Digital Modelling as Interdisciplinary Design Practice: A Focus on Microclimate Simulation

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Abstract: This paper examines a precinct scale urban design redevelopment in Melbourne, Australia, and explores how environmental simulation modelling is used within the multi-disciplinary workflow of architecture, engineering and landscape architecture. While digital environmental simulation models are powerful and innovative mechanisms for pulling together multiple disciplinary knowledge to address complex microclimatic conditions, the organisational structure and inter-disciplinary relationships in which they are introduced have a considerable impact on how these tools are adopted and applied. Drawing on practitioner interviews and workflow analysis, we highlight how different disciplinary values relating to accuracy and performance and 'cause and effect' influence the way architecture, landscape architecture and environmental engineering engage with a complex climate simulation model during an urban design process.

Keywords: Microclimate, simulation, urban design, environmental modelling

1 Introduction

Increasingly landscape architecture design practice calls for the digital modelling of environmental, economic and social systems. In the context of climate change, the interrelated factors of climate pose ever-more complex challenges for designers, requiring multiple disciplinary perspectives and specialisations. Digital modelling tools are becoming progressively powerful vehicles for crossing these disciplinary boundaries. Yet despite this, design methodologies and workflows for creating and operating digital models in practice are still largely described and delivered from particular disciplinary perspectives. For example, environmental digital modelling and simulation are often undertaken by specialised engineering consultants, and then communicated back to the designers for their consideration. Even as the technical accessibility of digital models continues to broaden, the traditional divides between disciplinary 'world views' directly challenge the opportunities for increased interdisciplinary practices. While scholars from environmental studies, geography, economics and data analytics have highlighted the importance of recognising different disciplinary values, traditions and vocabularies (CALLARD & FITZGERALD 2015, MACMYNOWSKI 2007, RASMUSSEN & ARLER 2010, SCHMIDT & NEUBURGER 2017), in design practice, these divisions are too often overlooked as business as usual.

2 Why Do We Need Interdisciplinarity in the Built Environment?

Across sustainability research, it is agreed that multidisciplinary perspectives are required for addressing the complex issues raised by climate change. The magnitude and multiple social

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and environmental impacts of increasing heat, extreme weather or sea-level rise are too complex and interconnected to be solved from singular disciplinary perspectives (HADORN et al. 2006, MAX-NEEF 2005, POHL 2005, SCHMIDT & NEUBURGER 2017).

Likewise, built environment design research is increasingly developing methods for incorporating specialised knowledge from environmental science and engineering into evidence-based design solutions. Digital environmental and microclimate simulations have emerged as important tools for integrating principles of environmental science with design. The parametric nature of these models means that the physical laws and principles of thermodynamics and fluid dynamics are embedded directly into the model, and design can be explored against those rules. Thus, the model acts to directly connect design with scientific knowledge. Further, digital simulations are dynamic, offering an understanding of environmental forces and flows according to scientific principles and data. Consequently, the ability to see change through the model can allow the multiple disciplinary perspectives of landscape architects, sustainability consultants, architects, and environmental engineers to test design propositions against the same criteria.

This proposition surfaces critical questions: How do these innovative digital tools merge with already established workflows in design practice? As urban design teams continue to incorporate a wider variety of specialisations, how do these diverse groups negotiate the outcomes derived from an environmental simulation? For example, are there disciplinary differences in how change and accuracy are conceptualised? We explore these questions through an examination of an urban design project where microclimate simulation modelling was used within a multi-disciplinary workflow.

This research uses a case study investigation of the early design stages of the precinct scale design development of the New Student Precinct (Figure 1) at the University of Melbourne in Australia. The scope of the project incorporates ten buildings, two large external areas and multiple smaller outdoor spaces in a design brief that engages a large multi-disciplinary group of designers, engineers and sustainability consultants. Within the precinct, the external spaces have a significant role in providing valuable student amenity (Figure 2). However, given Melbourne's renowned variable and rapidly changing weather systems, the microclimatic design will have a considerable impact on the value and use of the outdoors across days and seasons. Thus, the brief for the project included criteria for generating microclimates for year-round external thermal comfort (2017).

In addition, the comprehensive redevelopment of the site involved significant manipulation of the ground plane and the removal of some existing buildings. This meant that prior topographic and spatial conditions were no longer relevant in determining the future microclimatic conditions. In contrast to a more traditional emphasis in landscape architecture in analysing *existing* conditions, the extensive spatial changes associated with the redevelopment required an understanding of the *projected* climatic performance of the developing design.

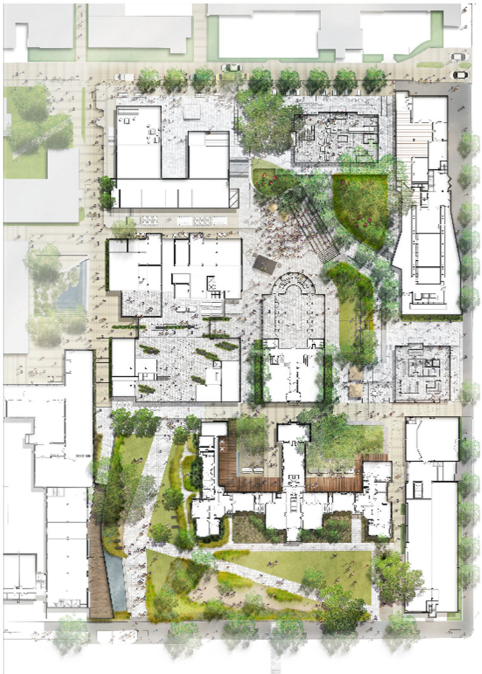

Fig. 1:
Design concept plan for the New Student Precinct site; incorporating ten existing and refurbished buildings joined by a variety of external spaces including lawn, courtyards, event space and access (LYONS ARCHITECTURE 2018)

Fig. 2: Concept render of the redesigned site. As illustrated, the external environment is central to activating the new student precinct. Thus, design of this space must extent the inhabitation of this space throughout the fluctuations of seasonal weather (UNIVERSITY OF MELBOURNE 2018).

The significance of the project, together with the growing concern over Melbourne's warming climate, meant that resources were available for the Environmental Systems Design (ESD) consultants and engineers to produce a detailed environmental microclimate simulation model. Developed in OpenFoam, the parametric site model (Figure 3) combined computational fluid dynamics (CFD) modelling of ground-level wind flow with the mean radiant temperature of surrounding surfaces, humidity and standard air temperature. In addition, the engineers applied a standardised metric (UTCI) for measuring potential thermal comfort. The resulting simulation provided a comparative indication of the site's potential thermal experience at all moments of the year.

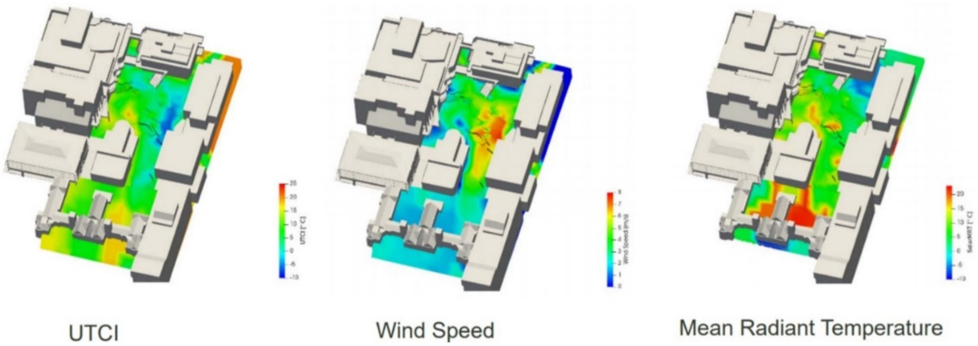

Fig. 3: The microclimate simulation model showing the comparative influence of wind and mean radiant temperature on human thermal comfort (AURECON 2018)

The microclimate simulation was requested by the architectural and landscape design teams and produced by the ESD engineers, who also reported the results. Consequently, our research uses a series of semi-structured interviews to compare the different perspectives on the role and use of the microclimate simulation; from the designers who requested the work to the engineers who consulted on the project. As SWAFFIELD (2017, 111) writes, 'comparison between interpretations can have a significant explanatory power'. Using this methodology, our research aimed to understand the differences in disciplinary approaches to the simulation results and further, find out whether the use of the digital model generated interdisciplinary opportunities within the existing design workflows.

3 Negotiating Disciplinary Differences Through Microclimate Modelling

Although the simulation offered a comprehensive whole-site model of thermal comfort, the interviews with architects, landscape architects and environmental engineers revealed tensions in negotiating design territory. For example, the architects were interested in wind and sun exposure on the open rooftop gardens and balconies, wanting to address these issues within the building envelope, whereas the landscape architects used the simulation to understand cooling potentials at the ground level. Although it is standard for design specialists to take on different parts of a project, the overarching challenge of designing the microclimate blurred the usual distinctions between physical spaces. For example, the design of the building, including the height and material selection modifies the sun, shade and wind behaviours of the microclimate on the ground. Thus, designing for the external microclimate demanded a more holistic focus on the whole of the site which revealed new challenges for the design teams in separating work based on disciplinary focus.

A further tension arose over the model's ability to accurately predict climatic performance. Architecture and engineering have a long history of working together on architectural environmental systems using physical and digital simulations to achieve prescribed environmental standards. Given architecture's ability to directly mediate environmental effect through built form and mechanical and passive systems, the simulation model offers *definitive* information to guide architectural decisions. For example, the engineers worked closely with the architects on measuring the microclimatic performance on balcony heights and awnings, where environmental factors such as wind, solar access and thermal comfort could be precisely ameliorated by modifying the design.

However, understanding the thermal effects of the fluctuating external environment in such a decisive manner is impossible; with the simulation instead offering information about variable and shifting climatic *behaviours*. Consequently, the performance of the landscape design cannot be measured as a precise 'cause and effect' as is the case with the architectural form. Instead, the landscape architects necessarily adopted more tactical and relative strategies such as aiming to extend the thermal comfort of areas during certain times of years (as distinct from achieving a uniform thermal comfort standard).

Here we can see a major difference in how the two disciplines of architecture and landscape architecture conceptualise accuracy and performance in engaging with the same simulation model; definitive versus behavioural outcomes. As the project developed, this difference manifested in the climatic performance of architecture being privileged over landscape architecture due to the difficulty of accurately predicting the climatic performance of the external spaces; including the complexity of modelling living material.

For example, in the next stage of design, the landscape architects asked for trees to be included in the digital simulations. As the spatial decisions were becoming more comprehensive, it was hoped that the simulation would prove the cooling effects of increased canopy cover. Trees had been excluded from the first iterations of the model due to their variable form. As Science engineer Ben MALIN (2018) explains:

> Architects always ask about trees. It's hard to answer. I don't think anyone is modelling trees for this sort of application. In our wind simulations, we don't include trees because trees can be trimmed back or moved or not included, not to mention that in really windy conditions trees won't even grow. Plus, trees don't always have a lot of volume so their interaction with wind is variable.

The difficulty of modelling trees highlights the paradox of precision and accuracy in external microclimate design. Although the real site incorporates mature trees and these have a substantial influence on the local microclimate, the digital model is still perceived to be more accurate without them. Consequently, the digital model may be more accurate, however, it does not represent the actual design. Regardless of the difficulty of accurately modelling with trees, the next version of the thermal comfort modelling results showed that in hot conditions the trees could provide a potential decrease of up to 7ºC in certain external microclimates (Figure 4).

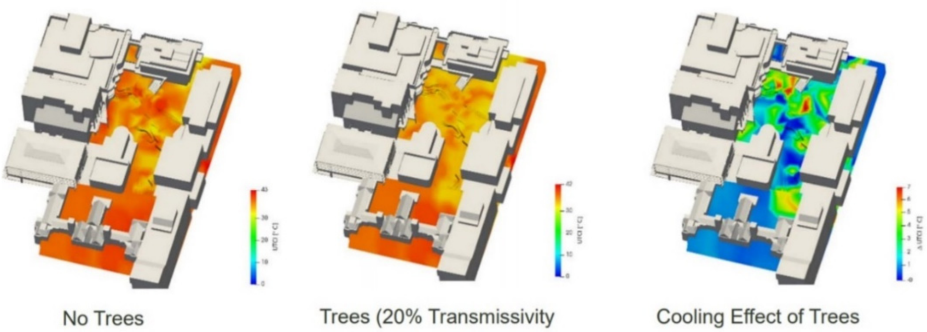

Fig. 4: The microclimate simulation model showing the impacts of a mature tree canopy coverage. Trees were shown to decrease the UTCI compensated temperature by up to 7 ºC in hot conditions (AURECON 2018).

The discussion of green infrastructure provides further evidence of differing disciplinary values relating to climatic performance. For instance, the architects argued for the incorporation of green infrastructure onto external facades rather than, as recommended by the landscape architects, simply planting trees outside the building. Despite the simulation results, there was no precise assessment of the environmental influence of the trees on the building. The inability to define a measure of the environmental performance worked against the landscape architects, along with their limited experience with climatic simulations. Unlike the architects who have extensive experience working with environmental engineers, the landscape architects were more passive to the simulation model results, tending to accept the model as information, rather than proactively working with the simulation as part of their design development processes.

While the engineers offered comprehensive feedback on the simulation results, the landscape architects asked very few questions of the model results. In addition, the ESD engineers were more confident in making recommendations for solvable problems. In this instance, the ambiguity of external environmental conditions works against landscape architecture's authority in discussions enabled by environmental simulation. Without being able to replicate a negotiation based on the certainties and established forms of evidence provided by the simulation, the landscape architects did not fully utilise the model.

4 Identifying Pre-analytical Assumptions

This case study highlights how disciplinary hierarchies and values have a major impact on the contribution of innovative environmental simulation in a design workflow, acting as a barrier to potential interdisciplinary activities. Simply having access to simulation tools does not directly equate to collaborative design processes, thereby more attention must be paid to the disciplinary expectations of what these increasingly powerful models produce. It is apparent that the value of models differs significantly amongst disciplines, necessitating more precise articulation of 'pre-analytical' hidden assumptions (Lawrence 2015, RASMUSSEN & ARLER 2010). In addition to descriptive accounts of modelling processes, designers and project managers need to critically engage with the way knowledge is constructed in models and the underlying hierarchies and power within design workflows and frameworks.

This calls for an increased emphasis on interdisciplinary design methodologies, which acknowledge how disciplines differ in the conceptualisation of accuracy and predictiveness, optimizing processes versus generative potentials and framings of cause and effect. Presently, emphasis is placed on 'static' attributes. However, there are clear potentials embedded within emerging digital technologies which allow a more comprehensive engagement with dynamic climatic performance. Nevertheless, without developing a more critical understanding of disciplinary dynamics and the structural frameworks of built environment projects, designers will miss the opportunities for using digital environmental simulations, both for informing rigorous practices of microclimate design and enhancing interdisciplinary collaborations.

This research has implications for other interdisciplinary innovations in the built environment. For example, Building Information Modelling (BIM) has pursued improved methods of communication and collaboration, largely defined as *technology-enabled workflows*. This considerable body of research explicitly focuses on centralised digital models which not only contain complete design information but can also be accessed and edited by concurrent teams (AIBINU & PAPADONIKOLAKI 2019, EASTMAN et al. 2018). Increasingly BIM research is looking to the early stages of design, and how environmental simulations and other data-driven tools might be integrated as collaborative processes (ROCK et al. 2018, WALLISS & RAHMANN 2016). Yet to maximise these collaborative opportunities, recognition must be paid to understanding the existing hierarchies of the built environment. It is evident that successfully applying multiple disciplinary knowledge's is not just about accumulating different perspectives but in how these differences are negotiated.

5 Conclusion

While digital simulation tools are powerful and innovative mechanisms for drawing together multiple disciplinary knowledge and for grounding design decisions in potential future conditions, disciplinary relationships and values are often overlooked. The considerable difference in conceptualising climatic performance as a design driver reveals the need for more diverse applications of knowledge beyond simply accumulating different perspectives. As the imperative of design briefs shifts towards larger-scale systems issues of environmental and microclimatic performance, project managers, designers and engineers will be forced to rethink how they negotiate overlapping design territories. For landscape architecture in particular, (which has been slow to engage with digital modelling), the question is no longer if we should use digital models, but rather how we develop a clearer understanding of how knowledge and values are constructed through these models. More importantly, how the innovative nature of these models operates within our own practices and relationships in the expanding field of interdisciplinary design.

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