Thermal, Visual and Energy Performance in LEED buildings: Two Case Studies

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ABSTRACT: The sustainability movement has influenced and changed the architecture practice and client’s expectations. After focusing on building aesthetics and code compliance for many years, the architecture practice has been educated to put more responsibility in the building performance by the recent sustainability movement. This responsibility shift affects how architects approach a design and how design excellence is perceived.

This paper focuses on the use of post occupancy evaluation (POE) in thermal, visual and energy performance in HMC’s Concours and Frontier projects, two LEED certified buildings. The evaluation of design intent versus real performance was analyzed by using measurement and statistical models. Both subjective and objective measurements were employed. To analyze energy performance, the actual energy usages were compared with initial energy simulation calculation.

Due to POE, problems were found with both buildings, but overall the buildings performed fairly well. Based on the findings, the corrective measures were taken to remedy the buildings and to enhance the building performance. In energy performance, the assessment showed that the energy model was capable of predicting the trending of the real usage although there were some number discrepancies.

Keywords: Thermal Comfort, Visual Performance, Daylight, POE, Energy

1. INTRODUCTION

The green building movement has grown into a major architectural discourse to create ideal cities in the mid-21st century. Unfortunately, the movement has been focused on implementing sustainability metrics such as LEED and green building codes. The implementation of the metrics and codes that form sustainable buildings and cities assist designers in determining their sustainability target during the design process, but there is a discrepancy between the target and the real performance of the buildings - especially in thermal, visual and energy performance. Therefore, Santos (2007) suggested that the post construction performance shall be included in the LEED rating system.

To determine the real performance, a post occupancy evaluation (POE) is the key. Preiser (2002) described the origin of POE which was started in the late 1960s. The latest step in the evaluation of POE is to emphasize a holistic and process oriented approach to evaluation. The following research was based on two LEED buildings, the Concours Office Building and the Frontier Project. In the two cases, thermal, visual and energy performance were studied along with the correlation between the sustainability target and the real performance of the buildings. The Concours Office Building is HMC Architects' Ontario, California office and it is LEED Silver certified under LEED version 2.1. The Frontier Project is LEED Platinum certified under LEED version 2.2. The buildings are only three miles apart.

POEs consisted of subjective and objective measurements. The subjective measurement was based on the occupant responses in thermal performance and visual performance; while the objective measurement was based on the data collection based on the measurements. In energy area, the real energy usage would be compared to the LEED energy simulation performance results.

Regarding the benefits of the POE, Preiser (2008) mentioned that the POE, a rigorous systematic assessment of past successes and
failures, can build knowledge, improve future designs, and demonstrate the contributions of the design professions to the community. Additionally, the Higher Education Funding Council for England (2006) defined 3 type benefits such as short term, medium term and long term benefits. The short term benefits include:

- identification of and finding solutions to problems in buildings;
- response to user needs;
- improve space utilisation based on feedback from use;
- understanding of implications on buildings of change whether it is budget cuts or working context; and
- informed decision making.

For medium term benefits, they consist of:

- built-in capacity for building adaptation to organizational change and growth;
- finding new uses for buildings; and
- accountability for building performance by designers.

Moreover, the longer term benefits are:

- long-term improvements in building performance;
- improvement in design quality;
- strategic review

For the research, the intents are to provide feedback to the building management for improving their building performance and to give invaluable information for the designers, especially at HMC Architects, for enhancing their design. Moreover, the study proposes solution for issues in those building, to enhance the performance and to increase occupant satisfaction.

2. Project Backgrounds and Methodology

The research studies two LEED certified buildings that are HMC Concours (See Figure 1: HMC Concours (photo: Ryan Beck)) and Frontier Project (See Figure 2: Frontier Project (Photo: Ryan Beck)). HMC Concours has received LEED Silver certification level under LEED version 2.1 and the project achieved 34 points. Frontier Project (See Figure 2: Frontier Project (Photo: Ryan Beck)) is a showcase building for energy efficiency and sustainable strategies. The second floor of the project is used for the office area for Cucamonga Valley Water District, the owner of the building. The Frontier Project received LEED Platinum certification level under LEED version 2.2 with 56 points.

Both projects achieved different level certifications, but for thermal performance and visual performance related credits, the projects have similar credits achievements. Additionally, during the certification process, the HMC Concours building substituted some its version 2.1 credits requirement with version 2.2 credits.

<table>
<thead>
<tr>
<th></th>
<th>HMC Concours</th>
<th>Frontier Project</th>
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<tbody>
<tr>
<td>I. Min. IAQ Perfor.</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td>II. Outdoor Air Delivery Monitoring</td>
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<td>✔️</td>
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<tr>
<td>III. Increased Ventilation</td>
<td>✔️</td>
<td>✔️</td>
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<tr>
<td>IV. Controllability of Systems: Thermal Comfort</td>
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<td>✔️</td>
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<td>V. Thermal Comfort: Design</td>
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<td>VI. Thermal Comfort: Verification</td>
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TABLE 1: THERMAL PERFORMANCE RELATED CREDITS

<table>
<thead>
<tr>
<th></th>
<th>HMC Concours</th>
<th>Frontier Project</th>
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<tr>
<td>I. Controllability of Systems: Lighting</td>
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<td>✔️</td>
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<tr>
<td>II. Daylighting and Views: Daylight 75% of Spaces</td>
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<td>✔️</td>
</tr>
<tr>
<td>III. Daylighting and Views: Views for 90% of Spaces</td>
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TABLE 2: VISUAL PERFORMANCE RELATED CREDITS

The Frontier Project achieved more the thermal performance credits than the HMC Concours building, but both buildings achieved the same visual performance credits. (see Table 1 and Table 2).

Figure 1: HMC Concours (photo: Ryan Beck)

In the optimize energy performance credit, the frontier project performed 45.8% better than Title 24 2005 and earned 10 points while the Concours performed 17.9% better than Title 24 2005 and earned 3 points based on the energy simulation calculation.
For the data collection sampling method, each building used a different sample type due to its number of occupants and its occupancy type. The HMC Concours Building used cluster sampling method based on sitting locations that represent the relationship between the building orientation and the proximity to the windows. There were 5 sitting areas that were investigated in the study. The data collection focused on the open space office area where most of the occupants were located in the building. For the Frontier Project, since the number of the occupants is relatively small, the survey forms were provided to all full time employees that are seven persons.

As a result, 41 survey responses from the HMC Concours and 6 survey responses from the Frontier Project were collected. The collected data were utilized to analyze thermal performance and visual performance. Because the HMC Concours had bigger sampling data and different cluster sitting areas, the more robust and detailed statistical method by using ANOVA would be employed.

3. Thermal Performance Data and Analysis

3.1. Thermal Performance Data – HMC Concours

Based on the survey, the thermal performance result was summarized in two major areas such as: occupant temperature perception (see Figure 3: Occupant Temperature Perception during Winter and Summer at HMC Concours) and occupant thermal comfort perception (see Figure 4: Thermal Comfort Perception at HMC Concours).

Based on the feedback, there was 24% dissatisfaction in the thermal comfort perception. This number was slightly higher than LEED and thermal comfort condition standard that requires no more than 20% dissatisfaction. The result aligned with the occupant temperature perception that described the temperature tended cooler during summer and winter.

To analyze the thermal impact perception, Anova method was utilized to see the perception in each cluster. The result (see Figure 5: Anova Analysis for the impact of thermal comfort) showed that the thermal impact perception to the staff performance was same because the F was lower than F critical.
Figure 5: Anova Analysis for the impact of thermal comfort at HMC Concours

<table>
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<th>V</th>
<th>F</th>
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<tr>
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ANOVA

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<th>MS</th>
<th>F</th>
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<td>4.03</td>
<td>2.213</td>
<td>0.132</td>
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<tr>
<td>Within Groups</td>
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<td>36</td>
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<tr>
<td>Total</td>
<td>88.09</td>
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<td>1.000</td>
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</table>

Figure 6: Temperature and Humidity data at HMC Concours

Figure 7: Occupant Temperature Perception during winter and summer at Frontier Project

Figure 8: Thermal Comfort Perception at Frontier Project

3.2 Thermal Performance Data – Frontier Project

In the two thermal major areas, the result of the survey at the Frontier Project demonstrated that the building performed slightly better than HMC Concours (Refer to Figure 7: Occupant Temperature Perception during winter and summer at Frontier Project and Figure 8: Thermal Comfort Perception at Frontier Project).

The better performance was illustrated in both above figures showing the thermal comfort for the staffs were good and conformed to the design intent. The dissatisfaction was less than 20% in this building. The occupant temperature perception also showed a comfortable range (all occupants responded in from 3 to 5 range value in the Figure 7: Occupant Temperature Perception during winter and summer at Frontier Project). Based on the interview with the facility manager, he said that he was very satisfied with the HVAC system for the office area located on the second floor of the building. The Frontier Project uses VRV system for that area.
Data loggers were also located at Frontier Project for a week to verify the performance of the systems. Interesting findings were found. The second floor where the staffs work on showed comfortable temperature and humidity range. However, the first floor supplied by the under floor system with evaporative cooling unit had slightly high temperature during noon time. The high temperature was expected during the design since the system relies on 100% OSA (outside air). However, the thermal condition would be sufficient to provide comfort to the visitors in the exhibition area.

3.3. Visual Performance Data – HMC Concours

To identify the visual performance and its relationship with the LEED points, the survey was conducted with focusing on electrical lighting performance and daylight performance. The result described that the building performed well in term of the visual performance. The less preferable and negative responses were less than 10% for this survey (see Figure 10: Visual Performance Survey at HMC Concours)

There were a few comments from occupants regarding the lighting performance. Some of them concerned about the direct sunlight during certain time. To address the issue, the automatic blinds were adjusted accordingly to eliminate the direct sunlight coming to the office area.

The measurements were also taken in the sampling cluster areas by using a light meter on March 20th at 12 noon. The results (see Figure 12: Illuminance level samplings on the first floor at HMC Concours and Figure 13: Illuminance level samplings on the second floor at HMC Concours) showed that the lighting levels were at least above 20 fc.

The design intent in the building was to keep the illuminance level in the lower side of the standard requirement because the occupants work primarily with computers and they could request task lightings on their desk. There was no complaint or comment regarding the electrical lighting from the occupants in this survey.
3.4. Visual Performance Data – Frontier Project

Similar to the HMC Concours, the survey collected the visual performance information at the Frontier Project. The result showed interesting information (see Figure 14: Visual Performance at Frontier Project). Most occupants felt satisfied with the daylight performance but they were dissatisfied with the electrical lighting. 50% of the respondents concerned about the electrical lighting performance in this building.

The follow-up interview revealed that the problem was in the photo sensor. Apparently, the furniture cubicle system that has high partitions did not reflect the original design intent that allowed the daylight to penetrate inside the room (See Figure 15: The Interior of the office area at Frontier Project). The measurement taken in the office area on March 21st at 12 noon also showed the similar issue. The daylight wasn’t distributed evenly. To resolve the issue, the corrective measure by adjusting the photo sensors were planned and conducted.

3.5. Energy Performance Data – HMC Concours

To study the energy performance data, the real usage was collected based on the energy bill. The data from the energy bill was compared to the energy simulation result that was submitted for the LEED certification.
The result showed that the electricity actual usage was 28% higher than the predicted number (see Figure 17: HMC’s predicted energy usage vs. actual usage). Based on the analysis, the discrepancy was occurred because of the longer office hours and the plug loads in the building. The problem in temperature consistency shall be conducted later to determine the direct correlation between the occupant thermal comfort issue and the energy usage.

Additionally, the natural gas actual usage showed higher usage than the predicted number due to the longer office hours, and the load of the equipments.

More detail assessment in this issue may be required to get more detailed explanations. However, the current information showed similar trending between the predicted usage and actual usage.

![Figure 17: HMC's predicted energy usage vs. actual usage](image)

3.6. Energy Performance Data – Frontier Project

For the Frontier Project, the real data was collected based on the touch screen kiosk that is available in the exhibition area.

Comparing to the HMC Concurs, the real usage at Frontier Project was very close to the predicted energy usage. The discrepancy between both data was only 0.1% in the electricity usage and 6% in PV production, while the natural gas real usage was 41% from the predicted one. (see: Figure 18: Frontier Project’s predicted energy usage vs. actual usage)

Per initial analysis, the heating portion in the first floor might be less than what we initially predicted in the energy model. The higher occupancy during the event and instantaneous heat gain may be the primary source. However, the further study shall be conducted to test the initial analysis/hypothesis.

![Figure 18: Frontier Project's predicted energy usage vs. actual usage](image)

5. CONCLUSION

Both projects were designed to achieve the thermal comfort. However, there were few problems found during the POE which showed that the thermal comfort had not been accomplished. The problems were related to more to the installation than to the design process.

In lighting performance, both projects achieved same points. Although most of the occupants in both projects were satisfied with the lighting performance, each project had different issues the lighting system. The HMC Concours had an
issue with the daylight while the Frontier Project had an issue with the electrical lighting.

The study in the energy area revealed that the predicted energy simulation could provide good trending information for the real energy usage, although there were discrepancy numbers. By comparing the energy usage, thermal performance and visual performance, there were a few initial relationships that can be analyzed further to reveal the issues.

The research was able to reveal and identify a few problems in the buildings. As a result, the corrective measures had been exercised to enhance the performance of the building. The implementation of the POE definitely has assisted the buildings performing better. Therefore, the POE shall be conducted in each building to enhance its performance and to give feedbacks to the designer on how his/her design works and impact the occupant satisfaction.

6. ACKNOWLEDGEMENTS.

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7. REFERENCES


