# LIGHTING INSTRUMENTATION, MEASUREMENT AND PERFORMANCE REPORTING OF MABEL - AUSTRALIA

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## 1. Introduction

The Mobile Architecture and Built Environment Laboratory (MABEL) program is a pilot study to building performance measurement and analysis. A comprehensive set of Indoor Environmental Quality (IEQ) performance parameters are assessed to ascertain where weaknesses occur, commissioning is lacking and improvements can be made. Foremost, it is intended that the findings of measurement will provide the much needed feedback loop to our building design, detailing and construction assembly processes as suggested by Hawken, 1999, Hyde, et.al. 2007, and Lstiburek, 2008**.**

In relation to such work the European Commission (CEN prEN15251 Standard, 2005) and an alliance between ASHRAE, the U.S. Green Building Council and CIBSE, 2010, to name a few, have produced protocols on an IEQ measurement processes.

Perhaps the ultimate result is to reach a single value IEQ performance-rating indicator, which (if needed), can be further analyzed under its individual category parameters (Figure 1, Luther, 2009).

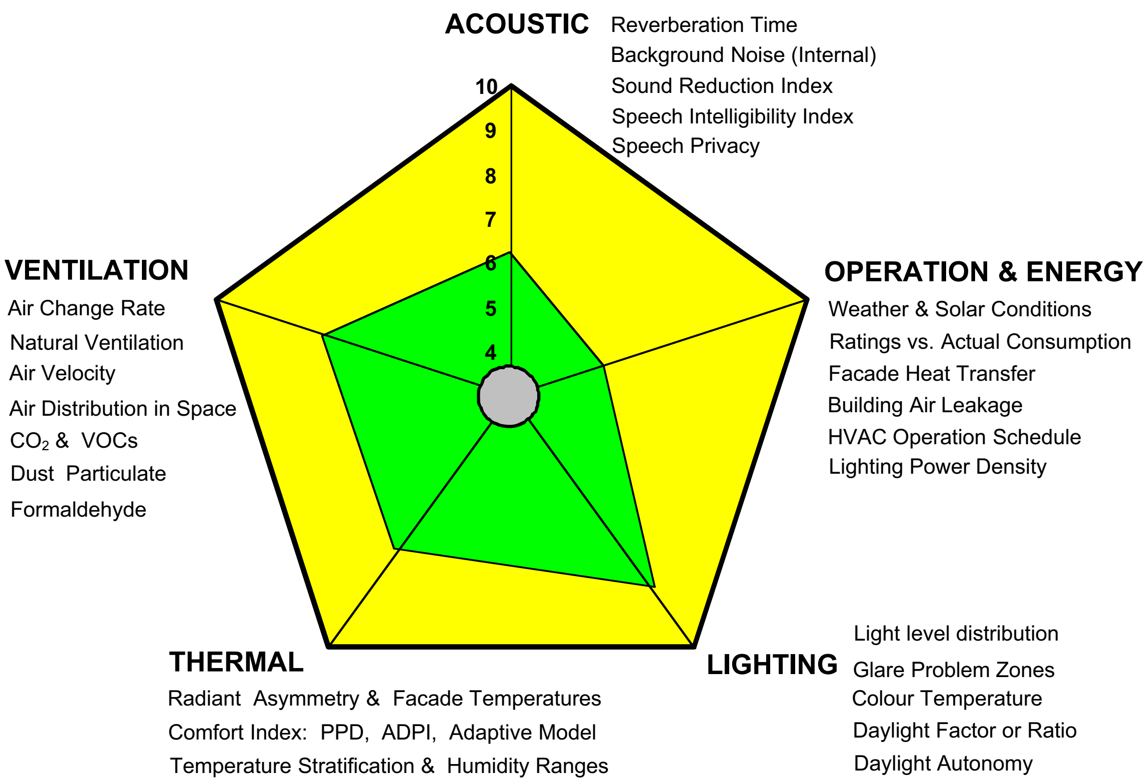


**Fig. 1 MABEL's development towards a single IEQ evaluation scheme**

In this paper we will concentrate on the complexities involved with the 'Lighting' criteria of the IEQ evaluation.

### *1.1. Instrumentation*

The forthcoming intends to provide a brief explanation of the instrumentation in the lighting facility of MABEL, followed by methods of measurement, processing and presentation of the results.

The instrumentation comprises the measurement of the two principal lighting parameters;

- illuminance (lux, lighting falling onto an particular plane) and,
- luminance (the surface brightness or light from a particular object).

There are six Minolta CL-200 Illuminance / Colorimeter sensors that are hooked up to a 'recorder program' using a tailored routine in MATHLAB. For all six sensors the illuminance (lux) measurement is recorded as well as its colour temperature - °K (and/or colour coordinates). The measurment occurs over a three minute period and an average reading is provided.

A Nikon Cool Pix 5000 and a 5400 Camera each calibrated with a fisheye lens provide for luminance measurements. The ENTPE laboratory in Cedex, France calibrated these. Today, many CCD cameras exist and are almost common practice (Coyne, 2006). What lacks is a practical evaluation tool for these fisheye lens luminance results. We discuss these deficiencies and their possible future development in this paper.

After several initial pilot projects it became apparent that workplaces were the primary concern of most lighting measurements. The inception for a 'visual comfort meter' that considered the seated position of an occupant at their workplace became the creation of a combined instrument measuring illuminance and luminance (Figure 2.0).

Fig.2 Showing the 'Visual Comfort Meter' in illuminance (left) and luminance (right) measurements.

### *1.2. Evaluation*

The bottom line of any MABEL assessment is to obtain an evaluation of performance of the particular criteria under consideration, in this case lighting. These evaluation criteria often initially derive from common practice and developed standards.

Since there are numerous criteria to be considered when evaluating lighting for an environment we should discuss what these might be. In hindsight, and after several projects, it is suggested that perhaps a basic assessment of the interior lighting at the workplace might include several of the criteria provided in Table 1.0.

| | Rating | | | |
|---|---|---|---|---|
| WT | -1 | 0 | 1 | Lighting Assessment Criteria |
| | X | | | Work place Wall Surface Reflectance |
| | | X | | Work Place Ceiling Surface Reflectance |
| | | | X | Work Place Desktop Reflectance |
| | | X | | Work Place Horizontal Illuminance |
| | | | X | Vertical at Screen |
| | | X | | V-H Ratio Balance @ Occupant |
| | X | | | Luminance General Background |
| | X | | | Luminance Visual Field |
| | | X | | Color Temperature(Uniformity) |
| | | | X | Visual Noise(Clutter) |

**Table 1.0 A possible evaluation for lighting in a workplace**

The means and methods, to which several of the individual criteria in Table 1.0 are derived upon, have yet to be completely developed. It may also be realized that several specific criteria are more significant (hold more weight) in determining a successful luminous environment than others. All of the above may be considered benchmark to the evaluation of lighting for a particular space.

In particular the luminance measurements are the most interesting, desperately requiring an objective evaluation of the subjective questionnaire in Figure 3.0.

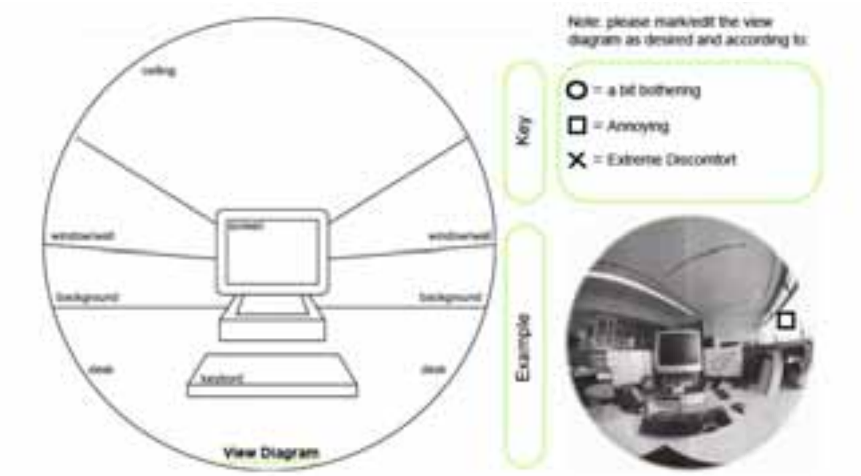


Fig. 3 Luminance occupant questionnaire for the workplace

## 2. Case Study Examples

The following provide example assessments of lighting measurements in a variety of different building types. The unique aspect is that each of these cases provide real on-site information through measurement and analysis.

*2.1 A Sports Centre (Gymnasium)*
In this case there were no measurements made as the building was in its design stage. Deakin university was planning a new 'precinct' of buildings for its Melbourne campus and a gymnasium would be part of this. Day-lighting had not been considered as an environmentally sustainable option. The architect immediately took note of this oversight and had us provide several studies (Figure 4a). The relatively narrow skylight aperture was augmented by a flared (angled out) ceiling immediately underneath. This provides a huge luminous surface area, evenly distributing diffuse light onto the court floor plane. As a result there is very little glare (if any) from the surrounding surfaces (see Figures 4.0). It is remarkable as to how much lighting actually is provided from the relatively small skylight openings.

In contrast to the previous gymnasium is another one where the entry of daylight and the form of diffusing it was overlooked (Figure 5). In this case, glare from glass block sidelights as well as sources of direct lighting mirrored from a highly reflective floor surface, make the lighting for some sports activities almost impossible.

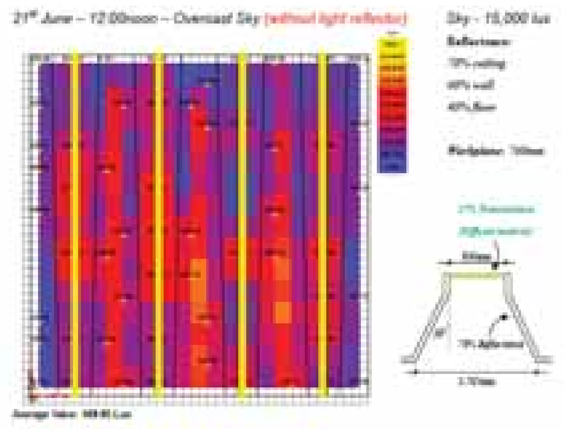

Fig. 4a Light level simulation example

Fig. 4b Resulting Skylight Solution in Gymnasium

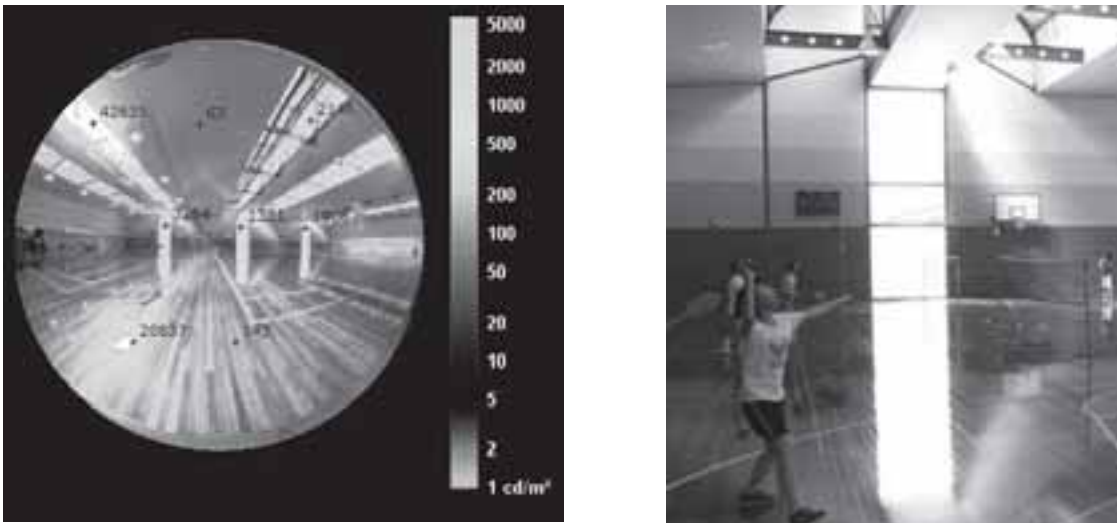


Fig. 5 A design example where glare is problematic in a gymnasium

*2.2 A School Building*

This next example illustrates how realistic day-lighting autonomy can be for school classrooms and laboratories. In this example a retrofit took place and we examine the before and after cases in regards to lighting improvement. Figure 6 below indicates the case where the space was altered from side lighting (only) to side lighting with a clerestory. The retrofitting has transformed the space from a electrically intensive lighting to one of a fully day lit autonomous space. Note that such improvements in the building envelope design are an essential consequence of the end result.

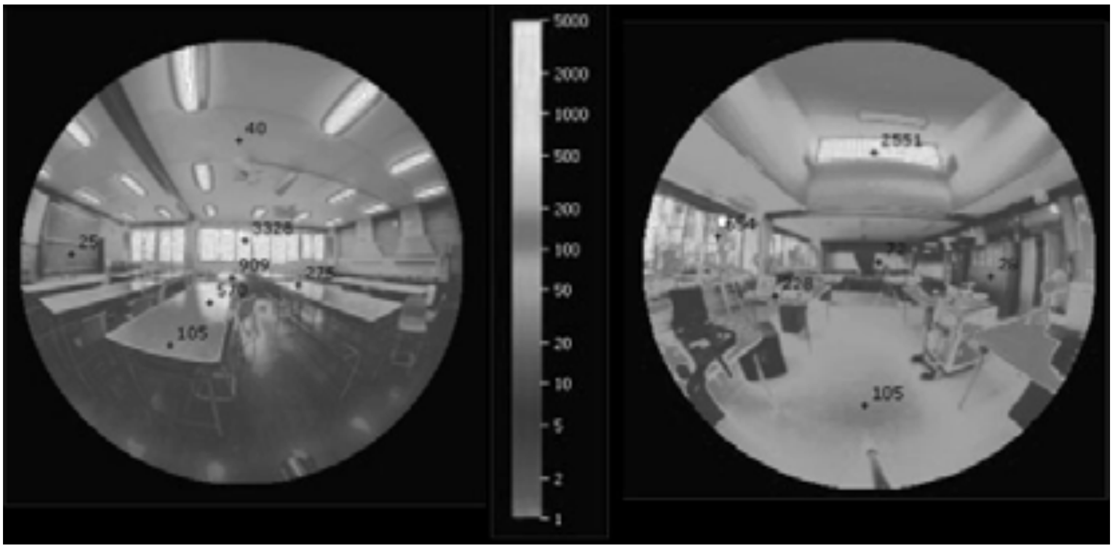


Fig. 6 A before and after retrofit luminance mapping for a school classroom at approximately 10,500 lux external measurement.

*2.3 An Office Building*

As illustrated in previous examples, daylighting can turn a liability into an asset when proper design is in place. We need to learn how to diffuse and direct light onto surfaces of uniform reflectance. One of the real challenges in lighting design is our workplace, the office. For this building typology daylighting can often present serious problems and poor lighting design practices are often the norm. We return to the MABEL intentions of developing a 'visual performance index' and provide an example of the measurement surveys (see Figure 7).

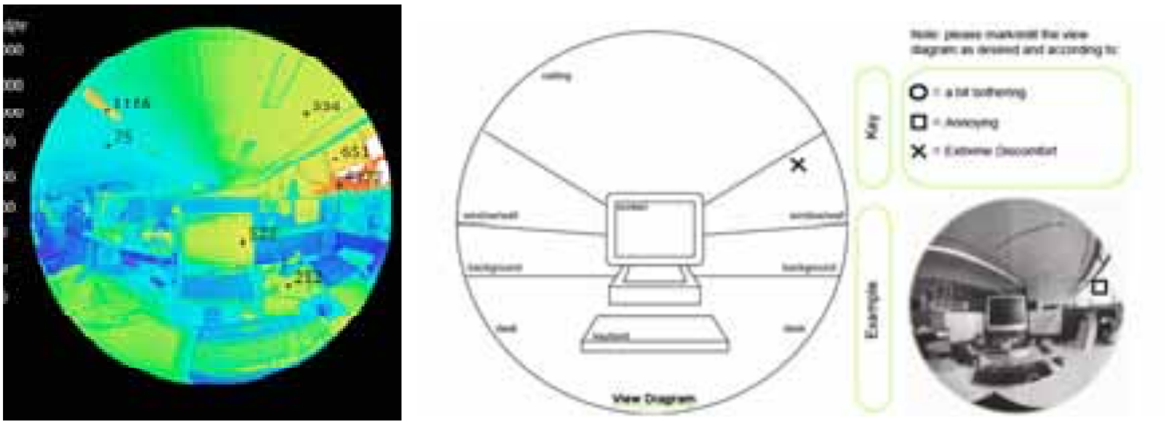


Fig. 7 Office workplace lighting: luminance mapping and glare problem questionnaire

Figure 7 illustrates a case with the luminous camera result along side the occupant survey result. In this case the blinds are not fully drawn and the user is not satisfied, receiving excessive glare from the façade. There is a substantial section of brightness levels over 5000 cd/m2, compared to the normal 180 cd/$m^2$ at a workplace. This measured result is a good indication of what can occur when the blinds are not in use.

A hand held investigation of daylight penetration through the blinds indicates that they are about 8-10% transparent. This blockage of daylight penetration may not be adequate for the present arrangement of the workplaces. It is discovered that the problems primarily occur when the blinds are not drawn. However, this design approach (drawing the blinds) defeats the idea of maximum daylight use and diffuse lighting penetration into the depths of the office space.

One of the features of the workplace measurements, using the visual comfort meter, is the mapping of illuminance levels. As mentioned earlier in this paper, there are 6 Minolta CL-200 illuminance / colorimeter sensors that aim at providing the light levels received at the head of the occupant (see Figure 8), the light onto the computer screen as well as the light onto the desktop (workplane). The analysis of these sensors has yet to be fully applied and understood. Several analytical intentions would be to define:

- a vertical to horizontal illuminance ratio
- a contrast (or difference) ratio between maximum and minimum illuminance levels.
- an average illuminance level received from all six points
- a ratio or illuminance difference between the vertical screen and the vertical occupant face.

At this point in time we have yet to ascertain a proper method of analysis for this illuminance data. The only result at present is the work-plane (horizontal illuminance) and its respective colour temperature. An example is shown here indicating the tremendous fluctuation in light levels and colour temperature at different workstations within the same open office (Figure 9).

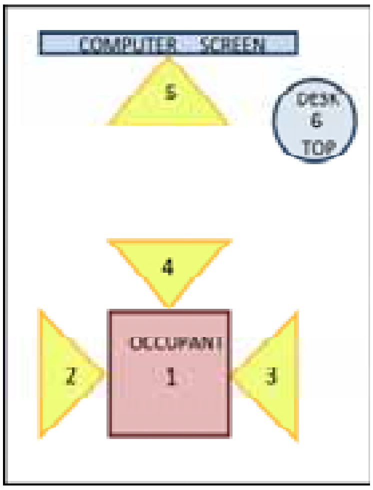


Fig. 8 Illuminance set-up for workstation measurement

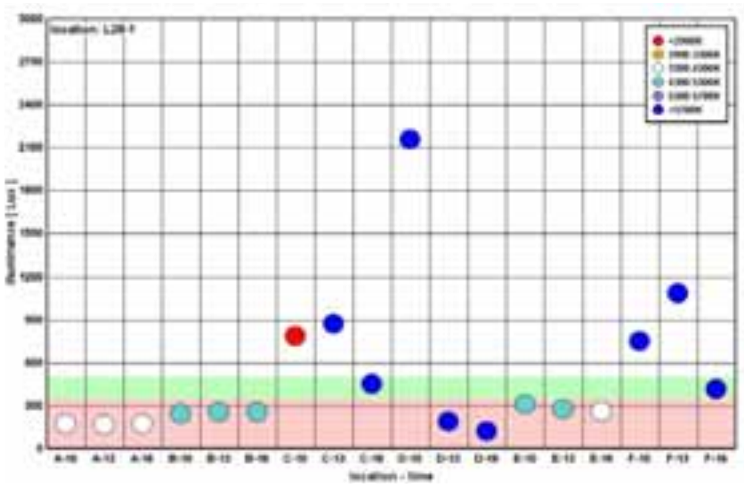

Fig. 9 Illuminance at desk top and colour temperature at different workstation locations in an office

## 3. Conclusion

Several examples have been provided in this report regarding daylight integration and its measurement with the Mobile Architecture and Built Environment Laboratory (MABEL) facility. It would be desired to compare these research findings and experiences with other research organizations involved with similar research. The shortcomings of daylight integration in today's architectural design are significant. Too often the option of day-lighting is rejected due to a lack of understanding how to control it. The research towards in-situ measurement of day-lighting projects is important because it can demonstrate successful designs and reduce the risk taking in future projects.

The need for a 'visual comfort meter' is an important aspect of this paper and requires international participation towards its development. Such an instrument was demonstrated for office workplaces here. The full interpretation of this data, providing luminance and illumance results, requires further analysis.

## 4. References

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