Towards an assessment framework for the environmental performance of alternative, multi-residential housing models

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Abstract: Reducing the environmental impacts of building whilst improving urban liveability has become a key challenge for the Australian multi-residential sector, as recent projects have been criticised for their poor environmental performance and internal amenity. Alternative models for multi-residential development – such as the Nightingale Model – are a recent response to this challenge. Employing an ‘architecture of reductionism’, the Nightingale Model seeks to deliver superior environmental and occupant outcomes. However, given the infancy of the model, an assessment of its performance is yet to be conducted. Assessments of building performance are critical to developing new and emerging approaches, yet existing evaluation methodologies are plagued by limitations. The most notable limitation is the lack of holistic frameworks that concurrently consider life-cycle ecological impacts and occupant wellbeing. The absence of such frameworks limits the ability to identify interrelationships between areas of performance and may possibly promote problem shifting. To develop an approach that can address this key limitation – and subsequently assess innovative housing models targeting a holistic approach to building performance – the paper concludes with a series of recommendations for approaching the creation of an integrated framework of assessment, which will quantify impacts to ecological and human systems in parallel.

Keywords: Performance assessment; multi-residential; alternative housing models; Nightingale.

1. INTRODUCTION

The built environment and its allied processes substantially impact ecological systems due to their intensive resource use at various life cycle stages (International Energy Agency, 2013; Lucon et al., 2014). Compounding this issue are concerns regarding the liveability of urban environments, and the effect of buildings on occupant wellbeing. With a growing global population, there are legitimate concerns that without immediate action these issues will grow exponentially, leaving intergenerational damage. Therefore, improving the performance of buildings – both in relation to ecological impacts and occupant wellbeing – has become a key challenge for society.

This challenge is particularly relevant to Australia’s growing multi-residential sector, which has recently been criticised for demonstrating poor environmental performance and internal amenity in built outcomes (City of Melbourne, 2013; Jensen et al., 2017). Although compulsory regulations and standards play some part in addressing these concerns, the market has also responded with new approaches, such as alternative models of housing development. The Nightingale Model (TNM) is one example of an alternative housing approach that has emerged from this context. A key tenet of TNM is its triple bottom line approach to sustainability, and a design approach utilising an ‘architecture of reductionism’ (Breathe Architecture, 2015). Nightingale projects eschew the excess Australian dwellings have become accustomed to – by rationalising apartment functions, employing a dematerialised aesthetic, and removing active cooling systems. However, given the infancy of TNM, no assessment of its performance or verification of its aims has been conducted, nor is there a significant body of research quantifying the impacts of employing dematerialisation as a design approach.

Assessments of building performance – particularly post-occupancy – are an important component of developing and improving current practice, as they provide the evidence required for stakeholders to form a robust understanding of the real-world implications of decision making (Palmer, 2009). This feedback can be used to improve upon new and emerging approaches, encourage innovation, and validate claims of superior building performance. As design approaches – such as dematerialisation as employed in TNM – may affect multiple areas of building performance concurrently, an evaluation mechanism that can accommodate this complexity is required. Designers need to be able to understand the consequences
of their decision making, to achieve a balanced approach that does not negatively impact on either occupants or the environment. To provide that understanding and enable further sophistication of the multi-residential building sector, an evaluation method that can identify performance gaps, trade-offs and interrelationships between the areas of building performance relating to human and ecological systems is required.

Following a short description of TNM and the context from which it emerged, this study critically examines existing building assessment practice. The objective of the study is to highlight limitations of existing methodologies that need to be overcome to establish a new approach for assessing the effects of multi-residential building design on both occupant wellbeing and ecological systems. The study concludes with a series of considerations for developing a new assessment methodology. The outcome of this study will inform an ongoing doctoral research project looking at the performance of multi-residential housing in the Australian context.

2. MULTI-RESIDENTIAL HOUSING IN AUSTRALIA AND THE NIGHTINGALE MODEL

Australian patterns of urbanisation have traditionally been characterised by low-density urban sprawl around employment centres (McGee et al., 2017). As social changes have occurred and negative stigma attached to high rise living has dissipated, there has been a marked shift towards higher density forms of living, including apartments (Han et al., 2017) a spatial mismatch in the demand and supply of higher density housing will arise if planning for resource allocations continues to be based on urban density targets without a complete understanding of the dynamics of housing mobility patterns. Therefore through the application of a unique 3-fold longitudinal study this paper examines the housing mobility patterns over time by measuring changes in housing characteristics of housing tenure, dwelling type and location using the Household, Income and Labour Dynamics in Australia (HILDA). Boosted by foreign investment in Australian property, new apartment construction has rapidly accelerated over the past decade, with the annual number of completions having tripled since 2009 (Rosewall and Shoory, 2017). But as the quantity of apartments has increased, overall quality issues have emerged. Insufficient daylighting, inadequate natural ventilation, suboptimal orientation, thermal inefficiency, high embodied energy, poor construction quality, and poor internal layout are some of the problems highlighted by recent research (Urban Design Advisory Committee NSW, 2000; City of Melbourne, 2013; Jensen et al., 2017). In response, revised regulations and standards – such as the Better Apartment Design Standards in Victoria and State Environmental Planning Policy No. 65 (SEPP65) in New South Wales – have been introduced. The market has also responded in the form of alternative models of multi-residential development. One example is TNM, which was created in 2014 by Breathe Architecture following the completion of their project ‘The Commons’ in 2013.

TNM uses a triple bottom line approach, focusing on improving the ecological, social and financial sustainability of multi-residential projects. For buildings licensed under TNM, there is a set of criteria that must be addressed, including active and passive design measures. As a summary, TNM pursues an “architecture of reductionism” (Breathe Architecture, 2015), targeting simplicity and savings in function, materiality and impacts. This dematerialised approach to design intends to mitigate the development’s ecological footprint, by eliminating typical aspects of multi-residential buildings as shown in Figure 1.

![Figure 1: a summary of strategies that form part of the “architecture of reductionism” / dematerialised approach used in The Nightingale Model.](image)

It is assumed that such strategies intuitively deliver savings in embodied energy, however these have not yet been quantified. Nor have the associated impacts – positive or negative – on operational energy, ecological systems, or occupant comfort. For example, as yet there is no information on whether the absence of mechanical cooling leaves the buildings unacceptably hot in peak summer conditions. Nor has there been an evaluation as to whether improvements to the thermal envelope results in higher embodied energy. To improve future iterations of TNM, its dematerialised design approach and the broader multi-residential typology, comprehensive assessment of its as-built performance is required.

3. ASSESSMENT OF BUILDING PERFORMANCE

First emerging in the 1960/70s, building performance assessment has since developed into a unique field of research and practice. Assessments aim to provide information to stakeholders involved in building procurement on how various processes, practices and products of the built environment perform, and how they impact on aspects of the environment
and society (Cole, 2005; Palmer, 2009). Feedback from an assessment can be integrated into each stage of a building project, with rational decision-making underpinning the way that information is analysed and interpreted. Theoretically, this feedback is used to better inform design decision-making at various stages of the building procurement process, and iteratively improve built outcomes. Traditionally, assessments have been performed on a case-by-case basis using assessment methodologies that have been adapted to accommodate regional differences in building (Ding, 2008). However, as assessments are typically time and resource intensive, researchers are proposing the development of typology specific databases of performance information to help this area of research better infiltrate practice (Preiser and Schramm, 2005).

A variety of assessment methods exist, including but not limited to: life-cycle assessments (LCA), building performance evaluations, post-occupancy assessments, multi-criteria assessment frameworks, and sustainability rating tools. While each have their own nuances, they are all examining the critically important relationship between a building and aspects of its context, whether that be financial, social or ecological. Motivations for undertaking an assessment vary, depending on the context, client and aim of the assessor (Figure 2).

![Figure 2: Motivations for evaluation. (Source: Preiser and Vischer, 2005; Mallory-Hill et al., 2012)](image)

4. KEY LIMITATIONS IN EXISTING ASSESSMENTS OF BUILDING PERFORMANCE

When examining building assessment frameworks, tools and methodologies, it is apparent that this field of research has matured rapidly to provide a range of offerings to practitioners. Building performance assessment is continually evolving to overcome limitations in existing methods and accommodate new developments within the building and construction sector (Bragança et al., 2010). However, it is evident that key limitations remain within existing practice. The following section highlights key limitations of existing building assessment practice that would need to be addressed when developing a novel evaluation method that considers both occupant wellbeing and ecological impacts.

4.1 Siloing of performance areas and life-cycle stages

Existing assessment methodologies tend to use a “siloed” approach, isolating evaluation to specific life-cycle stages, building systems or environmental impacts (Ding, 2005, 2008; Conte and Monno, 2012). Mono-dimensional evaluations ignore the inherent complexity of building design, construction, and occupation, and fail to account for interrelationships or trade-offs between impact categories. At a high level, separate assessment methodologies for occupant wellbeing and ecological impacts are arguably the most notable example of the division within existing frameworks. To ensure that buildings remain fit-for-purpose, measures to improve ecological performance must be considered in parallel to impacts to occupants, as there are many aspects of building design and construction that impact both occupant wellbeing and ecological systems concurrently. For example, the use of dematerialisation as a design approach might reduce the embodied energy of a building, but also simultaneously affect indoor environment quality (IEQ). Alternatively, a highly insulated building envelope may promote superior thermal comfort but require higher embodied energy. Despite researchers noting that synergies between performance criteria exist (Reijnders and Van Roekel, 1999; Cole, 2005), few existing frameworks examine multiple areas of performance in an integrated, robust fashion.

From a life-cycle perspective, several assessment methodologies concentrate on operational impacts alone. This is despite research demonstrating that a full life-cycle approach is widely considered as one of the most comprehensive methods for assessing impacts on the environment or a building’s environmental sustainability (Crawford, 2007; Diakaki and Kolokotsa, 2009; Brejnrod et al., 2017). A bias towards the operational phase of a building’s life-cycle is particularly evident in industry-driven assessments, such as voluntary sustainability rating tools. By limiting focus to a single life-cycle stage, designers risk shifting problems to other phases or areas of performance unwittingly. Furthermore, when full LCAs are undertaken, there remain areas of building performance that are not examined. In their analysis of LCA-based environmental assessment instruments, Reijnders and Van Roekel (1999) though there are some exceptions in Denmark, the United Kingdom and the Netherlands. Guidance type instruments tend to be more comprehensive. Scoring instruments are relatively comprehensive but also rather superficial and ad hoc. They require a more solid basis. Instruments based on life cycle analysis (LCA noted that LCA-based methodologies do not consider the full range of relationships that exist between buildings and their environment. From their research, they found that the most notable exclusion was factors relating to the indoor environment. Such factors may be significantly affected by decisions made to reduce life cycle impacts in isolation,
however no single framework exists to thoroughly assess life-cycle ecological impacts in conjunction with impacts on occupant comfort. Therefore, despite being one of the most comprehensive evaluation methods for examining the building and environment relationship, LCAs still suffer from a siloed perspective of building performance.

### 4.2 Underrepresentation of the multi-residential sector

Despite a range of legitimate reasons for assessing a building’s performance, practical applications of evaluations remain sporadic (Cohen et al., 2001). Notably, research within this domain typically focuses on non-domestic typologies, such as offices, institutional and education buildings (Leaman et al., 2010). Despite the increasing importance of the multi-residential sector, there is a lack of information on the performance of multi-residential buildings, and few methodologies appropriate for assessing this typology, particularly post-occupancy (Teasdale-St-Hilaire, 2013). From a practical perspective, home environments present unique challenges for researchers, the most significant of which is gaining access to dwellings (Leaman et al., 2010). Other practical challenges include: complex stakeholder relationships in building governance and procurement, residents’ desire for privacy, time intensity of accommodating one-on-one interaction with individual occupants, and the need for unobtrusive methods of evaluation. Furthermore, researchers must also respect the more intangible aspects of assessing residential environments. The home is symbolically and psychologically important to individuals (Graham et al., 2015). Time, and resources to selecting, modifying, and decorating their living spaces, and they may be devastated when their homes must be sold or are destroyed. Yet the empirical psychological literature says virtually nothing about the roles that homes might play in people’s lives. We argue that homes provide an informative context for a wide variety of studies examining how social, developmental, cognitive, and other psychological processes play out in a consequential real-world setting. The topic of homes is also well suited to collaborations with a diverse array of disciplines ranging from architecture and engineering to sociology and law. We illustrate the potential insights to be gained from studying homes with an exploratory study that maps the psychological ambiances (e.g., romance, comfort, togetherness, and it is not uncommon for individuals to invest significant amounts of money, time and thought into the selection, maintenance, and improvement of their homes. Therefore, the activity of entering this private space to objectively ascertain its benefits and disadvantages may not be an attractive proposition to an owner or occupant. Considering the comparative ease of assessing other environments, it is understandable that evaluation of multi-residential environments is under-represented in existing research. Nevertheless, multi-residential projects should not be excused from assessment, as understanding impacts to both occupant wellbeing and ecological systems is essential to improving outcomes in this underperforming typology.

### 4.3 Assessing as-designed, rather than as-built

Selected methods, such as sustainability rating tools or frameworks for testing regulatory compliance, tend to base evaluations on simulations or as-designed specifications rather than post-occupancy data. Simulations are often regarded as being highly beneficial to informing designers of the consequences of their decisions prior to their implementation (Clarke, 2007). Simulations also help to inform designers of the advantages and disadvantages of certain materials, approaches or strategies during the stage of building procurement where their role is most influential: the design phase. However, despite these benefits, complete assessments of a building’s performance should not rely on as-designed specifications. Evaluations based solely on simulations may ignore real-world impacts on building performance, such as external conditions, unforeseen changes during construction, and occupant behaviours. Researchers have demonstrated that a performance gap exists between simulated assessments based on as-designed specifications and true post-occupancy performance (Menezes et al., 2012; de Wilde, 2018) the construction industry is faced with the challenge to ensure that the energy performance predicted during the design stage is achieved once a building is in use. There is, however, significant evidence to suggest that buildings are not performing as well as expected and initiatives such as PROBE and CarbonBuzz aim to illustrate the extent of this so called ‘performance gap’. This paper discusses the underlying causes of discrepancies between energy modelling predictions and in-use performance of occupied buildings (after the twelve month liability period. Therefore, evaluation needs to be framed within the building’s operational context, to ensure that the impact of users and occupants is not neglected (Cole, 2005). Although time, funding and access can impede post-occupancy evaluation, it is a more robust method for determining whether a building has met the needs of its client, occupants, neighbourhood and environment (Palmer, 2009).

### 4.4 Relative vs. absolute assessments

Communication of results from evaluations is a core component of building performance assessment frameworks and tools. A building performance assessment should aim to report results that are universally understandable, transparent, and accessible to the varying levels of technical proficiency held by different stakeholders. Currently, there is a strong emphasis on relative assessments. Relative assessments will typically report results relative to an average benchmark, often as a rate of improvement. Relative assessments and reporting can provide some useful context to a result that may otherwise be too abstract for the wider public to understand. Conversely, relative assessments alone may conceal specific or measurable impacts on the environment, hide differences in cultural expectations, and make it difficult to calculate global footprints or carrying capacities (Cooper, 1999). In contrast, reporting of absolute material and energy flows is more directly measurable by others, and can help to gauge progress towards proposed outcomes or facilitate international comparison. However, relative and absolute assessments are not mutually exclusive – both can be successfully used in combination with one another (Downton, 2011).
4.5 Reinforcing current best practice

Some evaluation methodologies use a list of pre-determined criteria that a project must attain to be awarded credits or points. Alternatively, tools that use relative assessments may compare a building’s performance to existing best practice on a closed scale of assessment. However, when a tool has no facility to award credits for projects that extend beyond the tool’s own perspective of best practice, there is little incentive for designers to innovate. As such, rather than encouraging the optimisation of performance to satisfy the needs of the multiple stakeholders impacted by development, these assessment methods simply reinforce current best practice and encourage point-scoring (Ding, 2008). Although this criticism is primarily levelled at sustainability rating tools, it is also applicable to any assessment method that communicates performance based on a closed scale. In developing assessment frameworks, it is essential that performance beyond the anticipated upper ceiling of the tool is accommodated to encourage innovation. Creating an ‘open’ rather than ‘closed’ scale of measurement (Cole, 1999) also helps to assess projects – such as TNM – that may not suit the rigid, formulaic nature of some building assessment frameworks. Furthermore, implementing an ‘open’ scale of assessment allows the methodology to transform at pace with the development of sustainable building practices.

5. DEVELOPING A NEW FRAMEWORK FOR THE EVALUATION OF MULTI-RESIDENTIAL BUILDINGS

As previously identified, the key challenge facing professionals in the built environment sector is the need to reduce ecological impacts, whilst simultaneously improving the liveability of constructed spaces. To tackle this challenge, industry requires a comprehensive understanding of the performance of existing conventional and innovative building practices. Critically evaluating existing buildings can provide this understanding, by identifying performance gaps, trade-offs and interactions. However, as the previous section has detailed, existing evaluation methodologies suffer from several key limitations. Most notably, these limitations demonstrate that currently no single assessment framework can provide information on the interactions between ecological impacts and occupant wellbeing in a robust and detailed way.

As environmental problems, building systems, and occupant expectations increase in complexity, more multi-dimensional and comprehensive approaches to understanding our built environment are required (Ding, 2008). Decision makers need to be able to address the functional aims of a project whilst not impeding on the quality of internal or external environments. This is particularly important to the Australian multi-residential sector, which is currently under scrutiny for demonstrating poor outcomes across an array of performance metrics. When reflecting on the specific example of TNM, the need for a multi-dimensional assessment methodology could not be more pertinent. The dematerialisation approach employed in TNM is motivated by a desire to reduce the embodied and operational resource consumption (e.g. energy, water, etc) of the building, yet there is no understanding of what consequences these decisions have on occupant wellbeing and comfort. With the current siloed nature of assessment tools, there is no immediately apparent mechanism that can help elucidate what relationships may exist between distinct areas of building performance affected by this approach. In order to better inform future practice, an assessment framework for TNM – and more generally multi-residential buildings – needs to adopt a holistic, full life-cycle perspective to building performance. Equally, occupant wellbeing should not be divorced from assessments of ecological impacts, with the two evaluated in an integrated way. An integrated assessment framework that looks at multiple criteria concurrently would provide the most holistic representation of a building’s performance, and would aid stakeholders in optimising built outcomes for both indoor and external environments. This is particularly relevant to future assessments of TNM, as it aims to be a catalyst in transforming the environmental performance of multi-residential development (Nightingale Housing, 2018).

Therefore, it is proposed that a new method of assessment, which addresses impacts to occupant wellbeing and ecological systems in a single, integrated framework, is developed. From the analysis above, a series of approaches that will guide the development of this framework emerge:

- **A toolkit approach:** to overcome the individual limitations of the various assessment methodologies, it is proposed that a ‘toolkit approach’ (Cooper, 1999) is adopted. A ‘toolkit approach’ coordinates a range of methodologies to assess targeted performance parameters either sequentially or in parallel. Individual methodologies – such as life cycle assessments, indoor air quality evaluations, and so on – have gone through years of application, testing, debate and refinement. Although they present limitations individually, combined they can present a comprehensive view of building performance. The resulting multi-criteria assessment approach will permit assessors to select methodologies appropriate to the aim of the evaluation – for example, LCA for evaluating ecological impacts or IEQ assessment for evaluating occupant comfort. Careful attention to the combination of several methodologies is required when developing this approach, as differences in time-scale, functional unit and system boundaries will need to be resolved prior to assessment. It is also anticipated that the greatest challenge for an assessor using this ‘toolkit approach’ lies in the analysis, interpretation and reporting of results. In this respect, the composer of the assessment framework needs to ensure that interpretation isn’t conducted in a piecemeal fashion so that results clearly convey a united message and underlying interrelationships are revealed;
• **Integrated result reporting:** innovation in building performance assessment lies in the interpretation and communication of results (Leaman et al., 2010). In addition to reporting absolute results, description of results relative to globally relevant benchmarks gives context to the building’s performance beyond local boundaries. Results from a multi-criteria assessment, particularly those using multiple methodologies concurrently, can be integrated during final interpretation, and results expressed to demonstrate if interrelationships exist. Interrelationships between the performance of several criteria will be clarified using graphic tools suitable for multi-variable data (e.g., radar charts). Integrating the reporting of results will also aid stakeholders who may have a narrow understanding of building performance relevant only to their individual practice. By demonstrating how a building’s performance rates globally or how one area of performance may interact with another, stakeholders can begin to understand the effect of their decision making on the project, local context, and global systems;

• **Post-occupancy:** post-occupancy evaluations have been in decline since the 1990s (Dodson, 2011), likely due to perceived barriers in their use and the proliferation of logistically simpler simulation tools and methodologies. However, the effect of occupant behaviour and external conditions still needs to be considered when assessing building performance. For the most accurate representation of performance it is proposed that assessments take place post-occupancy, at least one-year post-commissioning to allow for building defects to be resolved and occupant adjustment to new building systems. In conducting post-occupancy evaluations in multi-residential contexts, relationship management with current residents is crucial to the success of the evaluation, as an assessor relies on their cooperation to gain useful data and access to dwellings. As such, the aims and purpose of the study shall be clearly communicated in straightforward terms to occupants, and unobtrusive methods of evaluating wellbeing within residential environments will be mobilised (e.g. wireless monitoring of IEQ parameters rather than intermittent spot measurements);

• **Complexity vs. simplicity:** in the pursuit of a single, comprehensive, and integrated framework there is danger in overwhelming the assessor with a large quantity of performance criteria to be examined. The method of evaluation and reporting of results needs to achieve balance between thoroughness (in which complexity is inherent) and simplification, to be operationally viable yet useful. When reflecting on the communication of results, the influence of an assessment is limited by the number of stakeholders who can understand the totality of its output. Therefore, beyond integrating the reporting of several performance areas, results shall be communicated via means that can be understood by stakeholders with a wide range of technical proficiencies, for example through diagrams, tables and benchmarking against known standards or other projects. In the context of assessments for multi-residential housing models, selection of the parameters for assessment will be dictated by the aims the models set out to achieve but still be logistically feasible, especially considering the likelihood of encountering issues relating to access.

### 6. CONCLUSION AND FUTURE RESEARCH

The building and construction sector has the capacity to be a significant agent of change in the pursuit of a more sustainable, thriving future. To harness this potential, the implications of current practice – particularly in the underperforming multi-residential sector – needs to be better understood. To form this understanding, building performance assessments of existing conventional and innovative examples of multi-residential buildings are required. However, as this study has highlighted, existing methodologies for assessing buildings are largely inadequate for providing a holistic picture of their performance. Key limitations include assessments isolating specific building systems, life cycle stages or areas of performance, lack of transparency in result reporting, the underrepresentation of the multi-residential sector in assessments thus far, and the tendency to not assess post-occupancy. Significantly, the interrelationships that may exist between areas of building operation, performance or procurement, or occupant wellbeing, are not adequately elucidated by existing methods of assessment. To advance the performance of multi-residential buildings, the sector needs to improve the way they are assessed. From the limitations identified, this study proposes a series of fundamental recommendations for developing a new method of evaluating buildings in this typology.

This study forms the foundation of a larger doctoral research project investigating the performance of multi-residential buildings through the lens of TNM. The next phase of research will see the development of a framework that integrates assessment of several performance areas and employs the recommendations as outlined in this research. Ultimately, this research will conclude with a holistic assessment of the environmental performance of TNM, to subsequently inform the future development of design and construction processes in the multi-residential sector.

### ACKNOWLEDGEMENTS

The author gratefully acknowledges the Thrive Research Hub at the University of Melbourne, who is funding the PhD research project this work forms part of.
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