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A post-occupancy evaluation of a modular multi-residential development in Melbourne, Australia

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Abstract

Modular construction has been promoted to minimise the environmental impacts such as construction material use and waste, embodied energy and carbon emissions as well as construction time and cost reduction. Although the main focus has been on the construction technology, waste minimisation, energy and material efficiency and thermal performance of modular construction, limited attention has been paid to the building occupants. This paper aims to evaluate the resident lived experience of a modular multi-residential development in inner Melbourne. The case study building accommodates a total of 199 apartments and commercial spaces, and to date, it is the largest modular construction building in Victoria. A post-occupancy evaluation (POE) was conducted using the Building Use Survey (BUS) methodology. Overall building design, thermal comfort, noise, lighting and personal control over the indoor environment were evaluated on a seven-point Semantic differential scale. Although the building occupant survey showed a high level of satisfaction with overall building design and performance, two main issues, ‘thermal discomfort in summer’ and ‘noise from outside’ were identified. Overheating in summer is not clearly understood in this study, however, it could be interpreted that passive design strategies such as cross ventilation and landscaped shared open space increased noise. A further research on the effects of building design on occupants such as engineered light-weight concrete floor, prefabricated building façade, cross-ventilation, operable openings and the cooling systems of the individual apartments is necessary to resolve the issues and to examine whether the poor thermal performance in summer could be related to modular construction. This case study building was developed as a commercially replicable pilot, providing affordable and sustainable high-density housing in Melbourne’s inner suburbs. Thus, it is expected that this POE study could provide an insight into the interaction between the building and its occupants, particularly in the context of modular construction, and further contribute to developing high-performance modular multi-residential buildings.

Peer-review under responsibility of the organizing committee iHBE 2016.

Keywords: post-occupancy evaluation (POE); passive design; modular; multi-residential; building occupants

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1. Introduction

Modular construction is becoming a popular method of construction in Australia due to energy and material efficiency as well as construction time and cost reduction. It consequently reduces negative environmental impacts and greenhouse gas emissions. The main focus of previous research has been on the construction technology, waste minimisation, energy and material efficiency and thermal performance of modular construction based on simulation and experiment [1,2,3,4], however, there seems to be a tendency to overlook the actual performance of the buildings-in-use such as a particular focus on the building occupants of modular construction, due to the difficulties in observing and measuring related data [5].

The project building in this paper is an affordable and sustainable high-density, mixed use development in inner Melbourne. Melbourne is one of the fastest growing cities in Australia, with a prediction that the population will increase from 4 million to 7.7 million by 2051. It is interpreted that the projected population growth requires double the amount of existing residential dwelling by the time [6]. Thus, high-density development in the existing land within inner Melbourne suburbs has been promoted to protect the urban fringe from development as well as to utilize current existing infrastructure. The project building was developed as a commercially replicable pilot, accommodating a total of 199 apartments and commercial spaces. To date, as the largest modular construction building in Melbourne, the individual apartments of the project building were manufactured offsite, delivered to site and stacked and bolted together to form the project building. This method of construction can reduce construction time and environmental impact such as local disruption, construction material use and waste, embodied energy and carbon emissions [7,8].

This paper aims to evaluate the resident lived experience of a modular multi-residential development in inner Melbourne, using a standardized occupant survey, the Building Use Survey (BUS) methodology. A post-occupancy evaluation (POE) was conducted to examine overall building design, thermal comfort, noise, lighting and personal control over the indoor environment.

2. The project

2.1. Climate and building thermal performance

The project building is located in a suburb in Melbourne, Victoria and its local climate is classified as a mild temperate (climate zone 6) in the eight National Construction Code (NCC) climate zones in Australia (Fig. 1). The local climate data have been plotted in Fig. 2, the 38-year statistics (1979-2016) show an average 1 ºC lower than the temperatures in 2014 when this research was conducted. In particular, the summer months from January to March in 2014 show an average 2.75 ºC higher maximum temperature than the same months in the 38-year statistics.

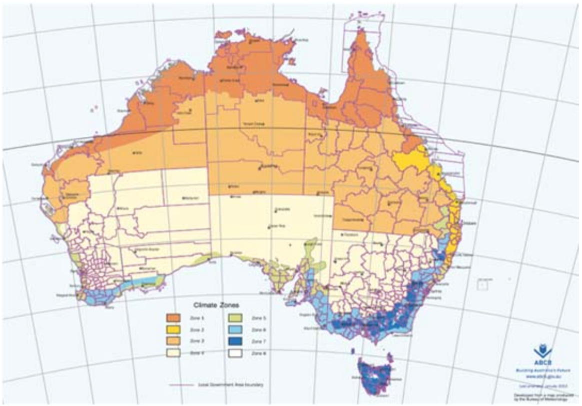
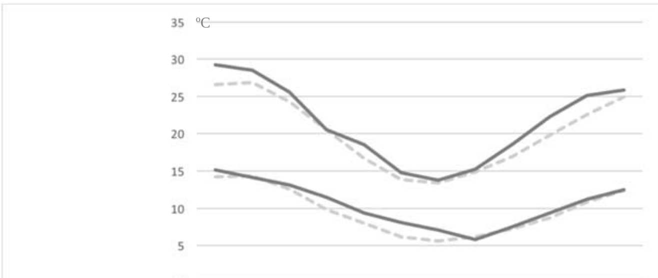


Fig. 1. Australia climate zones
source: Australian Building Codes Board (ABCB)



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max Temp 1979-2016	26.6	26.9	24.3	20.5	16.7	13.9	13.4	14.9	17	19.8	22.6	24.9
Min Temp 1979-2016	14.2	14.3	12.6	9.8	8	6.2	5.6	6.2	7.3	8.7	10.8	12.4
Max Temp 2014	29.2	28.5	25.6	20.5	18.5	14.8	13.8	15.2	18.6	22.3	25.1	25.9
Min Temp 2014	15.1	14.1	13.1	11.5	9.4	8.1	7.1	5.8	7.5	9.4	11.2	12.5

Fig. 2. Local climate - monthly mean max and min temperature
data source: Bureau of Meteorology

In Australia, under the NCC, the energy efficiency of buildings is regulated so as to use energy more efficiently and reduce greenhouse gas emissions. The compliance requirements can be achieved by either using software rating tools (e.g. AccuRate Sustainability, FirstRate 5 and BERS Pro Plus) based on NatHERS (Nationwide House Energy Rating Scheme) or alternatively complying with all the relevant NCC Deemed-to-satisfy provisions, where minimum allowable elemental R-values are prescribed. A sample of 18 dwellings were selected from the project building and assessed by using the FirstRate software, and the average of 6.17 stars was achieved based on the NatHERS 0 (worst) to 10 (best) scales [9]. The 6 star rating is the current building energy efficiency compliance, meaning that the annual energy consumption for space heating and cooling is 114 MJ/m^2 in inner Melbourne [10]. It is understood that the project building achieved a higher building thermal performance than the compliance requirements when the project building was designed.

2.2. Sustainable design strategies

The project building (Fig. 3) is not only a modular construction but also has a number of sustainable design features [7,8,9]. A landscaped shared open space (courtyard) on the second floor gives natural ventilation and shading and also potentially increases social sustainability providing the residents with social catch ups (Fig. 4). Skylight windows and void to maximise daylight and winter sun, which give a reasonable amount of light into the building cores and corridors with the support of artificial lighting. Openings towards the building core to increase cross ventilation help the residents control their environment. A central gas boosted solar hot water system and water recycling treatment plant are installed in the project building.

Fig. 3. The project building

Fig. 4. Courtyard *image source: Design Inc*

3. Research Method

A post-occupant survey was conducted in 2014, by using the Building User Satisfaction (BUS) survey, 'Housing Evaluation.' The questions of the Housing Evaluation include background, the residence overall, indoor conditions and personal control, lifestyle and utilities cost. The questions are mainly measured on a seven-point Semantic differential using two adjectives with a neutral point (e.g. '1=too cold and 7= too hot'). The background section includes demographic information (e.g. age and gender) and residence information (e.g. the number of residents, the type of tenure). The residence overall section includes location, space, layout, storage and appearance, and additionally asks, 'how well the facilities provided (e.g. kitchen, bathroom, living room, garage, etc) meet your need?'. The indoor conditions section includes thermal comfort, noise, lighting and personal control over the indoor environment. A comment section is also provided after each question for further feedback. For the occupant survey the RMIT human research ethics approval was granted (Project number: CHEAN A&B 0000015822-11/13) with a low risk.

The format of the survey is a three-page hard copy and the survey was distributed to all 199 apartments in the project building via the post boxes in the foyers. To encourage the residents to participate in the survey, an incentive of the chance to receive a $100 gift voucher was offered. However, a total of 28 households were responded, representing a 14 percent response rate.

4. Results/Discussion

This section presents the analysis results of the occupant survey followed by discussion. Both quantitative and qualitative data were involved in the analysis.

4.1. General characteristics of the respondents

A majority of the respondents were aged 30 years or over (80.8%) and female (73.1%). They have lived in the apartment for a year or over (84.6%) with an average of 1.85 years and stated that they normally stayed at home in the evening and on the weekend only (73.1%). 69.2% of the respondents lived in a rented apartment and the rest were owner-occupied (30.8 %). Although a majority of the respondents (69.2%) reported their life had been changed after moving into the apartment such as good location of the residence, easy access to public transport, shorter journey to work and close to shops and restaurants, others reported no change (23.1%). The residents were also asked about their utility costs and they demonstrated that they spent lower utility costs for heating (3.13), electricity (3.26) and water (2.83) compared with the previous accommodation. It is noted that the questions were measured using a seven-point Likert-type scale from 1 'much lower' to 7 'much higher' with no consideration of the residents' previous dwelling type, size and location.

4.2. Occupant survey

The overall building design was evaluated by the respondents over seven variables measured using a seven-point Semantic differential scale. Fig. 5 demonstrates the mean scores of the residence overall. The respondents were satisfied with their residence location (5.96), appearance from outside (5.96), layout (5.42) and overall residence design (5.15). They also reported the facilities of the residence met their need well. However, the space (4.92) and storage (4.81) of the residence seem less enough than the respondents' expectation. The small internal floor areas of the individual apartments could cause the lack of space, and the separate storage areas from the individual apartments could not provide the full convenience despite the storage provided in common areas. Although the internal floor areas of the apartments vary from 28 to 60 m^2, more than half of the apartments belong to the smallest type, 'Studio or 1bed + 1bath'. The residents also commented, 'very good for single person' but 'not enough for two adults and a child'.

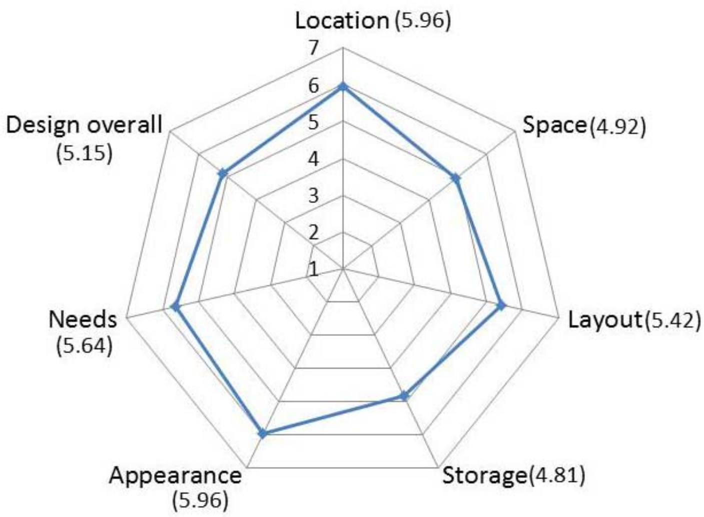


Fig. 5. Mean scores of the residence overall

The indoor conditions of the individual apartments were evaluated by the respondents over four criteria: thermal comfort, noise, lighting and personal control over the indoor environment. Thermal comfort was evaluated over eight variables using a seven-point Semantic differential scale with a 'neutral' point of 4 which can be acceptable and comfortable for the respondents. Fig. 6 presents the mean scores of thermal comfort in winter (in blue) and summer (in red). Although the respondents expressed overall satisfaction with their overall conditions in winter (5.77), they expressed dissatisfaction with their overall conditions in summer (2.79). Also, they were thermally comfortable (6.04) in winter, but seemed uncomfortable (2.25) in summer. Thermal discomfort in summer was identified, reporting overheating (1.58), dry (3.26) and stuffy (5.05) conditions. This result could be interpreted in a number of ways: firstly, the overheated condition in summer simply arose due to the higher local temperature in 2014 when the survey was conducted as explained in Figure 2, in the section 2.1. Secondly, this could be linked to building design, in particular, passive design strategies such as cross-ventilation and operable openings integrated into this project building and the cooling systems of the individual apartments. Lastly, it could be related to building materials and construction type as the project building is a modular construction with engineered light-weight concrete floor and prefabricated building façade.

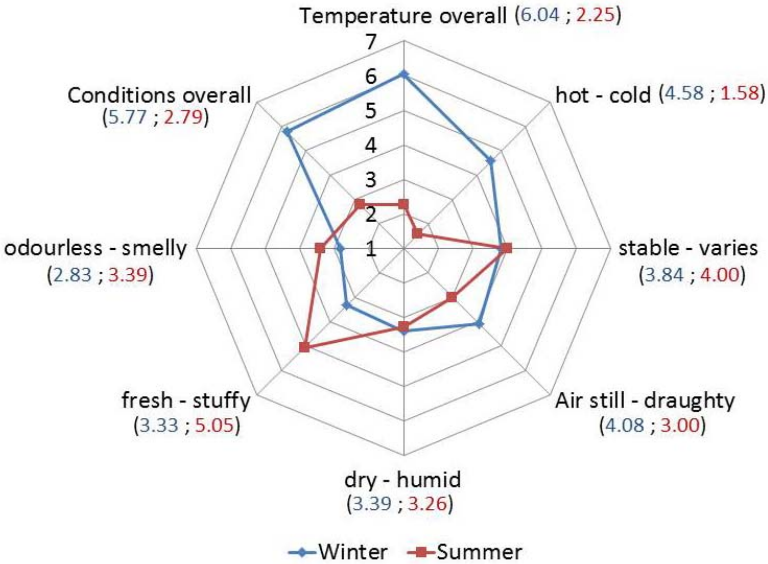


Fig. 6. Mean scores of thermal comfort – winter and summer

The noise and lighting of the individual apartments were evaluated by the occupants over seven variables (Fig. 7). Overall, the respondents were satisfied with noise (4.31) and lighting (5.54). Although they were less likely to report noise from people between rooms (3.52) and from neighbors (3.38), they were more likely to report noise from outside (5.08). Also, most of the respondents commented a higher level of 'traffic noise', but 'noise between apartments is acceptable'. The respondents also expressed an acceptable level of both natural (4.46) and artificial (4.38) light. Although it is obvious that all the individual apartments cannot have the same performance, in general the respondents reported that lights were bright in the lounge and master bedroom but too dim in the kitchen and bathroom.

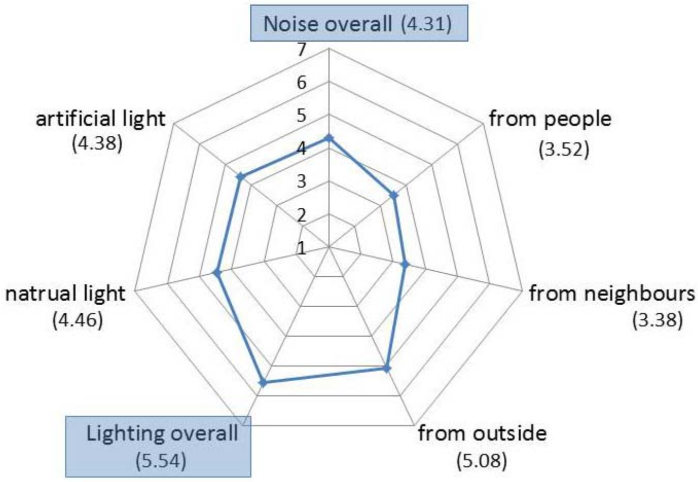


Fig. 7. Mean scores of noise and lighting

Personal control over the indoor environment including heating, cooling, ventilation, lighting and noise was evaluated by the occupants over five variables (Fig. 8). The respondent perceived a high level of control over heating (6.42) and lighting (5.81) and a medium level of control over ventilation (4.65) and cooling (3.77). However, they expressed that they had a low level of noise control (2.88). This results seem to be consistent with the project building design and facilities provision. A gas heater installed in the apartment enables them to maintain thermal comfort in winter and lighting switches give them flexibility depending on their occupancy and behavior. Operable windows and door (ventilation hatch) give some control over ventilation and an electric ceiling fan does over cooling. Noise, particularly from outside such as traffic, nearby factory and communal garden, seems less controllable.

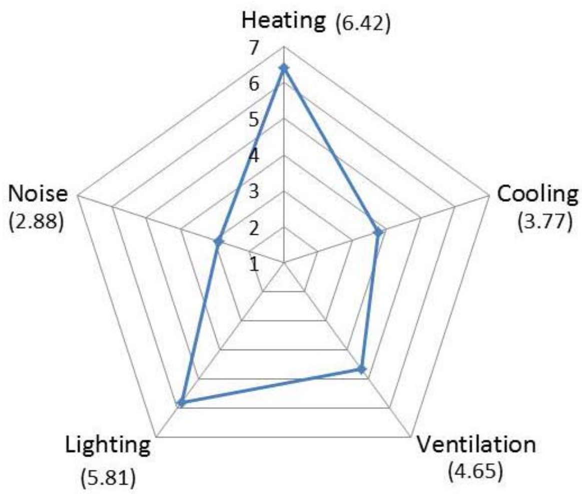


Fig. 8. Mean scores of personal control

5. Conclusion

This paper evaluates the resident lived experience of a modular multi-residential development in inner Melbourne. A post-occupancy evaluation (POE) was conducted to examine overall building design, thermal comfort, noise, lighting and personal control over the indoor environment. Overall, the respondents were satisfied with the residence including location, layout, appearance and overall design. They however reported insufficient space, both the residence and storage. Although the respondents expressed thermal comfort and satisfaction with their overall conditions in winter, they expressed thermal discomfort and dissatisfaction with their overall conditions in summer. There seem no specific issues identified in noise and lighting, indicating a high level of occupant satisfaction. The degree of control over the indoor environment seems to increase according to building design and services provision. Two main issues, thermal discomfort such as overheating, dry and stuffy condition in summer and noise from outside such as traffic, were identified in the occupant survey. A further research on the effects of building design on occupants such as engineered light-weight concrete floor, prefabricated building façade, cross-ventilation, operable openings and the cooling systems of the individual apartments is necessary to resolve the issues, and further to contribute to developing high-performance modular multi-residential buildings.

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