Collaborative creativity: building envelopes and construction innovation

Blair Gardiner and Giorgio Marfella
The University of Melbourne, Melbourne, Australia
blairmg@unimelb.edu.au, giorgio.marfella@unimelb.edu.au

Abstract: There is a trend in contemporary institutions to commission buildings characterised by façade designs of increasing formal complexity. Building façade systems are an area that demands specialist expertise and that has critical influence on overall building performance, marketing value and construction cost. These buildings can offer, at least in principle, a potential to promote construction innovation. By looking at a highly specialised area of the construction sector, this paper presents the findings from a pilot study that investigates industry perceptions and experiences on innovation through architecturally complex façades. The context of this study is a recently completed tertiary education project in Melbourne built with a novated ‘design and construct’ method of procurement. Semi-structured interviews with key project leaders engaged in the design and delivery of the façade systems offered an in-depth exploration of the differing perceptions about the interpretation of construction innovation among the participants. According to this pilot inquiry, in the context of novated contracts, the industry recognises the critical role of a design ‘gatekeeper’ engaged collaboratively with sub-contractors while the prevailing industry mandate in Victoria, as shared by the participants, is to give priority to innovation opportunities that minimise on-site labour and reduce construction time.

Keywords: Innovation; institutional buildings; specialist subcontractors; building façades.

1. Institutional projects and innovation opportunities in building envelopes

Architectural design trends in recent Australian tertiary educational projects are displaying interest in multi-layered and geometrically complex building envelopes setting performance standards recognised through such criteria as those established by the Green Building Council of Australia. In this setting of apparent challenged ‘buildability’ (Hyde, 1995), are there opportunities to foster construction innovation? The target of this study is the role of specialist façade subcontractors in their capacity to take a pivotal role in the design development and the construction management of façades characterised by formal and technical complexity. Through this lens the potential available through cooperation between supply chain actors to bring into being that which otherwise would be standard
operative processes is investigated. This potential is described here as collaborative creativity, out of which innovation may be borne.

Tertiary education projects, given the privileged and the potentially illuminated role of their commissioners, may have an inherent potential to push construction innovation, but at what level does construction innovation happen, if at all, in these projects? Does the complexity and the challenged constructability of the façades of these project translate into new developments in construction process or production? Does it encourage the use of new materials, systems and components? Does it affect organisational structures and/or new methods of production? And lastly, do these highly complex building envelopes reflect an institutional push from the clients to achieve higher performance targets?

The Organisation for Economic Cooperation and Development (OECD) has set the benchmark for the definition of innovation that has come to be recognized by policy makers. It establishes innovation in terms of the creation and diffusion of new or significantly improved products (goods and services) and processes and methods supported by factors of research and development (OECD 2005, 2010, 2015). The full applicability of this definition to the construction industry has come into question, in challenging the low ranking of the construction industry in comparative industrial innovation performance data (Winch, 2003; Reichstein et al., 2005) and the nuances in innovation that apply to the project-specific problem solving characteristic of the sector (Slaughter, 1993, 2000; Winch, 2000; Tombesi, 2002).

Although literature abounds on identifying the sources of construction innovation motivation and obstacles (Whythe and Sexton, 2011; Blayse and Manley 2004) and the pressure on the Australian construction industry from a productivity innovation point of view (Ashurst, 2014), little investigation has taken place in relation to construction innovation grounded in the supply chain dynamics that apply to the project-based nature of the construction industry. There has been recognition of the importance of the role of sub-contractors (Gil et al., 2001), as well as studies from single specialist subcontractor perspectives (Holt and Edwards, 2012) and from component manufacturers (Larsson, Sundqvist and Emmitt, 2006). Loosemore (2014) has undertaken a study on Australian tier-one subcontractors from a productivity perspective which briefly touched on the question of innovation, linking innovation opportunity to subcontractor productivity.

It is therefore pertinent to ask, how innovation is understood by the construction industry at consultant, contractor and subcontract level.

2. A pilot case study: methodology and approach

The aim of this paper is to gain insight into construction professional’s perceptions of innovation and how these perceptions may be exemplified through the building façade and envelope. At face value this building element offers innovation opportunity by its intrinsic design and technical requirements and in addition by being a key component on the construction critical path program. The building façade system as an environmental moderator potentially intersects with construction technical innovation but also with issues of broader significance for innovation in architectural design and construction management. It also offers an area of investigation for aspects of construction projects that require understanding of perspectives on collaboration (Hughes et al., 2012) in a context where design imperatives are more stringent (Fox et al., 2002).

The method of gaining information at this stage was not to investigate the façade components for their innovation outcomes but to obtain an understanding of how key stakeholders in the supply chain identified elements of the façade as being innovative within their own frames of reference and within
the context of the part they played in the project. The research takes a case-study approach where value is identified by providing insight into the very specific nature of project-based innovation dynamics that occur in the construction industry (Winch 1998; Tombesi, 2002) but which has remained unattended by recent studies.

The study adopted a qualitative research method. An open-ended interview based on the same set of questions being presented to each stakeholder representative was used to determine each viewpoint and perspective. The study methodology sought the participation of the primary actors in the façade design and supply chain by engaging with design, contracting and subcontracting teams. This afforded a holistic view of innovation from design to implementation. In total six senior leaders from six different professional and construction organisations were interviewed – two were key personnel responsible for architectural design and specialist façade consulting, one responsible for design management from the head contractor and three senior management representatives from three different specialist subcontractors involved in façade delivery and installation.

The participants were asked six general questions in common and they were encouraged to expand their views on aspects of construction innovation in relation to the project. The key topics covered by the interviews can be summarised in three areas:

- The meaning and value of construction innovation from the perspective of the participant’s role in the process and in function of their position in the supply chain of the building envelope;
- The level at which opportunities for construction innovation originated in the project (e.g. at the level of new materials, fabrication processes and/or management resources) and the relationship of these opportunities with the complex nature of the architectural design of the façade;
- The opportunities and the restraints for the implementation of construction innovation in relation to the procurement system adopted – in this case a ‘design and construct’ contractual scenario.

The scope of this pilot inquiry was to test the effectiveness of the questions raised in the interviews, to identify patterns of perception and experience about construction innovation in the sector of architectural façades and to develop a protocol that can extend the interviews as a multiple case-study project that involves a number of similar projects located in other Australian States.

By targeting a small number of institutional projects with an embedded focus on building envelopes, the case study research methodology was chosen to explore in depth the mechanics of construction innovation. The aim of the investigation is to establish how and why construction innovation is introduced at a level of the façade sub-contractor in the supply chain of institutional projects.

The focus of this paper lies with the initial case study used as pilot for a larger research project that will investigate a number of tertiary educational projects completed in Australia in the last five years, with each having a project budget above fifty million Australian dollars. The pilot case study building is a six storey teaching and research facility of around sixteen thousand square metre gross floor area, procured under a novated consultant contract system, with a construction period of eighty weeks. Its façade system consists of a mixture of cladding components including precast reinforced concrete panels, aluminium framed glazing systems and metal screening. The building’s sustainability credentials have been recognised under the Green Star – Education V1 rating by the Green Building Council of Australia. A novated design and construct procurement method was utilised to offer the benefit of contractor input into the design management process to generate cost and time efficiencies in order to meet project budget and to deliver the project within the time requirements dictated by an academic
teaching calendar. The pilot study is not directed to investigate the efficacy of the procurement system or the façade system in meeting its intended outcomes but to consider these in relation to the question of stakeholder perceptions on construction innovation within the project.

3. Participants’ perceptions on construction innovation

There is consistent academic literature that defines innovation in construction (Slaughter, 1998; Winch, 1998) and another stream of studies that defines causes and sources of motivation for the implementation of innovation in the building industry (Seaden et al., 2003; Hartmann, 2006). How innovation is defined and understood by the construction industry at consultant, contractor and subcontractor level is instead less documented. The participants of this pilot study were asked to define their understanding of innovation in relation to their role in their organisation and position in the supply chain of the project.

The architect and head contractor interpreted innovation chiefly in terms of market advantage. The architect saw innovation in terms of design creativity in interpreting programmatic requirements. The contractor saw the terms of market advantage instead as a capacity to deliver tertiary sector buildings outperforming cost and time parameters.

The architect saw a driver of innovation in the nature of the contractual regimes that are now the norm in the industry, design and construct, guaranteed maximum price and management contracting in particular. These contracting systems have afforded greater early engagement with the head contractors and partial access to subcontractors by being embedded within the contracting team, which is not facilitated by traditional forms of procurement prior to completion of contract documentation. This has not necessarily translated into material technology innovation but consideration for innovation in design, product and process innovation in support of on-site labour minimisation, construction program time and constructability. The architect saw this driving a shift from traditional construction methods to an engagement in building systems that lend themselves to prefabrication and unitised systems. The nature of these contract systems, it was argued, also held difficulties. The development of innovative façade systems in consort with specialist suppliers was seen as being difficult due to perceived project risks of losing competitive advantage in being tied to a single supplier. Furthermore the difficulty was seen in the contractor’s acceptance of risk by committing to untested building systems.

The architect also recognised innovation in terms of establishing bench marks for architectural design and building performance. These bench marks could, in the architect’s view, be achieved via the introduction of new building systems as well as by questioning and/or integrating existing construction materials and methodologies to achieve better design and performance outcomes. The architect identified the capacity to achieve complex design and performance outcomes as an innovative trait of the professional services offered. In the context of multi-storey institutional buildings the architect’s point of view on innovation was explained as the mastery of skill and awareness of the industrial reality while combining different building systems into a coherent design outcome. An approach of direct collaborative participation with sub-contractors and the necessity to engage in pro-active industry inquiries from the schematic design stage was identified by the architect as a critical aspect for the successful outcome of this process.

The perception of the value of innovation from the point of view of the façade specialist subcontractors concentrated instead on the ability to meet a wide range of different demands from the
designers in response to ad hoc performance requirements that can vary significantly from project to project.

The contractor’s perspective lay in the mindfulness of meeting or improving on performance outcomes whilst being conscious of overall project responsibility related to cost and time. A key feature was an acceptance of the architectural design intent and building performance criteria. Innovation strategies therefore were seen as those generated in meeting or exceeding building performance criteria where the methodology of achieving these criteria were not clearly resolved and in those strategies directed to achieving early project delivery.

Subcontractor perspectives on innovation were in terms of internal systems and processes directed towards capacity development to demonstrate architectural design delivery at the system element level and to facilitate operational, fabrication or installation capacity to minimise project risk and project time.

The glazed façades subcontractor involved in the fabrication and installation of windows and shopfront façades explained construction innovation as the capacity to find the most effective solution to different design intents in terms of cost and time. In synthesis for this contractor the meaning of innovation was interpreted as effectiveness in delivery combined with a capacity to design and develop bespoke façades.

The architectural metal fabricator responsible for the fabrication and installation of external balustrades, metal sunshades and relative secondary steel supports interpreted the meaning of innovation as the capacity of ‘taking the normal stuff and turning it on its head’ in order to meet ever-changing design challenges posed by different projects. This subcontractor explained innovation as the ability to come up with ‘always something little cleverer’ by transferring hindsight from previous projects. However innovation in this trade was not related to a matter of questioning the basic techniques of metal fabrication (e.g. welding, bolting, folding et cetera) but rather as the ability to question everything else surrounding the production process. For this subcontractor innovation consists in essentially making fabrication simpler, updating and developing better finishes, and providing pre-assembled and modular solutions to reduce site work and manage delivery with better quality control in the factory. The subcontractor stated also that ultimately ‘most of what we change is what you don’t see’.

A key feature in common to all participants on this project was the notion of the importance of being proactive in developing a collaborative creative approach that fostered openness to innovative solutions in design resolution and project delivery.

4. Where did construction innovation occur in building envelopes?

The participants were also asked to comment in relation to specific instances where innovation occurred in the project.

The architect and façade engineer identified one of the primary design features of the building, its metal folded façade screening system, as being an element that required new product and process development. By being a frameless system, extensive research and testing was required in material technology and structural design to identify an appropriate material and support mechanism for these cantilevered screens. Research was undertaken in metal thickness and folding techniques to generate appropriate structural capacity in maximising sheet span to minimise fixing points. In being perforated, 3-D design modelling software was aligned with production manufacturing system capacity which was
itself modified to significantly reduce production times to meet construction program imperatives. Prototypes were developed which underwent wind tunnel testing to ensure structural integrity and to test noise generation in its future varied configuration arrangement across the façade.

The contractor also put forward the metal façade screen system as an exemplifier of project team collaboration in delivering this significant design feature within the contract obligations to meet time and cost.

The glazed façades subcontractor stated that the façade industry has now transformed into a highly bespoke trade practice where most systems used in medium-large institutional projects rarely contemplate the use of ‘off the shelf’ glazing suites. The professional design industry, from this trade perspective is now shifting towards a very high level of project specific production where ‘everyone wants something different, everyone wants a different appearance from their extrusions, everyone wants a different performance and everyone wants a different colour’. For this contractor the ability to gain flexibility including ex-novo aluminium extrusions in the delivery of the project is now paramount in order to gain competitive advantage in the sector of architectural façades.

The aluminium manufacturer has reinforced this view indicating that in some instances the bespoke nature of the glazing system required twenty extrusion dies to be cut for the project. This large variation of extrusion profiles was partially in response to a multitude of window alignments and in part in response to a more industry-generalised necessity to provide glazing pockets for a wide range of non-standard double glazed units. A current and local trend in the façade sector is that glass unit thickness can now vary significantly from project to project and also from system to system within the same project in response to structural, thermal and acoustic requirements set by façade engineering specifications. This non-standard, performance-based approach makes it necessary for subcontractors to develop a multitude of different extrusions with the effect of eliminating the use of ‘off-the-shelf’ framing systems outside the domestic market.

The glazed façades subcontractor produced in close collaboration with the aluminium manufacturer a set of specifically extruded window systems, louvres including relative brackets and a large prefabricated skylight system. According to this sub-contractor the project was symptomatic of a current trend where bespoke unitised structural glazing systems are transferred from high-end façade systems into smaller institutional project where finished-off products can be delivered pre-glazed directly from factory to site. The unitised approach, traditionally associated with large multi-storey curtain walls now provides significant cost benefits also at smaller scale due to increasing costs of site-labour and managing issues of dealing with construction management issues of building sites on a day-to-day basis. Beyond the immediate consequences for this sub-contractor to develop more extrusion dies in collaboration with the aluminium manufacturer the company had to accommodate for the project significant process changes in the layout of the factory, due to the necessity to have products completed off-site. While identifying production process changes as one of the modality through which innovation occurred in the project, this subcontractor highlighted the impact on employee profiles required in the factory by seeking different people with new skill-sets, for example with capacity to use cranes and slings. In this regard the pre-assembly of a glass roof element in large unitised sections was exemplary of this innovation mechanism at process level. The same sub-contractor also acknowledged an imperative to innovate that was generated by the design of the building, arising from its design form, geometry and size, as well as by requirements to achieve particular architectural and performance criteria such as glass set at different alignments. The sub-contractor recognised that working on these
types of building brings a marketing advantage for the company in a market where ‘the more you move from the norm, the more competitive you become’.

The architectural metal fabricator also identified changes in the processes of fabrication as one aspect induced by the project. The need to fabricate large Vierendeel steel trusses triggered the need to develop a new type of self-rotating rotating jig – the participant defined this the ‘spit-roast jig’; where parts could be worked by the fabricator on both sides without turning it over, with the result of saving labour and handling time. Other items of innovation identified by the same sub-contractor were the need to modify initial connection details of the sunshade screens by using three-dimensional modelling. The use of three-dimensional documentation tools, however, was already in place in the company before the project in case.

**5. Discussion**

When facing the question to define their understanding of construction innovation the participants gave different examples as a demonstration of their capacity to be innovators in their respective fields. For those involved downstream in the supply chain it was difficult to define innovation coherently, revealing confusion between innovation as a process of substitution with elements of novelty and the inevitable creative problem solving associated with a project with a low level of standardisation. The word innovation was often misinterpreted as the capacity to meet project specific challenges indicating a incongruity with the more rigorous and broadly encompassing definitions adopted instead by academics, which more often define instead innovation as a process of substitution capable to extend its influence from one project to another and preferably from one project to an entire industrial context.

For this project, from the head contractor’s perspective, innovation was identified primarily as a process of improvement directed to meet performance standards set by the designers and to meet cost and time imperatives. Subcontractor interests were directed to component innovation to reduce on-site work and to improve productivity with more efficient factory fabrication methods. Another element that emerged within the perspective of the constructors was an idea of innovation not as a simple response in productivity directed to reduce construction cost. Innovation was claimed to be part of a more complex set of causes related with risk mitigation, programmatic pressures and opportunities to facilitate site management by minimising on-site labour.

A common understanding however was identified in the recognition of innovation as a means to obtain a competitive or a market advantage through increased efficiency and flexibility in production and delivery. The participants shared the view that the competitive advantages given by being perceived as innovators in their respective field is a key source of motivation to adopt innovative practice.

Two key considerations can be drawn from this pilot study and these allow setting a pathway for further research activity.

- The importance of having a ‘gatekeeper’ in the design team, which in this case was impersonated by the façade architect, was identified by the participants as an essential feature that ensures that the design intent and the performance requirements of the envelope could be carried out successfully from conception to completion of the project. The role of the gatekeeper was recognised by the participants significantly in the context of ‘design and construct’ procurement. In virtue of the constraints imposed by the design gatekeeping, the participants of this case study have suggested that the challenge to meet a design intent that is closely monitored by the designer can be a significant trigger of change from normal practice.
• Time-related pressures in the delivery of the project were identified recurrently by the participants as the primary source of motivation to engage in innovative forms of practice in construction. The need to speed up the building process was described as a make-or-break contextual condition setting the stage for improvements in fabrication methods and processes, the substitution of design elements or the introduction of new methods of installation. This scenario was deemed particularly effective in relation to items that were in the critical path towards what some participants defined as the ‘lock-up’ stage of the project, or in other words the time in the program when the initiation of the internal fit-out stage can occur in a weather tight environment. As one example of this form of time-induced innovation, several participants identified the process of maxi-prefabrication and redesign that was required by the timely delivery of a large atrium skylight, which in their experience resulted in ‘never done before’ building practice.

The participants indicated that the construction industry may find innovative benefits by working in a context where, at least in relation to the sector of building envelopes, the designers can work collaboratively in direct contact with specialist sub-contractors from the early stages of the project. This consideration leads to the need to understand the contractual dynamics that are established within a project.

This pilot case study suggests also that opportunities for innovation may not necessarily be excluded within projects that are procured with design and construct methods and where the designers are in contact, by virtue of the contractual necessity set by the novation, with the head contractor and potentially also directly with the specialist sub-contractors. These opportunities are however dependent on the specific modality of collaboration that is set in the project and by the attitude and the experience of the organisations and the individuals involved. In this case study, the head contractor and the architect have allowed a fruitful level of collaboration to occur weekly with intensive design meetings, where different sub-contractors, and at times product manufacturers, could enter in a direct relationship of collaboration with the designers.

The intensity of the collaboration is reliant on other variables related to the intrinsic nature of the architectural design of the building envelope. The gatekeeper in this case study took the role of custodian of the original design intent of the façade systems, which were conceived, developed, and agreed with the client following the successful outcome of an international design competition. During the design development and the subsequent documentation and construction stages of the project, design gatekeeping became the discriminant that ensured that the aesthetic design intent set with the client could be met. Gatekeeping implied, in this case, meeting not only specified performance requirements but also locked-in architectural appearance.

6. Conclusions and further research

There is an incongruity of meaning between the definition of innovation established by OECD definitions and the understanding of the meaning and value of the word innovation among a number of participants of this study at sub-contractor level. The difficulty within the building industry to define innovation seems to lie principally in the incapacity to recognise the different levels of intensity where innovation can occur. This study has shown that some of facets of the broader meaning of innovation are not always contemplated by the building industry. At a level of academic recognition, innovation would be considered as the adoption of non-trivial changes in process, component or systems which would go beyond the project specific challenges set by a bespoke component of the design. The industry
perception of the building industry seems to focus instead on the idea that to possess organisational flexibility and capacity to engage efficiently in project specific problem-solving is a sufficient condition to gain a market recognition as ‘innovators’ in their fields.

This pilot study suggests however that there are significant elements and patterns of change within the sector of façade specialist sub-contractors based in Victoria. The need to reduce on-site labour alongside with the imperative to reduce overall construction time is currently a robust driver of change which has the potential to make sub-contractors receptive of considerable innovative practice. In the sector of architectural façades, this time-induced motivation for change is favouring, for example, the adoption of bespoke design and fabrication of unitised façade systems also in medium-large educational projects by smaller and locally based façade sub-contractors, while traditionally these systems have been used as a prerogative of large multi-storey commercial projects by larger, and often off-shore based suppliers.

There are differences in the perception of the value of innovation which change according to the role taken by different participants in a project. Moving upstream in the supply chain, designers and head contractors seem to be more aware of the broader implications of innovation that can go beyond project-based practice. Designers and consultants, such as architects and façade engineers, may see as the chief driver of innovation the need to seek superior performance and the need to control design appearance through the different stages of the project. Head contractors may favour cost and time outcomes and subcontractors may seek benefits in efficiency and time-control as motivating factors for change. It is therefore necessary to engage with the contextual dynamics that are established by the method of procurement in a project and in that context it is also plausible to assume that these dynamics are related to the nature and the level of the risk taken by each participant.

It remains to be established how procurement systems can have an impact on the potential to introduce innovation in the construction sector, and more specifically in contemporary building envelopes in Australian tertiary education facilities. This consideration leads to the definition of a set of questions that should be analysed further with a multiple case study approach:

- Do design and construct systems of procurement preclude rigorous research and development activity in construction? Does competitive tendering require the actors playing downstream in the supply chain to withhold innovative strategies until certainty of contract is established? Was the outcome of collaboration unique for this case or related to the typology of novated contracts?
- Where does innovation capacity lie in the sector of specialist façade sub-contracting? Is it related to performance improvement or does it lie in construction management of a significant critical path item? Is it the critical path program that drives innovation?
- What mechanism is there to promote improved performance standards? Where are the incentives for innovation to improve performance standards? Is the lowest regulatory or rating regime becoming the benchmark?
- What role do bespoke projects in tertiary education sector play in being innovation incubators and is there evidence for this through multiple case study analysis?

Acknowledgements

The authors would like to acknowledge the contribution of those who were interviewed or who explored elements of this paper’s evolution. Thanks are extended to the staff of the architects, façade
consultants, head contractor and sub-contractors associated with the façade works who participated in the interview process. The funding support of the research through the Brookfield Multiplex Research Program Awards is gratefully acknowledged.

References


