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Objective and subjective measurements of office meeting rooms

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SUMMARY
This research is a preliminary investigation of the objective measurements of thermal comfort and CO₂ levels as well as subjective user evaluation surveys in six meeting rooms. The ongoing objective measurements were taken via thermal comfort carts while the surveys evaluated parameters of temperature, lighting, air quality, meeting effectiveness etc. The outcomes are of particular interest since some of the objective measurements clearly do not support those of the users. In fact, the investigation has triggered off further interest in refining questionnaires to develop more precise indicators of ‘discomfort’.

Furthermore, meeting rooms present a challenge when it comes to conditioning spaces (HVAC design) which are sporadic in use and often with high occupancy for short periods. This paper investigates meeting rooms in four different buildings and their conditioning control concepts are discussed in relation to measured results.

KEYWORDS
Office meeting rooms, Indoor air quality (IAQ), Thermal comfort, Occupant surveys

INTRODUCTION
A project was commissioned by Sustainability Victoria, Australia to examine the interior environmental performance assessment of the former and the new meeting rooms of Sustainability Victoria’s offices. In particular this study is directed towards the thermal comfort, CO₂ levels, air change rates, and occupant surveys of these meeting rooms.

The objective of the study is to utilise the findings of the occupant surveys conducted by Business Outlook & Evaluation (BO&E) along side the results of the Mobile Architecture and Built Environment Laboratory (MABEL) objective measurements. This post-occupancy evaluation is to provide a comparison between the perceived ‘expected’ and the ‘as built’ result.

A general description of each office and their meeting rooms follows:

Casselden Place: is an open office located on the 12th floor level of the building cornering Spring St. and Lonsdale St. The office is fitted out with conventional materials and construction: carpeted floor on concrete slab, plasterboard framed portioned floor to ceiling walls, and a suspended tile ceiling. The floor to ceiling height is approx. 3.0m. The meeting rooms are small and located in the centre away from any visual outlook.

Spring Street: the location of this office is right off ground (street) level entry on Spring St. It is a big open office with a 3.5+ meter high ceiling at the foyer entry level. The street façade is a curtain wall (floor to ceiling glass) and the floor consists of a non-carpeted concrete slab.
in the foyer area. In the office desk area the floor is carpeted and there is a high suspended ceiling. The meeting rooms are adjacent a perimeter wall or centrally located to the entrance foyer and provide some outlook.

**Albert Street:** This is similar to the office construction at Casselden Place. Here, however, the main difference is the minimal external wall exposure. Although most of the perimeter office wall is actually external, it is practically adjacent to another building such that daylight penetration is minimal. The carpeted floor and suspended ceiling make it a very typical open office arrangement. The meeting rooms are spacious but located in the centre with no external outlook.

**The Urban Workshop 50 Lonsdale:** building is a newly designed multi-story office building. Its exterior façade design is typical of most contemporary office buildings, consisting of a floor to ceiling glazing unit. Shading is provided in the interior only through manually drawn meshed fabric blinds. A carpeted floor is the finish in the open office and meeting room areas. Two of the selected meeting rooms (‘Port Phillip’ and ‘City Loop’) are located on the office perimeter. The ‘MCG’ meeting room is centrally located. Even the central meeting rooms have a transparent outlook through the office to the perimeter.

All the buildings operate under a conventional HVAC Variable Air Volume system consisting of ductwork in a dropped ceiling cavity. With the exception of the new 50 Lonsdale St. offices having individual fan coil units to the meeting rooms, all the former meeting room locations rely on the general HVAC system conditioning. All of the office buildings have fixed (non-operable) windows. This defines the building ventilation operation as strictly mechanical, subscribing to the conventional comfort model of ISO 7760 (Fanger).

**MEASUREMENT**

The MABEL weather station was positioned on the rooftop of the Spring St. building, in order to receive the best possible solar exposure. Solar radiation levels, air temperature, humidity, wind speed and lighting levels were taken before, during, and after the measurement periods for the three (former) office building locations. The weather conditions are representative of a winter/spring season where non-overheating periods are expected.

![Figure 1. Weather and solar results as measured for the former offices.](image-url)
It is noted that the interior core temperature of the building is maintained well within the boundary temperature conditions of 18-26°C (green band) in all of the offices during occupied hours. Since Australians generally clothe themselves in response to the prevailing external weather conditions, a slightly warmer clothing level may be applied (other than the average 0.8 CLO) according to the seasonal changes in outdoor temperature.

In the case of the new office building at 50 Lonsdale St., the weather conditions are representative of a pre-winter season where non-overheating periods are expected. The average outdoor temperature during the days of measurement is at 16.8°C. It is noted that the interior central temperature of the office is well maintained within the boundary temperature conditions of 18-26°C. The solar radiation levels are about half to two-thirds of what they might be during peak summer periods. The average outdoor temperature is quite temperate although on the slightly cool side. In fact, these outdoor conditions should be ideal for 80-100% economiser cycle operation.

Sustainability Victoria expressed a concern with their meeting room comfort and indoor air quality at all the different office locations. In response to this, MABEL positioned a comfort cart together with CO₂ monitoring within a specific meeting room at each office location (Figure 2). A B&K INNOVA Tracer Gas analyser was also used in several meeting room and open office spaces to obtain CO₂ levels as well as air change rates (Figure 3). This continuous monitoring took place for a full week. A similar measurement process was performed at the new office location for its three meeting rooms. For the most part it could be claimed that the meeting rooms operate under a different environment from that of an open office area.

An occupant survey, an investigation of sick leave, as well as a self-assessed staff performance evaluation in meetings, was conducted by the Business Outlook and Evaluation (BO&E) group. A survey questionnaire was designed to gauge meeting participants’ perception of both the physical conditions in the meeting rooms and their personal level of concentration and engagement during the meetings. These studies provide the subjective user preference and evaluation of the former and the newly moved into offices. It is the objective of this report to combine both objective (MABEL) and subjective (BO&E) measurements into a single evaluation regarding the performance of the meeting rooms.

Figure 2. Comfort cart with CO₂ sensor. Figure 3. B&K INNOVA Tracer Gas Analyser.
RESULTS
This study found that Sustainability Victoria’s (SV) move to its new office, which was designed and fitted out for better indoor environment quality (IEQ), has led to improvements in two indicators of staff productivity: sick leave as a quantitative indicator of organisational performance, and self-assessed staff performance in meetings. The latter metric was chosen because meetings play an important part in SV’s office coordination, decision-making and program implementation.

The Study found a significant fall in sick leave from 6.65 days per employee per year to 4.7 days. The statistical significance of this result is greater than 97%. This decline in sick leave days translates to a current annualised saving of $76,000 to SV.

The results are consistent with those found in both physical monitoring of building air quality and temperature, and with surveys of staff attitudes to the new offices. The general staff survey found an overall workplace performance increase of 13% relative to previous SV premises.

Effectiveness of meetings
Prior to the move, most staff believed that the physical conditions in the room did not affect their concentration and level of engagement. Most felt that their levels of concentration and engagement were determined primarily by the meeting’s topic and agenda, the effectiveness and skill of the Chair, and their potential to participate. Most felt that the physical environment in the room had little impact.

This attitude shifted markedly following the move. While staff still believed that the meeting content and conduct were the most important factors, they strongly perceived an improvement in IEQ and believed that it contributed to better concentration and engagement during meetings.

The pre-move and post-move surveys showed significant improvements in participants’ self-assessment of concentration and engagement in the new meeting rooms. The concentration index rose by 34%, while the index for engagement rose by 41%. As the pre-move and post-move surveys were separated by 6 months, it is unlikely respondents could remember their pre-move responses, and so the gain is more than just a favourable backward comparison.

The pre-move and post-move surveys also showed that air quality and ambience in the new meeting rooms were perceived to be better than those in the old meeting rooms. Staff rated air quality ranging from stuffy to fresh, and applying an index scale, the air quality index rose by 15% while ambience improved by 19%.

• In summary, the staff surveys produced the following results: (This result was from an examination of leave record, not from the staff surveys) Staff concentration in meetings improved by 34%
• Staff participation in meetings improved by 41%
• Results correlate with physical measurements of air quality

The reported concentration and engagement levels, both pre-move and post-move, correlated with the objective measures of air quality. However, an analysis of the MABEL findings on the three pre-move rooms also showed some interesting anomalies between measured and perceived IEQ: the pre-move room with the worst perceived comfort, concentration and
participation during meetings (Casseldon) had better measured air quality and thermal comfort than the other two pre-move meeting rooms.

The anomalies between measured and perceived IEQ in the old rooms and the enthusiasm for aspects such as the outlook in the new rooms, show how important perceptions are in IEQ. But the superior performance of the new meeting rooms on all counts show that the best productivity response comes when both objective IEQ and perceived IEQ are aligned.

**Thermal comfort and CO₂**

The predicted percentage of occupants, which would be dissatisfied under the measured conditions, is calculated according to ISO 7730. This calculation integrates the environmental condition (air temperature, radiant temperature, humidity, velocity) a surveyed parameter for the occupants clothing (CLO) and an assumed activity (MET). These two figures chart the Predicted Percentage Dissatisfied (PPD) which will never be less than 5% (PPD) due to human nature. Therefore, it is generally considered that conditions within a 20% PPD are still acceptable.

Figure 4 indicates the comfort levels achieved for the occupied hours between 8:00a.m.-7:00p.m. In this case the Predicted Mean Vote is applied. Comfort ‘votes’ between -0.8 to +0.8 are within the 20% PPD range. The Spring St, and Albert Street meeting rooms are of some concern. The discomfort does not appear to be due to dry-bulb temperature alone (at Spring St.) and this requires further investigation into the data. Air velocity and mean radiant temperatures due to high ceilings and colder surfaces may offset the ‘vote’ towards this discomfort. These results appear to contradict user survey preferences to some degree and such also requires further investigation.

Figure 4. The cumulative density function (frequency) of comfort ‘Vote’.

The CO₂ levels ranking for each of the meeting rooms are provided in Table 1. Again, this analysis is performed for the occupied hours between 8:00a.m. – 7:00p.m. over the week.
Table 1. Percentage of CO₂ levels over 500 ppm.

<table>
<thead>
<tr>
<th>Meeting Room Location</th>
<th>Percent time that CO₂ &gt; 500 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casselden</td>
<td>3%</td>
</tr>
<tr>
<td>Albert</td>
<td>78%</td>
</tr>
<tr>
<td>Spring</td>
<td>27%</td>
</tr>
<tr>
<td>Port Phillip – 50 Lonsdale</td>
<td>24%</td>
</tr>
<tr>
<td>City Loop – 50 Lonsdale</td>
<td>20%</td>
</tr>
<tr>
<td>MCG – 50 Lonsdale</td>
<td>15%</td>
</tr>
</tbody>
</table>

**Air change rates**

The air change rate effectiveness is measured during mechanically ventilated (daytime) and non-ventilated (night-time) period. It is intended that this air change rate at nighttime is representative of the buildings infiltration rate, since the mechanical system is not in operation during this period.

Table 1 provides information on the air change rates within several areas of the former office spaces and meeting rooms. The important aspect is to notice the Air Change Rate differences (if any) for an ‘active’ HVAC (heating ventilating and air-conditioning) period as well as a ‘non-active’ (infiltration) night-time period with the system shut down. These single value results are an average over 20-30 sampling periods after dosing with a tracer.

Table 2. Air change rates of former offices and meeting rooms.

<table>
<thead>
<tr>
<th>Casselden Place</th>
<th>HVAC Operation ACH</th>
<th>Night-time ACH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Casselden Mtg. Rm</td>
<td>4.0</td>
<td>0.1</td>
</tr>
<tr>
<td>Open Office</td>
<td>2.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Meeting Room B</td>
<td>2.0</td>
<td>0.2</td>
</tr>
<tr>
<td>Spring Street</td>
<td>HVAC Operation ACH</td>
<td>Night-time ACH</td>
</tr>
<tr>
<td>Meeting Room</td>
<td>1.8</td>
<td>0.5</td>
</tr>
<tr>
<td>Open Office</td>
<td>0.85</td>
<td>0.4 - .09</td>
</tr>
<tr>
<td>Albert Street</td>
<td>HVAC Operation ACH</td>
<td>Night-time ACH</td>
</tr>
<tr>
<td>Albert St. Mtg. Rm. 1</td>
<td>1.0</td>
<td>0.25</td>
</tr>
<tr>
<td>Meeting Room 2</td>
<td>0.8</td>
<td>1.1</td>
</tr>
</tbody>
</table>

Air changes are a consequence of higher CO₂, increased temperatures and poorer air quality in these spaces. Finally, these air change rates all need to be evaluated in accordance with the CO₂ levels generated and sustained within each of the locations (see Table 2). It is noted that the CO₂ levels are the worst in the Albert St. location, with Spring St. significantly less and
Casselden as near perfect. When the CO₂ values are low and well within reason it can be assumed that the air change rates supplied during occupied (active) hours for the open offices are satisfactory.

Casselden Place appears to provide the highest result of air change rate effectiveness and it would seem to offer good air change rates when the HVAC system is in operation. However, the ACH rates can be misleading since the Casseldon meeting room is the smallest and would be expecting higher air change rates than the other two meeting rooms (Spring St. and Albert St).

The new offices also undertook air change rate measurements and are shown in Figure 5. A quick and simple analogy of these air change rate figures indicates that for the open office an ACH (air change / hour) rates are between 0.5 – 1.0 ACH on average. It is also noticed that these rates drop substantially during the night time period to about 0.25 ACH. The night time value could be considered as the infiltration rate. This rate is quite acceptable, however, it should be considered that external temperatures were temperate and that external wind speeds were at a relatively low level implying that greater infiltration rates may regularly occur.

It is noticed here that the MCG meeting room has a high ACH rate which is quite acceptable considering that there are more occupants per volume when meetings take place. What is more of a concern is that this ACH is quite constant throughout the night-time, indicating that there is an active operating system 24 hours a day.

![Figure 5. Continuous air change rate measurements at 50 Lonsdale offices.](image)
CONCLUSION
While the study found a positive link between staff productivity and the move to a new green-designed office, the results do not provide a predictive model for productivity gains from sustainable office accommodation. They do, however, contribute further to other recent similar findings that collectively make a compelling case for a business decision to occupy sustainable accommodation.

The anomalies between measured and perceived IEQ in the former meeting rooms and the enthusiasm for aspects such as the outlook in the new rooms, show how important perceptions are in IEQ. The superior performance of the new meeting rooms, on all accounts, show that the best productivity response comes when both objective IEQ and perceived IEQ are aligned. Finally, solutions to better mechanically controlled meeting rooms providing improved thermal comfort and reduced CO2 levels should to be considered. Several pathways to improving such are suggested here:

- a presence detection system with temperature, humidity and CO2 monitoring, controlling variable speed driven fans.
- A manually switched ventilation system which ensures 100% fresh air ventilation.
- A possibility of exhausting all open offices through the meeting rooms (or)
- The idea that all meeting rooms get 100% fresh supply air which is exhausted through the general office area. Note that the meeting rooms would be slightly more pressurized than the offices.

In providing better HVAC control it is concluded that the following objectives be seriously considered in meeting rooms:

- Eliminate all down draughts from the supply diffusers
- Reduce the background noise to appropriate levels
- Reduce the CO2 when occupied
- Provide optimized ISO 7730 comfort standard conditions

This pilot study has allowed us to provide several insights into future research in this area.

REFERENCES