1	9·5	9·9	10·2	10·9	11·4	11·9	12·3	12·6	13·2	13·6	14·1	14·9
∞	0·1	0·2	0·5	1·0	1·5	2·1	2·8	3·4	4·2	5·0	5·7	6·3	7·0	7·6	8·1	8·6	9·1	9·5	9·9	10·3	10·9	11·5	11·9	12·3	12·7	13·3	13·7	14·2	15·0
0°	6°	11°	17°	22°	27°	31°	35°	39°	42°	45°	48°	50°	52°	54°	56°	58°	60°	61°	62°	63°	66°	67°	69°	70°	72°	74°	76°	79°	90°
	Angle of obstruction																												

Figure 12: The BRE Table for Sky Component

3.5.2 Externally Reflected Component

Derived from the same technique as the Sky Component. It is assumed that the default reflectance of the obstructions is 0.2, ie. that the ERC is 20% of the Sky Component it replaces.

3.5.3 Internally Reflected Component

The IRC may be estimated by several methods of combining the relevant variables, which relate to the areas of the internal surfaces, and their average reflectances. Of particular interest is that the current standard British calculation for IRC includes a factor for the sky component visible at the window, but the BRE tabular method does not.

3.6 Limitations of the Split Flux method

The BRE Split Flux method can produce relatively useful estimates of daylight factor as long as one does not ignore its inherent assumptions. These assumptions behind the BRE Daylight Factor calculation are now quite difficult to track down, because the relevant texts all date from the 1960's and 1970's. They are never, to my knowledge, declared by the people who employ the technique.

The specific difficulty is in using the method to evaluate the daylighting of rooms in lightwells. This is best illustrated by a case study.

3.7 Case study

Complex lightwell of five storeys, serving the windows of two bedrooms at each of five levels. The lightwell is divided at the boundary line by a beam/column grid. The question of interest was:
Is there a likely issue with the daylighting available to the rooms at the lowest level of the lightwell?

A simulation study was performed using the commercially available software package "AGI32" by Lighting Analysis, Inc. Figure 13 illustrates a view of the simulation model, showing both sunlight and daylight penetration of the lightwell.

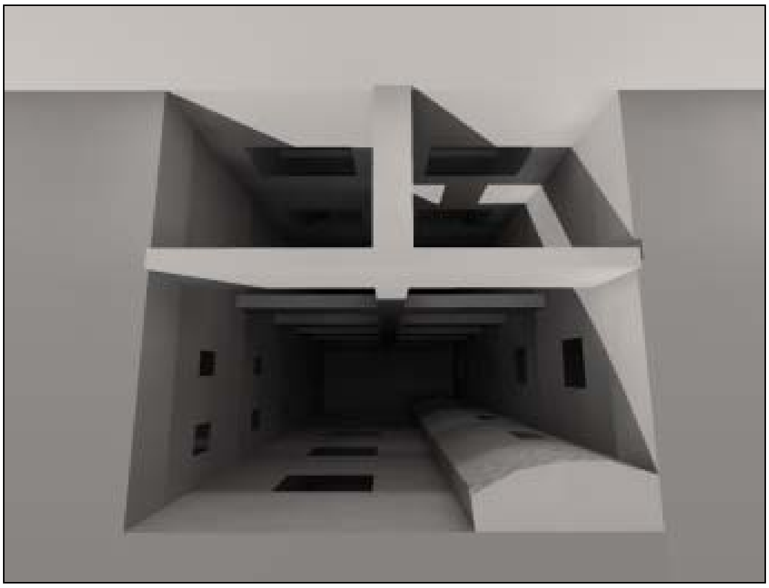

Figure 13: A lightwell simulation

For this discussion, I do not reproduce the detailed simulation outcomes. Included in the reported outcomes of the simulation study were Daylight Factors under a standard overcast sky derived for the assumed mid-point of the rooms at the different levels of the lightwell. The relevance of the estimated Daylight Factor (DF) is that it allows comparison with the commonly used British recommendations, and more particularly that it allowed comparison with the commonly used 'Split Flux' hand calculation method.

Table 1 shows the Daylight Factors calculated from the Illuminance values predicted by the simulation, for different dates and sky conditions.

Table 1: Simulation outcomes for a lightwell

Single Point Calculation
Centre of a 3.6 x 3.6 room
June 21st, 12 noon, Overcast Condition

Level	ILLUMINACE				DF
	Clear	Partly Cloudy	Overcast		Overcast
5	1006	639	151		1.3
4	355	230	62.6		0.5
3	99.2	76.2	23.3		0.2
2	52.7	54.4	14.9		0.1
1	34.5	44.7	11.6		0.1

The Daylight Factor at the centre of the rooms at the lowest level was then also calculated for standard overcast conditions using the common hand methods. The following observations are pertinent:

- The 'Sky Component' is actually a simple geometric estimate of the sky patch visible from the reference point. Of course, in the rooms in question, there is no such sky patch visible, so the Sky Component is zero.

- The second external source of daylight is the 'Externally Reflected Component'. The BRE method assumes that the ERC is just like the Sky Component, except reduced in proportion to the reflectance of the surface that is 'obstructing' a piece of the sky patch. In the rooms in question, the relevant point sees only such a surface, the wall/window on the opposite side of the narrow, deep lightwell. This is the first issue.

- The BRE method is clearly predicated on an assumption that the Externally Reflected Component may be estimated because the obstructing surface is itself an outside wall, and therefore should be reflecting a substantial part of the sky. It is not, to my knowledge, intended to be used to estimate the light available from a vertical surface at the bottom of a narrow lightwell, with little sky visible. As, in our case, this ERC is the only source of Daylight, the use of the BRE method without serious modification would almost certainly represent a wild over-estimate of the available light on that reflecting surface.

- The technique for calculating the remaining component of the Split Flux Method, the Internally Reflected Component, is then also problematic. Neither common method on which it is calculated makes any reference to limiting conditions, but in reality all formulae and the tabular method are actually based on assumptions about a factor by which the incoming light is multiplied to obtain the 'additional' light at a given point. Therefore applying it in an inappropriate situation (viz. where the window itself doesn't see any sky) will give a potentially serious over-estimate of the available internally reflected component, compounding the over-estimate related to the ERC.

Table 2 shows the comparison of the DF values derived by the three methods, namely simulation, the BRE Protractors and the BRE formula for the Internally Reflected Component, and using the BRE Tables. The table also shows the Illuminance values in Lux to which they translate based on a Standard Overcast Sky for Sydney.

Table 2: Comparison of predicted Daylight Factors and Illuminances

Method	DF at centre of room	Illuminance on Standard Overcast Day
Simulation	0.1	11.6 lux
BRE Protractors	2.2%	253 lux
BRE Tables	2.7%	315 lux

In the case of the BRE Tables, the over-estimate of likely light levels is compounded. The calculation for the Internally Reflected Component does not discriminate for floor levels (ie. differences in distance from the top of the lightwell). Once the point of interest is beyond the distance from the window at which there is a sky view, the predicted DF will be the same whether the room is say four floors below the top of the lightwell, or twenty.

It is clear that when examining daylighting for rooms served by lightwells, any quantitative analysis by the common BRE Split Flux method must be viewed with extreme suspicion.

3.8 What do the Lux values mean?

3.8.1 Accuracy of the predictions

The appropriate simulation models will give reliable relative differences of calculated Lux values. But the calculation is highly sensitive to small differences in parameters such as reflectances of both inside and outside surfaces, and to their detailed physical configurations.

Thus, in terms of the case study lightwell the calculated mid-point Lux value for the Level 1 room — currently expressed as 11.6 lux — could vary between approximately 8 lux and 30 lux depending on assumptions. This bracket of values includes the calculated values for Levels 2 & 3. Comparing Illuminance values for the same room on different levels of the proposed lightwell, it will be apparent that a significant difference can only be attributed to the bottom three levels as compared to the top two levels — and that *even simulation cannot be used with confidence to make decisions concerning the absolute quantitative compliance impact of the depth of the lightwell.*

3.8.2 Acceptable light levels

The following recommendations are abstracted from AS/NZ 1680.2, but should not be given undue weight in any compliance determinations in residential settings:

- Crudely speaking, lighting levels below 50 lux can be said to be ambient lighting only, usually safe for circulation, etc. but not suitable for any activity requiring visual acuity.
- At 100 lux, one begins to feel confident of most normal domestic activities, and sustained screen based work, such as in a study bedroom.
- In excess of 250 lux is comparable to commercial and educational settings for normal visual tasks.
- Over 350 lux can support visual tasks requiring discrimination of fine detail.

The application of these values as acceptable minima is further complicated by the large variability of natural light levels in domestic interiors. In domestic environments, we can also put up with much lower *average* Illuminances than in working environments. The main reason for this is the relative freedom to use different parts of a room for different tasks.

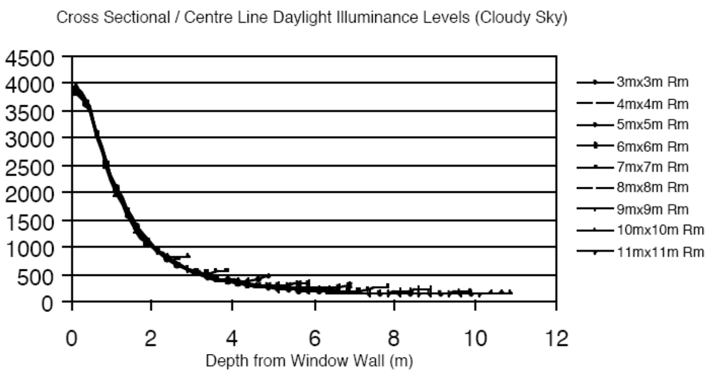

Figure 14: Light gradient in typical side lit room

Figure 14 illustrates the variation in Lux levels as the distance increases from the window of typical side lit rooms. It is notable that the daylight levels within a zone near the window approximating the width of a desk will have very high Illuminances, sufficient to carry out even critical visual tasks, while the centre of the room may have much lower light levels.

This makes it difficult to establish critical quantitative compliance standards even for apparently poorly daylit rooms in residential buildings.

3.8.3 Measurement and perception

Finally, it should also be understood that Lux values should not be compared by simple ratios because the perception of light levels by human beings is not linear but logarithmic. In other words, if the issue is the use of a room by people, comparisons expressed as percentage difference, increase or decrease are meaningless.

Glossary

Altitude The vertical angular distance of a point in the sky (usually the sun) above the horizon. Altitude is measured positively from the horizon (0°) to the zenith (the point in the sky straight overhead, 90°).
Ambient Lighting General illumination.
Azimuth The horizontal angular distance between the vertical plane containing a point in the sky (usually the sun) and true north. In other words, the angle of sun from true north as seen in plan view.
Brightness The subjective perception of luminance.
Brightness Glare Glare resulting from high luminances or insufficiently shielded light sources in the field of view. Also called direct glare.
Color Rendition The effect of a light source on the color appearance of objects.
Contrast Glare Glare resulting from a large brightness difference in the field of view.
Daylight Factor The ratio of daylight illumination on a horizontal point indoors to the horizontal illumination outdoors, expressed as a percentage. Direct sunlight is excluded.
Diffuse Lighting Lighting that does not come from any particular direction.
Glare The sensation produced by brightness within the visual field that is greater than the brightness to which the eye is adapted and thus causes annoyance, discomfort, or loss in visual performance and visibility.
Horizontal Shadow Angle The plan angle of the sun in relation to a line normal to a façade of given orientation.
Illuminance Amount of light incident on a surface.
Light Shelf A horizontal element positioned above eye level to reflect daylight onto the ceiling.
Lumen A common unit of light output from a source.
Luminance Amount of light coming from a surface; in other words, how bright it is.
Luminance Ratio Ratio between different brightnesses in the visual field. Lux The metric unit for illuminance. The U.S. unit is the footcandle.
Photometer An instrument for measuring light.
Reflectance The ratio of energy (light) bouncing away from a surface to the amount striking it, expressed as a percentage.
Reflected Glare Glare resulting from mirror-like reflections in shiny surfaces.
Shading Coefficient the ratio of the total solar heat gain through a window to that through 1/8" (3 mm) clear glass.
Solar Heat Gain Coefficient Solar heat gain through the total window system relative to the incident solar radiation.
Task Lighting Light provided for a specific task, versus general or ambient lighting.
Transmittance The ratio of energy (light) passing through a surface to the amount striking it, expressed as a percentage.
Veiling Reflection A condition where light reflected from a surface masks the details of that surface. A common occurance when glossy magazines are read under bright, direct lighting.
Vertical Shadow Angle The apparent angle of the sun to the horizontal in section, relating to a wall or window of given orientation. Derived by trigonometry, or graphically by the use of the Shadow Angle Protractor in conjunction with a sun position diagram.
Visual Acuity A measure of the ability to distinguish fine details.
Visual Comfort Probability Rating of a lighting system expressed as a percentage of the people who will find it free of discomfort glare.
Visual Field What can be seen when head and eyes are kept fixed.
Visual Performance The quantitative assessment of a visual task, taking into consideration speed and accuracy.
Workplane The plane at which work is performed, usually taken as horizontal and at desk height (750mm) from the floor.