Punching Above Your Weight

DIGITAL DESIGN METHODS AND ORGANISATIONAL CHANGE IN SMALL PRACTICE

Rory Hyde Spatial Information Architecture Laboratory, RMIT, Australia

Expanding bodies of knowledge imply expanding teams to manage this knowledge. Paradoxically, it can be shown that in situations of complexity—which increasingly characterise the production of architecture generally—the small practice or small team could be at an advantage. This is due to the increasingly digital nature of the work undertaken and artefacts produced by practices, enabling production processes to be augmented with digital toolsets and for tight project delivery networks to be forged with other collaborators and consultants (Frazer 2006). Furthermore, as Christensen argues, being small may also be desirable, as innovations are less likely to be developed by large, established companies (Christensen 1997).

By working smarter, and managing the complexity of design and construction, not only can the small practice “punch above its weight” and compete with larger practices, this research suggests it is a more appropriate model for practice in the digital age.

This paper demonstrates this through the implementation of emerging technologies and strategies including generative and parametric design, digital fabrication, and digital construction. These strategies have been employed on a number of built and un-built case-study projects in a unique collaboration between RMIT University’s SIAL lab and the award-winning design practice BKK Architects.

'PUNCHING ABOVE YOUR WEIGHT' IN A CONTEXT OF COMPLEXITY

This research has been undertaken in collaboration between RMIT University's SIAL lab and BKK Architects, a design practice comprised of a small number of people, in which the investigator is embedded as a participant-observer. The research, developed within this unique structure, was initiated as a means for research undertaken within the university to be directed toward current issues encountered in practice. A two-way dependent relationship is established whereby RMIT offers a resource network of technical experts, equipment and training, and BKK brings real-world projects with the associated real-world issues to which this expertise can be applied.

What is particular about BKK is that the directors of this practice are intent on limiting the number of people in the practice as a way of remaining close to the designs, collaborators, staff, and clients. In an interview with the partners, director Simon Knott stated "when we first started, we said 'we want to be a big international practice,' and now we're thinking maybe we don't want that, maybe we want to be hands on, and keep it back to 10 or 15 people in the office" (Hyde 2006). The partners also consider the practice's high design quality to be their greatest interest and competitive strength—staying small is one strategy to ensure this continues to be so.

There is a strong culture of small practices in Australia; Ian McDougall, during his presidency of the Victorian Chapter of the RAIA, stated, "small practices are the site of experimentation and innovation" (McDougall 2001). Indeed, Australia's only Pritzker Prize Laureate, Glenn Murcutt, has a practice size of one. However the range of scale and complexity that can traditionally be managed by a small practice is limited. The RAIA's Small Practice Survey (2002) shows the market dominance of large practices in the case of large projects. Of course there are many factors informing this trend, but one could argue that it is due to large practices having the resources to manage the complexity of procurement for large projects. This leaves small practices—even the highly talented and successful Murcutt—to cater for the smaller markets of housing, retail and small commercial projects (Carter Brown et al. 2002).

This issue is further compounded by the increasing complexity of the practice of architecture. One issue, which Robert Venturi addressed as early as 1966, is that "architecture is necessarily complex and contradictory...today the wants of program, structure, mechanical equipment, and expression, even in single buildings in simple contexts, are diverse and conflicting in ways previously unimaginable"(Venturi 1966). But rather than retreat to simplicity in response to this increasing complexity—the "less is more" attitude for which Venturi criticised the Modernists—many architects today are actively pursuing it. Spurred on by the new possibilities offered by rapidly increasing processing power, increasingly sophisticated CAD software, and the concurrent developments in digital fabrication, architects are everywhere exploring a formal language of complexity (Jencks 2003).

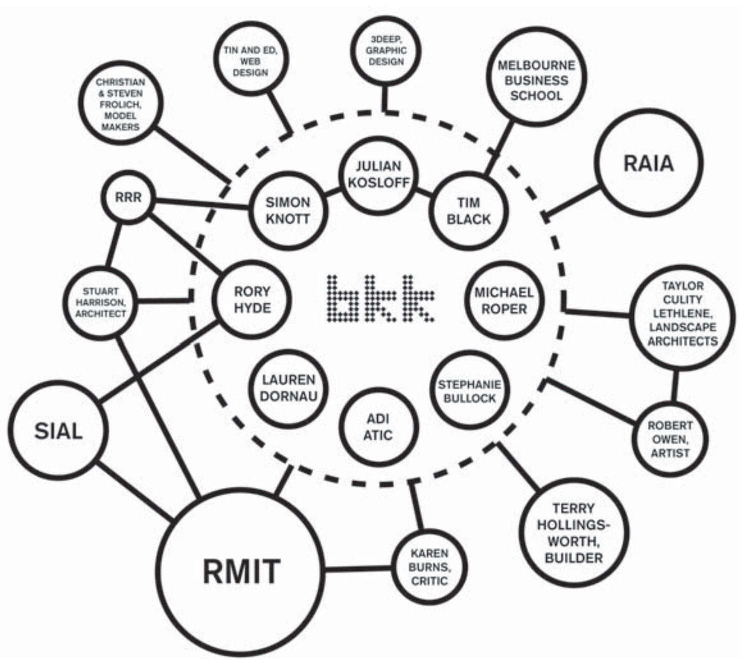

FIGURE 1 Practice network diagram

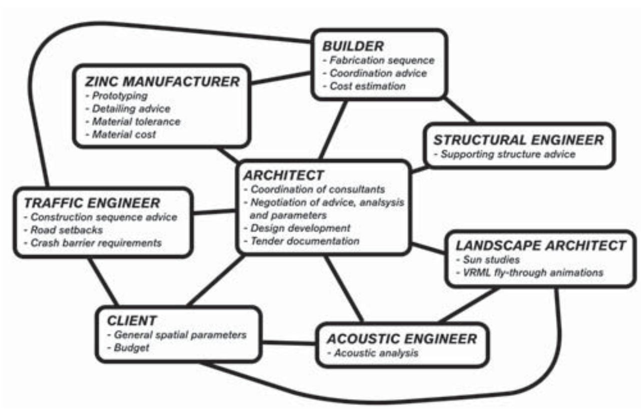

FIGURE 2 Sound-wall—collaborative network diagram

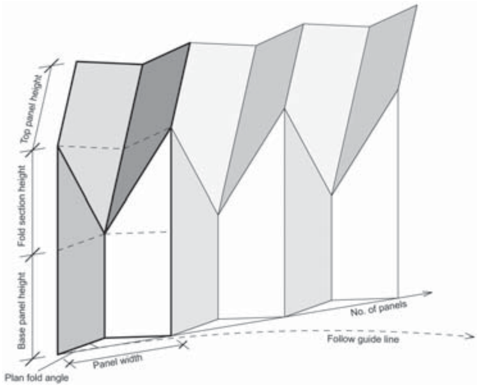

FIGURE 3 Sound-wall–geometric parameters diagram

When what is proposed is not conventional, the various subsequent stages of production can also become more complex. Formal complexity leads to constructional complexity, which leads to representational complexity, which in turn leads to the complexity of information management, which implies a larger team to manage this information. This research proposes that, by developing integrated design strategies that incorporate these many layers of complexity, namely material constraints, the process of construction, and the means for representation, innovative, high quality design can be pursued without the subsequent increase in the number of people required to manage this complexity.

TECHNOLOGY AND PRACTICE SIZE

While this challenge is in response to one practice's particular desires, there is a growing body of economic theory which argues that the new economic era will increasingly favour small firms. Bjerke and Hultman argue this shift is largely due to the changing nature of competitive business assets, whereby "production capacity and financial strength are to an ever increasing extent replaced by more intangible, but yet more relevant and adequate, skills of constructing and using information and knowledge." Furthermore, they state, "these capabilities do not seem to improve with size" (Bjerke and Hultman 2002).

This shift toward more intangible competitive assets is well underway in architectural practice. The task of construction documentation, which is traditionally assigned the greatest number of person-hours to deliver (RAIA 2005), is being made increasingly efficient by CAD documentation systems which can automate the production of drawings and specifications from a coordinated 3-D model. It is the intangibility of the digital information produced, when compared with the

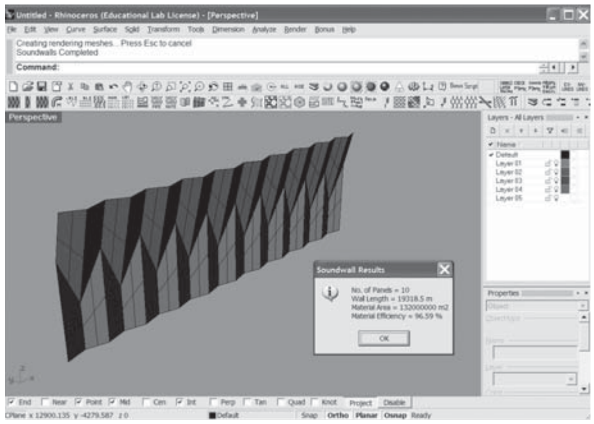

FIGURE 4 (right) Screen grab of sound-wall script in Rhinoceros with performance parameters pop-up displayed

FIGURE 5 (below) Appearance of compression and expansion using identical sound-wall panels

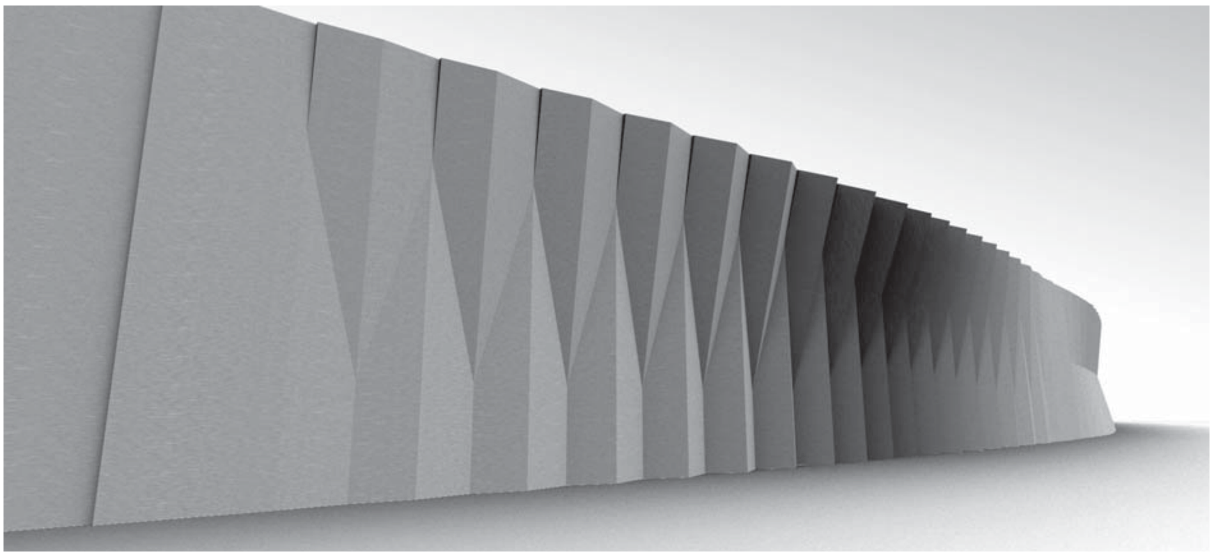

FIGURE 6 Sound-wall in construction

traditional method of hand drafting, that enables this increased productivity. Information can now be migrated easily between the various stages of resolution, and be repurposed for various types of analysis. Furthermore, changes in a parametric environment can often be made seamlessly, avoiding the time-consuming process of erasure and redrawing.

An interesting side-affect of these technological developments is the impact they may have on the organisational structures of practices. While E. F. Schumacher in 1973 blamed modern technology for the irresistible trend of firms becoming even bigger, it now appears technology may offer the potential to reverse this trend. With the 'brute-strength' of a large documentation team being superseded by increasingly sophisticated CAD documentation systems, a large practice is no longer a prerequisite for tackling a large or complex project.

The question then becomes "what is the ideal size of a practice?" Baxter and Lisburn, using the example of the software development industry, argue that the new information-based organisation should be "flat and lean," meaning comprised of fewer people in a management structure of fewer tiers, as "you can get a team of six or eight into a *war room*—a single office with the same working conditions for everyone, and with everything and everyone to hand" (Baxter and Lisburn 1994).

The implementation of this approach is discussed by Frazer who uses Swire's *One Island East* project in Hong Kong as an example, which was designed and documented with only a very small, co-located, multidisciplinary team. Frazer notes that this model "could empower small practices to take on very big projects" (Frazer 2006). While *One Island East* was documented using the proprietary software *Digital Project*, which enables specialists from different disciplines to coordinate and share building information through one 3-D model, this represents just one approach for managing expanding bodies of design knowledge as a small team (Khemlani 2006).

SMALL, NETWORKED PRACTICE

Local research by Berry states that "industries in a world of flexible specialisation are increasingly driven by competitive pressures to 'de-verticalise'… creating interacting complexes of smaller firms specialising in different but linked parts of the overall production process" (Berry 2003). This structure has been adopted by BKK, which is comprised of a small number of people, but who make connections beyond the practice—with the university, professional bodies or media for example—and also by establishing ongoing relationships with consultants and collaborators, including artists and other designers (Figure 1). This network is constantly evolving as staff come and go and new relationships are formed.

If this network of resources and specialist expertise is critical for the small practice to innovate, then the strategies for capturing and integrating these bodies of knowledge into the design and delivery process also become critical. The following 2 case studies explore means for capturing knowledge and information, and propose strategies for implementing these bodies of knowledge as drivers of design processes.

CASE STUDY 1. SOUND-WALLS: DESIGN AS INFORMED EXPERIMENT

This first strategy adopts a script-based approach combined with an evaluation process to refine a design concept toward a desirable—but as yet unknown—outcome or goal through a series of experiments. As a means of illustrating this approach, I will describe how it was implemented in a real project for the design of freeway sound-walls by BKK Architects.

The technical complexity of this project necessitated a large number of stakeholders and specialists, who each brought particular expertise and requirements to the project. Figure 2 illustrates these various parties, what they bring to the project, and the paths of communication and negotiation between them.

Feedback from this collaborative network steered or limited the possibilities, and largely dictated our initial approach. The main parameters were: 1) that as much of the fabrication be done off-site as possible to avoid the need to block traffic; 2) that significant savings could be achieved by developing a repetitive system; 3) that the required height of the walls be adhered to; and 4) that panel widths be based on standard material sheets.

The design concept of *pleating* was established by the directors, a decision informed both by an intuitive response to the site, the practical constraints outlined above, and the project budget, as it could potentially offer a complex formal language entirely comprised of flat panels. Folded paper models were developed in parallel with manual 3-D modelling to explore the range of possibilities offered by this language, and also as a means to compile the geometric parameters (Figure 3).

These parameters were then used to inform a script written for the proprietary 3-D modelling program Rhinoceros using the 'RhinoScript' Visual Basic scripting plug-in. This script took numeric values for each of the geometric parameters as inputs and generated pleated panels in 3-D space using a series of modelling operations and transformations (Figure 4).

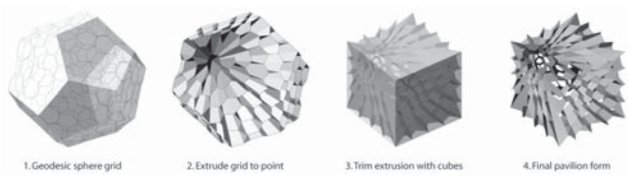

FIGURE 7 (top) Sequence diagram of construction of parametric model

FIGURE 8 (bottom) 2-D profiles being laser cut, 3 assembled and nested cells, completed 1:10 scale prototype model

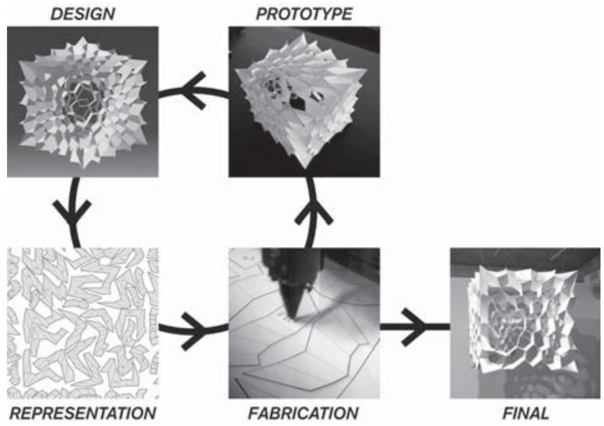

FIGURE 9 Diagram of "closed loop" production process

The quantifiable requirements determined by the network of collaborators were built into the script as bookends on the design space, so that only possible solutions are explored. Performance parameters of the walls generated by the script were also delivered as outputs. These included the amount of material used, the efficiency of this material compared with a flat wall, and the number of panels used to make up this wall. Experimentation subsequently occurs within this design space—as an experiment informed both by the range of possibilities and output properties.

Through experimenting with the script—or learning to play it—a system that used identical panels was developed that would still give the effect of compression or expansion just by incrementally varying the spacing of the structure behind (Figure 5).

There are a number of advantages to working in this way when compared with a traditional drafted approach: it avoids time-consuming erasure and redrawing, accepts the inevitable modifications required in design development, and information can be easily repurposed and exported for other uses including analysis.

What is important about this strategy in relation to the arguments of this paper and the conference theme is how it enabled a small number of people to manage the complexity of large amounts of tacit design knowledge to deliver a project typically outside the scope of a small practice (Figure 6).

CASE STUDY 2. PAVILION: DEFERRED DECISION DESIGNING

This design strategy implements parametric design software to create a "metadesign" model (Burry 2003), which is composed of relationships, but not explicit dimensions. These relationships are then adjusted and modified in response to site conditions, aesthetic requirements, material constraints, constructional issues etc., to determine the final, explicitly defined dimensions which are subsequently used for construction. This approach will be illustrated using a project for a pavilion, which BKK Architects was invited to design for an architecture exhibition mounted by the Monash University Museum of Art (MUMA).

The design concept was to investigate the pavilion type, while retaining some of the properties often explored through pavilions namely the single idea or gesture, continuity between wall and roof, and an integrated structural solution. Buckminster Fuller's geodesic U.S. Pavilion designed for the 1967 World's Fair in Montreal was used as a key precedent exhibiting these properties.

The geodesic structural pattern of Fuller's dome was located in 3-D space using the CAD program CATIA, with each honeycomb cell being constructed as a closed loop of straight lines. Each of these cells were then projected to a centre point located within this sphere, resulting in a set of joined surfaces converging on a single point. These surfaces were then trimmed against an inner and outer cube, resulting in a visually and geometrically complex hollow cube of closed honeycomb cells (Figure 7).

Each of these 3-D honeycomb cells were then unfolded in sequence and laid out flat in a 2-D plane. These 2-D profiles were then numbered with a part number, which could be referenced back to their 3-D source cell, and exported for nesting and subsequent cutting out. These 2-D profiles were then cut out of card using a laser cutter. The 2-D card profiles were then re-folded into 3-D cells and nested together to form the 1:10 scale prototype (Figure 8).

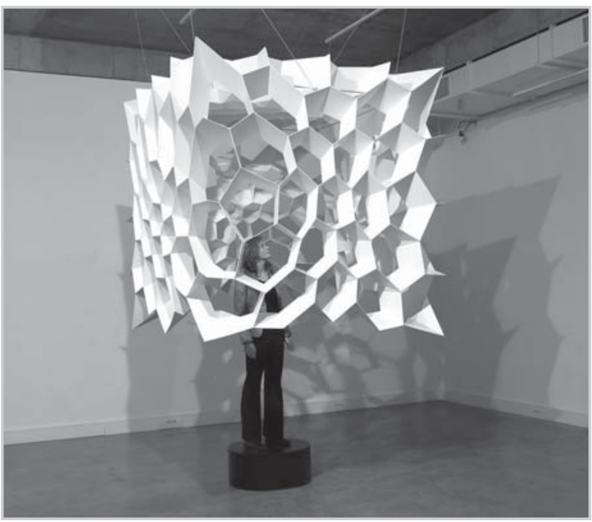

FIGURE 10 Completed pavilion with focal point positioned at viewer's head

An important aspect of this strategy is that changes to parameters defined early in the process are propagated downstream to update subsequent procedures without the need for erasure and redrawing, allowing design decisions to be *deferred* right up to the last minute. Furthermore, if these subsequent procedures are fabrication orientated, a closed loop between design and construction is established, whereby subsequent iterations can learn from or be informed by the previous iteration, simulating the common design refinement process of trial and error. Furthermore, by connecting the logic of design with the logic of production, cost and time efficiencies can be generated (Figure 9).

This potential to defer design decisions was implemented between the development of the 1:10 scale prototype and production of the 1:1 scale completed pavilion in response to how the pavilion was to be exhibited in the gallery. It was decided that the piece would be suspended from the ceiling allowing the audience to duck underneath it and experience the interior. The point of convergence—which for the prototype was located in an upper corner of the cube—was moved to a position lower down and centred, allowing the viewer to position their head at this point of convergence (Figure 10). When viewing the piece from this point, only the cell edges are visible, rendering the piece as a net devoid of depth, reinforcing the projected nature of the design. As this centre point—and indeed the entire model—was parametric, this late change did not require any extra work as all the unfolded profiles were parametrically linked to the 3-D model.

One way to illustrate the efficiency of this method would be to document this (twice!) using a set of traditional 2-D plans, sections, and elevations and compare the time it took to do so. Not only would it be extremely difficult to accurately calculate the positions of the complex geometry manually, these drawings would not communicate enough information to construct the piece. As this design is the result of an integrated 3-D process, it requires a customised approach to communicating this information.

This approach exploits the internalised operations of the software, so that the designer is not exposed to the geometric or mathematical complexity of the project, but is free to compose the process and manipulate the higher-level parameters that influence the outcome.

In reference to the broader proposition of this paper, this project is an example where design complexity was increased beyond what was previously possible to traditionally communicate for construction, but through the implementation of this project-specific strategy this complexity was managed and the project was delivered by a very small team.

IMPLICATIONS IN PRACTICE

This paper has sought to illustrate how new technologies—and specifically project-specific strategies which implement this new technology—can enable small teams to achieve more in situations of complexity. This section reflects on the implications of the adoption of these strategies in the real context of practice.

The ability to make radical changes quickly has influenced the way directors work with staff. Previously, a director would draw a sketch communicating design intent, which would get drawn up as an explicitly defined 2-D or 3-D CAD drawing by a student or graduate architect. This drawing would then get passed back to the director for marking up, and would then be passed back to the student or graduate to make these changes. This process is then repeated until a satisfactory design is resolved, or until the deadline approaches. Time to produce changes or iterations is limited by the slow process of erasure and redrawing and by the availability of the director to review these changes.

The introduction of parametric design and scripting into the office has meant that although there is greater investment of time up-front to build a parametric model or to write a script, once either has been produced, design discussions can move very quickly with revisions made in real-time, keeping up with this conversation. This model or script artefact also retains its usefulness beyond the design stage, and, as is often the case with scripts and depending on how generic the function is, can be used again on subsequent projects.

However, this shift has also brought with it some issues. Building a parametric model or writing a script requires a more rigorous approach than required when working with explicitly defined objects. Parameters need to be clearly articulated and structured in a manner that embeds the logic of the design in the model, while copying a sketch or making mark-ups requires very little understanding of what is being represented.

Furthermore, the introduction of these various new forms of digital media, has meant that there is no longer one default method of representation dictated by the office manual, but as many strategies as there are projects. At BKK, while most projects will still have a standard set of 2-D documents, these are increasingly being augmented by other forms of representation for direct communication to manufacturing machines, namely, spreadsheets, databases, unfolded templates, and 3-D models.

As reliance on the 'standard approach' recedes, which solution moves into its place is—in a minor inversion of the office politic—often most apparent to the operator who has worked through the parametric model or written the script, not the director in charge. BKK has recognised the importance of gathering this insight derived from the "front-line" and has developed strategies for the transfer of knowledge and information between the operators and directors. This is encouraged through regular review sessions where projects that are currently in design are presented by those actually doing the work to the office and directors for feedback.

CONCLUSION

It is strategies and projects like these that suggest it is both possible and desirable for a small practice to punch above it's weight because, as has been argued, these systems are much harder to establish underneath the organisational burden of a large practice, and geared toward the strengths of small practice—namely design innovation.

Have we punched above our weight? Certainly BKK are more efficient and capable of engaging projects of greater complexity, but to objectively measure whether it has competed with larger practices is difficult, as there are many factors involved. However, as a tentative conclusion, I will give an example of where the practice seems to have achieved this. The exhibition of pavilions mounted by MUMA featured 9 emerging practices of which BKK was one. Subsequently, and I would suggest due to the success of the piece, BKK was the only firm from the exhibition invited to participate in a competition for a substantial extension to their gallery against a field comprised of all larger firms. Further to this, BKK was also invited, by the same university, to participate in a competition for their new architecture school, again against a pool of larger, more established practices.

As a concluding anecdote, while the practice can now manage large or complex jobs while staying small, they have had to respond to expectations of clients where "capable" often means "large." In response to this, a curtain was installed in the office foyer to enable clients to make their way to the meeting room which concealed the rest of the office, making the true number of staff in the practice seem ambiguous.

ACKNOWLEDGEMENTS

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