BRITE Report 2003

Report 2001-012-A-07 Case Studies

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1. PREFACE

This internal report summarises the activities of the BRITE Project in 2003, which primarily involved undertaking six innovation case studies.

The overall objective of the BRITE Project is to improve the incidence and quality of innovation in the Australian building and construction industry. Many stakeholders in the industry are sceptical about the potential for innovation and its likely benefits. Many also lack the linkages and capabilities required for successful innovation. The BRITE Project will redress this situation through demonstration and benchmarking activities. The intention is to conduct innovation case studies every second year over the life of the CRC, and an innovation survey in the intervening years.

The innovation case studies form a collection highlighting successful implementation practices and measured benefits. The case studies demonstrate best practice and contribute to the enhancement of industry capabilities. The case study element of the BRITE Project has been inspired by the success of the Rethinking Construction, Egan Demonstration Projects. This UK initiative has had a positive impact on building and construction industry performance in that country.

The survey will measure the innovation activity of the industry over time, to benchmark performance and enable appropriate public policy development. The innovation survey element of the BRITE Project builds on the success of two previous surveys - the Australian Building and Construction Industry Innovation Survey undertaken by a team led by Price Waterhouse Coopers (PWC) in 2001; and the Queensland Road Industry Innovation Survey undertaken by Queensland University of Technology in 2002. The BRITE innovation survey will be conducted in 2004.

2. INTRODUCTION

This is an internal report of the BRITE Project's activities for 2003. The goal of the Project is to improve the incidence and quality of innovation in the Australian building and construction industry.

The primary aim of the year's work was to complete six case studies of innovation in the Australian building and construction industry. A secondary aim was to prepare for the Project's innovation survey to be conducted in 2004. The case study program was undertaken to demonstrate the benefits of innovation and show how businesses successfully implement their innovations. The innovation survey is intended to run every 2nd year over the life of the CRC in order to benchmark innovation performance as a tool for public sector policy development and business strategy development. Appendix A contains a list of papers produced by the BRITE Project in 2003.

The remainder of this report focuses on the case study program, which was successfully completed during 2003, with six booklets being produced.

2.1 Background

The case study program was driven by the interest of the Project's industry partners in improving innovation performance in the Australian building and construction industry. The program was designed to deliver six innovation case studies in A5 booklet form in 2003. The scope of each study and the format of their reporting were driven by the experience of the Movement for Innovation (M4i) in UK. The M4i has undertaken similar activities aimed at changing industry culture to make it more supportive of innovation. Their program is considered to be very successful.

In Australia, recent innovation case study programs have been driven by the Commonwealth Government's Innovation Summit in 2000 and the initiative to map Australia's science and innovation capacity announced in November 2002. The resultant case studies (e.g. Jones and Pagan 1999; Thorburn and Langdale 2003) analyse innovation at firm-level, often in the manufacturing industry. The BRITE Project's activities expand on this work by covering innovation in the construction industry at project-level. Innovation in the context of construction project-based activities is very different – often being more reliant on relationships between stakeholders and less reliant on R&D.

Further to this, the case study program was developed in response to poor innovation performance in the industry and an understanding by industry analysts that many industry participants were skeptical about the potential benefits of innovation – particularly small and medium-sized businesses.

The booklets were developed as an educational tool, to be vigorously diffused to promote an industry culture more supportive of innovation. The diffusion side of the program was, and is, taken very seriously, with a number of avenues being pursued, including distribution of findings through industry association magazines, CRC participant magazines, case study interviewees, ACIF, the CRC's Technology Transfer Strategy, industry gatherings; and a formal launch of the case study collection in February 2004.

The booklets are targeted to specific audiences, including public sector clients, private sector developers, consulting engineers, architects, contractors, product and equipment suppliers, and public sector policy makers.

2.2 Scope

The 2003 case study program focused on innovation on projects in Qld, NSW and Vic (the 2005 case study program is likely to be expanded to cover activities in the remaining states). The focus on building and construction *projects* arises because most readily identifiable innovation takes place in that context. The focus on Qld, NSW and Vic was driven by the location of the CRC's industry partners.

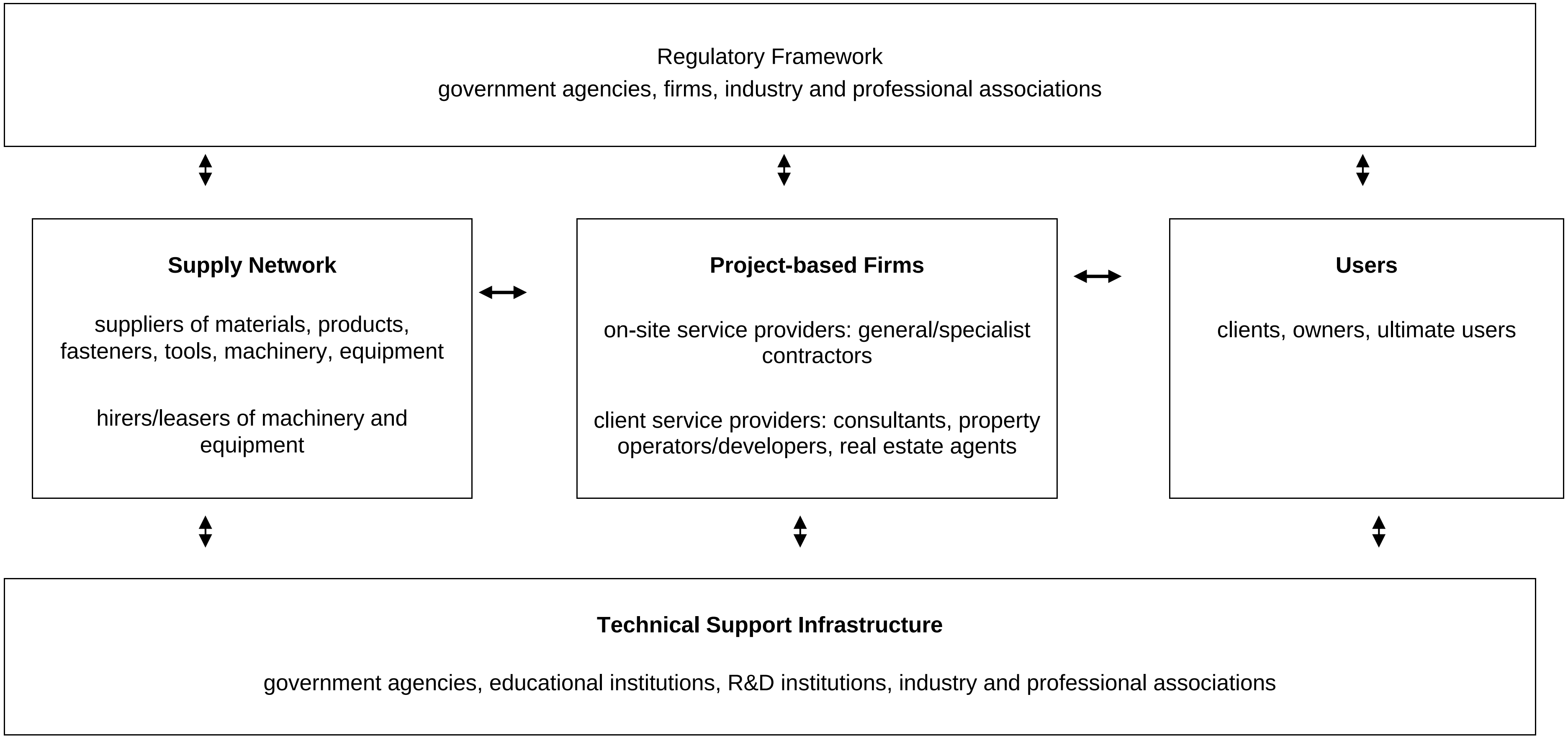
The case studies were nominated by BRITE project partners, and only examples with measured benefits arising from innovation were documented. The studies include innovation arising from the contractor, consultant, client and supplier sub-sectors.

The program was limited to the engineering and commercial building sectors of the industry, reflecting the absence of a CRC industry partner representing residential building. It is also true these sectors are the most innovative when measured by R&D expenditure, and that they are therefore likely to provide good examples of the benefits to be gained from innovation. The scope will remain similar for the Project's 2005 case study program, however examples are likely to be obtained through a public call for nominations, rather than obtained via CRC industry partners.

2.3 Conceptual Framework

The case studies were interpreted according to the influential work of Gann and Salter (1998) and Marceau et al (1999). These authors emphasise the non-linear and highly interactive nature of innovation processes, in the context of a broad view of the boundaries of the Australian building and construction industry. Figure 1 summarises their approach:

Figure 1 Participants and Potential Relationships in the Building and Construction Industry



(Source: Based on Gann and Salter 1998)

Figure 1 provides a good summary of the relevant participants in the building and construction industry and helped in structuring of the case studies and positioning key relationships. Figure 1 also provided a useful analytical tool to assist in thinking about the audience(s) for study output.

While Figure 1 assisted in 'mapping' our case studies, we used the results of our literature review to look for key patterns in the dynamics surrounding innovation processes. This was helpful in pinpointing the elements that were key to the success of each innovation. The factors in Table 1 were used to guide discussion of innovation in the case studies.

Table 1 Key Influences on Innovation in the Building and Construction Industry

• ***Industry relationships***	➢ *power structures, interdependence, workforce structure, appropriation of benefits, craft-based unions, etc.*
• ***Procurement Systems***	➢ *form of contract, legal issues, partnering, alliances, etc.*
• ***Clients***	➢ *level of demand sophistication, etc.*
• ***Regulations***	➢ *prescriptive or performance-based, etc.*
• ***Organisational Resources***	➢ *capabilities, labour relations, margins, champions, absorptive capacity, governance structure, etc.*
• ***Structure of Production***	➢ *project-based, high interdependence, temporary teams, uniqueness of projects, learning discontinuities, innovation brokers, etc.*
• ***Industry Culture***	➢ *adversarial attitudes in the industry create a culture unsupportive of innovation*

2.4 Methodology

The case studies were based on semi-structured interviews, and background documentation including award submissions, academic papers, magazine articles, internal reports and workshop presentations. Each case study involved multiple interviews covering at least two different organisations on the project being analysed. Each interviewee was a senior technical or management representative and the range of interviewees covered all types of industry participants including clients, contractors, consultants and suppliers. Most interviews were conducted face-to-face, with only a few being by phone. All interviewees have cleared the case studies presented in this report. Appendix B lists confidential interviewee details (these should not be employed by other CRC participants without clearance from the BRITE Project leader).

The following sections of this report constitute the six case studies, as presented to the industry in booklet form with photos and graphics.

3. INNOVATION CASE STUDY NO 1: Outstanding Whole-of-Life Gains Without Higher Up-front Costs

A suite of air-conditioning innovations on a new government office building in Cairns – William McCormack Place – is delivering substantial estimated benefits compared to a more conventional approach, including:

- *37% savings in energy costs; and*
- *61% savings in air-conditioning capital and maintenance costs.*

These and other innovations incorporated in the building demonstrate that environmental sustainability can be addressed without compromising quality, cost, time or scope.

3.1 The Project

William McCormack Place is a 4568m^2 (net lettable area) four-storey commercial office building in Cairns, Australia. It was built by a private sector construction manager under a two-stage, design and construct, guaranteed maximum price contract with an overall budget of $17.5m including fitout and public art. The building was opened in September 2002, delivered on time and within budget, after an 18-month design and construction program.

Table 3.1 Selected Project Participants

Client	Queensland Department of Public Works (DPW)
Project Manager	DPW
Design Audit	DPW
Managing Contractor	Barclay Mowlem Construction Ltd
Architects	Cox Rayner and C.A. Architects
Structural/Civil/Fire Engineers	ARUP
Mechanical/ Electrical Engineers	MGF Consultants (NQ) P/L (MGF)

Organisations consulted in preparing this report: DPW and MGF.

3.2 The Achievement

Queensland Department of Public Works (DPW) wanted to demonstrate that an office building could be constructed to meet strict environmental sustainability targets while remaining commercially viable. The Department stipulated that the building must meet a minimum 4-star energy rating under the Australian Building Greenhouse Rating Scheme, administered by the Sustainable Energy Development Authority (SEDA). In fact, the building has exceeded this standard without compromising commercial objectives.

An extensive energy audit conducted in August 2003 found that William McCormack Place has achieved a 5-star energy rating, which is the maximum possible under the SEDA scheme. William McCormack Place is the first commercial office building in Australia to be awarded this rating.

The client and project team have succeeded in designing and constructing a commercial building which minimises life-cycle costs without increasing project costs. The building cost no more to build than a comparable conventional building and will be nominated for the Facility Management Association of Australia, Awards for Excellence, 2004.

3.3 The Innovations

The ‘innovation’ on the William McCormack Place project is the adoption of a unique package of proven technologies and advanced practices, many of which had not previously been employed on DPW projects. The Department notes that often, improved building performance is ‘not a case of the development of complex or costly new technologies but one of effectively using a combination of existing technologies’.

The improvement in life-cycle costs at William McCormack Place is largely due to a collection of well-combined advanced and proven air-conditioning technologies, comprising:

- *chilled water thermal storage tank*: eliminating the need for a low-load chiller and associated prolonged periods of inefficient low-load operation of chiller sets
- *moisture absorbing thermal (heat exchanger) wheel*: used to recover cool and dehumidified outside spill air energy to precondition incoming hot, moist ventilation air
- *variable speed motor drives applied to air-conditioning pumps and fans*: so that only the amount of air or water required at any time is mobilised
- *‘duty-standby’ operation of the two 100% chiller sets*: reaping efficiency gains over the suggested alternative ‘lead-lag’ configuration of two sets at 70% each, plus a low-load set
- *rotary screw chillers and low fan power cooling towers*: facilitating high efficiency chilled water generation

The thermal tank and wheel are the most novel and influential elements of the air-conditioning system, and the focus of this case study. Internal and external quantity surveyors’ reports on William McCormack Place indicate that the cost of a commercial building *with* environmental enhancements, such as those listed above, need be no greater than the cost of a comparable building without such enhancements. The cost of some additional plant at William McCormack Place directly resulted in cost savings in other plant. For example, the cost of the thermal wheel was partly offset by an associated reduction in the required capacity for the refrigeration plant. Additional modest cost savings were achieved through a Value Management study.

3.4 The Benefits

The thermal tank and wheel are major contributors to significant energy savings. Energy costs for William McCormack Place are currently 37% less (on a per square metre net lettable area basis) than the energy costs for similar North Queensland government properties. The savings arise largely from the air-conditioning technologies, assisted by the building structure’s thermal qualities.

These substantial whole-of-life gains are augmented by savings in capital and maintenance costs due to adoption of the thermal tank in preference to a low-load chiller. Comparison of the projected hardware and service costs over 45 years shows savings of 61%. Over that period, the low-load chiller would require on-going maintenance, including a complete rebuild or replacement, while the thermal tank is largely maintenance free.

Overall, DPW wanted to show that an environmentally sustainable office building could be commercially viable. They are on their way to achieving this – the lower energy and maintenance costs for William McCormack Place will increase its capital value and attract higher rents, without having cost more to build.

The above project benefits have been achieved by the adoption of proven advanced technologies and practices, rather than through the development of original innovations. The extent of benefits indicates the significant value of adopting innovations that are simply new in a particular context, rather than necessarily 'new to the world'.

3.5 The Implementation Process

A key driver for adoption of the thermal tank and wheel was DPW's desire to improve the energy efficiency of its buildings, while the mechanical and electrical engineer, MGF Consultants (MGF), was motivated by the potential improvement to their reputation and the belief that this would enhance their competitive position in the marketplace.

Thermal Tank

DPW's original brief suggested that three chiller sets be installed to manage air-conditioning requirements; however, MGF's experience indicated a more efficient system would be to replace the third low-load chiller with a thermal tank to get maximum efficiency from the chillers. MGF designed the first large-scale tank in Australia in the late 1990s, roughly a decade after the first use of tanks overseas, motivated to do so after having monitored their performance via industry newsletters and networks.

MGF understood the technology and had 'runs on the board' proving its effectiveness and the accuracy of payback periods. DPW audit engineers reviewed the design and agreed that energy performance was likely to be significantly improved by the thermal tank. The adoption decision was made against the climatic backdrop of the building. The heat and humidity in Cairns is quite extreme, demanding the use of innovative technologies in order to minimise environmental impacts.

Thermal Wheel

MGF introduced the first total enthalpy thermal wheel into Queensland in 1986 and has since designed several hundred. They were early adopters of this technology, as such wheels only emerged globally in the mid 1980s.

The company's ability to encourage client use of the wheels was assisted by their review of developments overseas. Their knowledge and experience enabled them to strongly champion the use of a thermal wheel on the William McCormack Place project, and DPW was able to confirm the value of the technology with internal mechanical engineers who knew they were widely used in Europe.

The Queensland Government had an interest in local employment for this regional project through its Local Industry Participation Policy, which provided MGF with the opportunity to be involved. MGF was a local firm with considerable expertise, and experience with the often extreme local weather conditions, whilst also having linkages with the technical experts in Australia, America and Europe. The success of this project shows that regional firms can be technology leaders and that knowledge can be gained *from* them, rather than merely imparted *to* them.

3.6 Overcoming Obstacles

Obstacles to the adoption of environmentally friendly technologies, such as the thermal tank and wheel, have traditionally been high up-front costs and risk aversion. However, this case study has shown that:

- the cost element is circumventable when addressed in the context of the overall design and construction of a building; and
- clear objectives and design can reduce the risks for both managing contractors and clients to acceptable levels.

Another historical problem has been the lack of awareness of building users about the negative environmental impacts of conservative approaches to building. However, as concerns about energy and other conservation issues become more prominent, building users have become more savvy – demanding energy-minimising buildings and creating the need for appropriate project delivery mechanisms. The William McCormack Place building illustrates the positive impacts of this trend.

DPW's traditional method of delivery of new office buildings was for a specialist unit to manage the design and construction of a building and then hand it over to the property management area on completion. There were few drivers within this system to maximise building performance, particularly in terms of user-needs and whole-of-life costs. In the case of William McCormack Place, senior management decided that the team responsible for the ongoing management of the building would deliver the project. This gave the opportunity for project decisions to be made not only on the basis of time, budget and quality, but also in terms of the functionality and manageability of the property based on the building life cycle from a *facility management perspective*. This was the first time a major contract was managed by DPW in this way, with the facility manager playing such a significant role. The approach enhanced DPW's role as an informed client, with the required awareness to encourage the adoption of advanced technologies.

The adoption of advanced technologies was also facilitated by the construction management style of contract, which involved the builder very early in the design process. Their early involvement meant no 'rude shocks' when it came to advanced technologies being incorporated into the design. The guaranteed maximum price element of the contract ensured that the design was as thorough as possible, to reduce the builders' risk, and to ensure that the final design was 'buildable'.

Finally, there are often obstacles to adoption of advanced technologies and practices when tender selection is based solely on cost, as innovation is rarely associated with the lowest cost tender. In this case, the mechanical and electrical consultant, MGF, was selected on experience and ability, not just on competitive cost. This approach and MGF's selection was critical to adoption of the thermal tank and wheel.

3.7 Lessons Learned

Environment

- Up-front costs associated with environmental improvements can be modest and manageable, within the context of overall design and construction of a building.
- That environmentally sustainable technologies offer significant improvements in the performance of commercial buildings.

- That clear environmental objectives and thorough design processes reduce risk for both the builder and the client.

Local Firms

- Local firms can offer significant value on large projects, particularly in terms of understanding local conditions.
- Local firms are not always ‘behind the game’ and can in fact be technology leaders.

Clients

- Informed clients facilitate the adoption of advanced technologies and practices through their ability to expertly cross-check innovative proposals.
- Clients willing to entertain acceptable risks can lead the industry in demonstrating the benefits of innovation.

Innovation Processes

- Early involvement of users (eg. facility managers) can lead to optimal outcomes (eg. building performance)
- Attention to international developments is an effective way for industry participants to gain competitive advantage.
- Standards can drive innovation, particularly when set just beyond current capabilities.
- Innovation, via adoption of existing advanced technologies and practices, sits alongside original innovation, as a powerful driver of performance improvement.

4. INNOVATION CASE STUDY NO 2: Concrete Planking Innovation Saves over $300,000 on Major Sports Stadium

A new method of manufacturing concrete planks and connecting them to supporting steel beams has resulted in substantial benefits to the Suncorp Stadium project in Brisbane, Australia. The new 'composite' connection method generated estimated savings of:

- *$260,000 in steelwork costs; and*
- *$70,000 in labour costs.*

4.1 The Project

Suncorp Stadium is a 52,500-seat, world-class football facility, constructed by a private sector managing contractor under a two stage, document and construct, guaranteed maximum price contract, with a project budget of $280m. The stadium was opened in June 2003, delivered on time and within budget, after a 2-year documentation and construction program.

Table 4.1 Selected Project Participants

Client:	Sport and Recreation Queensland (SRQ)
Project Director:	Queensland Department of Public Works (DPW)
Project Manager:	DPW
Managing Contractor:	Multiplex Constructions and Watpac Australia, as the Lang Park Redevelopment Joint Venture
Architects:	HOK Sport and PDT Architects
Engineers:	Arup *Structural/Civil/Transportation/Geotechnical/Environmental/Traffic*
Plank Supplier:	Quickcell Technologies

Organisations consulted in preparing this report: Arup and Quickcell Technologies.

4.2 The Achievement

The 'clever plank' innovation involves the design of *formed* rebates in the ends of precast prestressed *polystyrene-voided* concrete planks, together with the design of concrete topping and reinforcement details, to provide a crack-free, reliable composite connection between the planks and steel beams supporting the grandstands at Suncorp Stadium. The two main elements of this innovation – the polystyrene-voided planks, and the formed rebate detail – have only been combined on a few occasions globally in the building industry. The *particular* planks supplied by Quickcell Technologies, and the *particular* rebate and associated details designed by Arup, are unique to the Stadium project and have resulted in substantial benefits.

4.3 The Innovation

Quickcell Technologies is a small Queensland company that supplied clever planks to the Lang Park Redevelopment Joint Venture. Their unique approach to constructing precast prestressed polystyrene-voided concrete planks contributed to their selection by the managing contractors. Instead of saving plank weight through a more conventional extrusion process which creates a hollow core, Quickcell casts polystyrene blocks into the planks to create voids. This technology is relatively common in the civil sector for bridge beams; however, it is only just beginning to be transferred and modified for use in the building industry. Bridge and building applications are very different; for example, building planks are often required in far greater numbers than bridge beams; further, building planks have a much lower depth and much higher width and a lesser requirement for load bearing, all of which results in different manufacturing processes.

Comparing clever planks to traditional extruded building planks reveals their greater flexibility in the occurrence of voids within each plank. The voids in the cast planks provided by Quickcell Technologies can be positioned to keep the ends of the planks solid, providing enhanced shear resistance, compared to extruded planks which have the same pattern of voids throughout their length. Arup recognised the opportunities offered by the casting process to shape the ends of the panels to achieve reliable *composite* connection to steel beams.

The Arup-designed rebates could be readily formed during the plank casting process, and facilitated efficient and effective composite connection of clever planks to supporting steel beams. The strength of the composite connection in turn created the opportunity to use lighter steel beams, which provided the key savings. Composite connections have been successfully made in the past between steel beams and extruded planks, but this has involved a labour-intensive process of on-site cutting and forming that has negated the cost benefits of the reductions in steel weight.

Quickcell Technologies was the first company in Australia to manufacture precast prestressed *polystyrene-voided* concrete *building* planks (as opposed to bridge beams), and one of the first in the world to do so. Their first use of voided planks was in 1995, and since then the planks have been used on a number of major projects, including the Brisbane Cricket Ground. The planks are protected by a range of intellectual property laws and treaties, domestically and internationally.

The efficiency of the clever plank, with its rebates and capacity for composite connection, was not covered by the Australian Building Code or available research data. Therefore, Arup sponsored an engineering student to conduct full-scale prototype testing to verify the performance of the novel connection design. The testing confirmed its structural efficiency, and the Stadium concourses have been successfully constructed with crack-free concrete topping. Arup and Quickcell Technologies are happy to share in the benefits of the innovation and both organisations intend to apply similar ideas on new projects.

4.4 The Benefits

The use of clever planks reduced the weight of the Stadium grandstand steel floor beams by approximately 25%, due to the efficiency of the composite connection between the planks and the steel beams. This translated to an estimated saving of $260,000, which represented approximately 8% of the cost of the grandstand steelwork. Further, the concrete topping detail resulted in toppings free of the cracking that normally occurs with use of standard planks. Not having to repair cracks resulted in an estimated saving of $70,000. These combined benefits, totalling $330,000, have been estimated compared to precast prestressed polystyrene-voided concrete planks with a conventional *non-composite* connection to steel beams.

4.5 The Implementation Process

The clever plank innovation arose in part from the opportunities for designer and contractor interaction inherent in a document and construct contract. Arup have noted that:

> … the contractual arrangement was not like a lump sum fully documented contract, where the contractor is basically given the design and told to go away and build it. Here, the Joint Venture was encouraged to look at alternative forms of construction.

The preliminary stadium design on which the managing contract was tendered incorporated a structural system assessed as the lowest cost option by quantity surveyors, that is, conventionally formed concrete beams and slabs. When the Joint Venture was appointed, they agreed that the conventional approach was the cheapest in direct costs; however, they pursued the idea of a steel beam and plank design, based on advantages related to time, risk and management of sub-contractors. The Joint Venture asked Arup to explore the technical feasibility of such an approach. It was found that while the components were more expensive for beam and plank construction, the timber and sub-contractor savings related to the absence of formwork were significant.

Formwork is very material and labour intensive. The advantages of not requiring formwork for the stadium included a less congested site without large numbers of form workers; reduced car parking and concrete truck access problems in the inner city location; and no concreter delays/disputes to hold up following trade work. Previous experience with highly unionised workforces and industrial action fed into the decision-making process. Further, the absence of formwork meant that areas underneath the grandstand were not obstructed with temporary propping, which restricts trade work. Finally, formwork is a relatively risky activity because when concrete is poured, subcontractors have to erect scaffolding, planks and ply, designed properly to support the weight. Quality control is an easier proposition, and standards can be guaranteed, when concrete planks are manufactured off-site.

The above advantages result for either extruded or voided planks employed in a conventional non-composite way, although voided planks can be more efficiently attached to supporting beams by adjusting the pattern of voids to create solid ends for more robust fixing. Arup looked beyond these advantages in response to the contractor's request to find further savings.

The contractor's interest in savings was driven by the form of contract. The contract allowed for the development of alternative designs and for shared benefits between the contractor and client if the project was delivered below the guaranteed maximum price. It seems this contractual driver helped to create an environment where innovative ideas were explored and embraced.

Arup's study of a series of steel and precast plank options identified the potential cost savings of lighter steel beams if a reliable and practical method of achieving composite connections between planks and beams could be developed. After consulting with leading researchers in the field of composite steel connections, Arup devised the innovative rebate design. They then calculated the theoretical capacity by extrapolating from available theory and codes, and arranged for full-scale prototype testing to verify the accuracy of the design calculations and the efficiency of the connections. The construction programme dictated that the manufacture of the clever planks commenced before the prototype testing was completed, but the designers were confident that the results would be positive. Arup's confidence in the design has subsequently been borne out by the prototype test results and the faultless performance of the planks and concrete topping on site.

The implementation of the clever plank innovation will not end with this project; both Arup and Quickcell intend to use the innovation on future projects. Arup will maximise these opportunities by publicising clever planks on their internal skills network, which is a formalised knowledge-sharing system operating across the organisation's global operations. They observe that this system 'is imperative because otherwise many of the benefits of a large organisation would be lost'. The company also plans to submit a paper for publication with the Institute of Engineers and is currently providing advice to colleagues considering similar plank and beam approaches. Further, the clever plank innovation has been submitted to Arup's innovation competition, which feeds into the organisation's marketing efforts. Such initiatives encourage employees to take the time to write up the benefits of their innovations, an activity that can otherwise be marginalised in the project-to-project rush of work.

4.6 Overcoming Difficulties

A large part of Arup's role as engineering consultants on projects is to provide ideas to clients and contractors, which benefit these two parties, but not necessarily Arup in a direct sense. Certainly, reputation is important for consultants, especially reputation for money-saving innovations, and Arup profits in this sense. Nevertheless, the benefits from construction innovation are not evenly spread along the supply chain, nor does the proponent/inventor necessarily profit directly. This problematic incentive structure is likely to constrain innovation efforts.

In the clever planks case, Arup was aware of recent changes under the Queensland Department of Public Works prequalification system for building industry consultants, which have seen 'innovation history' added as a criterion. Such moves help to make the benefits of innovation to a company's reputation more tangible, by recording and valuing the extent of the organisation's innovation activity.

Overall, there were few obstacles to the implementation of clever planks on the Stadium project, due to the positive drivers established by the form of contract, which encouraged the contractor to seek and support money-saving innovations.

4.7 Lessons Learned

- Contract type plays a critical role in establishing incentive structures for innovation on projects.
- Robust linkages between suppliers and more central project participants can yield significant dividends.
- Innovation is dependent on good linkages with global experts.
- Prefabricated building components can offer significant project savings.
- Local firms can be global technology leaders.
- Robust relationships between firms and universities provide mutual benefit, enhancing learning and innovation opportunities.
- Government clients play a key role in shaping the industry's innovation opportunities, through both prequalification activities and contract types.
- Internal company award competitions can provide incentives for learnings to be documented and encourage employees to suggest new approaches.

- Labour conditions associated with various trades can effect the direction of innovation by impacting on the likely cost of alternatives.
- Borrowing ideas from related industries is a useful innovation strategy.

5. INNOVATION CASE STUDY NO 3: Motorway Alliance Drives Performance Improvement

A project alliance, formed to design and construct the majority of works for the Port of Brisbane Motorway (POBM) in Queensland, has achieved considerable project benefits, including:

- 10% reduction in project cost;
- 30% reduction in time required for project completion;
- 10% reduction in traffic management costs; and
- 40% reduction in the lost time injury frequency rate.

These gains arose in large part from a preparedness to trial and implement new technology and procedures within the alliance framework, resulting in a project of greater functionality, quality and aesthetic value than was contractually required.

5.1 The Project

The POBM Alliance was formed to deliver five kilometres of four-lane motorway and 12 major new bridges, to carry an expected 8000 trucks per day by 2011, for a Total Cost Estimate (TCE) of $112m. The project was completed early and under the TCE, after a one-year construction program.

Table 5.1 Selected Project Participants

Client:	Queensland Motorways Limited (QML) for Queensland Department of Main Roads (DMR)
Franchisee Operator:	QML
Project Manager:	DMR on behalf on QML
Project Director:	DMR on behalf of QML
Port Motorway Alliance:	Port Motorway Ltd (an entity of QML), Leighton Contractors (Leighton), Parsons Brinckerhoff, Coffey Geosciences

Organisations consulted in preparing this report: QML, DMR, Leighton, Parsons Brinckerhoff, Coffey Geosciences.

5.2 The Achievement

Alliances are an innovative form of project delivery, with Australia leading the way in applying the approach to building and road projects. The POBM Design and Build road project alliance in Queensland appears to be the first alliance of this type employed internationally. It follows from the success of smaller road construction alliances undertaken in Queensland, the first building project alliance internationally (on the successful Australian National Museum project in Canberra), and the longer-running successes of project alliances in the gas and oil industry.

The success of the POBM Alliance arose out of a ‘value-for-money’ approach, which was supported by sound relationships focused around collective responsibility for project delivery, which fostered a ‘best-for-project’ philosophy between participants. The ‘partnership’ culture established was reinforced by contractual arrangements to share 'the pain or gain' depending on actual outcomes compared to target outcomes.

DMR has championed the use of road project alliances in Australia and has reaped the benefits of adapting the traditional alliance formula found on gas and oil projects to the unique demands of complex road projects.

The POBM has won a number of awards, including the Queensland Stormwater Industry Association Award for Design and Planning, 2002; Grand Prize under the Healthy Waterways Awards, 2002; a Commendation for Bridges, under the Public Domain Awards, 2003; Institution of Engineers Australia, Project Management Award, 2003; Case Earth Awards, Environment, Queensland, 2003; and Main Roads Excellence Award 2002 – Director-General's Relationship Award.

5.3 The Innovations

Innovation in project delivery systems is seen as a key means of improving the performance of building and construction projects. Consequently, there has been much work in this area, with project alliances emerging as one of the most recent and comprehensive innovations, focused on improvement through robust relationship management. In pursuing the alliance route, the client stated that:

> … the expectation is that an alliance will achieve the kind of breakthroughs that will be needed to meet or exceed the Project goals – breakthroughs that would not be possible using conventional delivery methods.

The POBM Alliance team was made up of senior representatives from the client, contractors and consultants. The Project Proposal describes the client's intentions with regard to the alliance:

> Unlike traditional forms of contract where risk is allocated to different parties, under a true project alliance, the Alliance Participants take collective ownership of all risk associated with delivery of the project, with equitable sharing (in fixed pre-agreed ratios) of the 'pain' or 'gain' depending on how the outcomes compare with pre-agreed targets. The risk/reward arrangements are designed so that exceptional performance will deliver excellent outcomes for all parties while poor performance will result in poor outcomes for all parties. This underlying commercial alignment is consistent with a 'no blame/best for project' alliance philosophy that focuses all parties on achieving common objectives, so as to attain a 'win-win' result.

These features led to harmonious project relationships and hence the pursuit of opportunities for improved project performance which would not otherwise have been explored. Innovation on the POBM project centred around the alliance itself, but also involved a number of associated developments which were facilitated by the alliance structure. These innovations included:

- three-dimensional Global Positioning System (GPS) to control machinery – adopted for the first time on a construction project in the southern hemisphere;
- third party certification for safety, quality and environment – using integrated management systems to achieve triple-certification for the first time on an Australian road project;
- slip-formed, reinforced bridge barriers – adopted for the first time in Queensland;

- water quality design – winning an Australian award; and
- elevated tri-level motorway interchange – the first designed and constructed in Queensland.

5.4 The Benefits

The benefits of the innovations adopted under the POBM Alliance are extensive. The main measured benefits included:

Table 2 The Benefits of Innovations

Project Cost	• 10% saving on the TCE – this amounted to a saving for the client of $13.4m, $5.5m of which was delivered as additional project scope
Time	• delivered 6 months ahead of expectations, representing a 30% reduction in time required for completion
Traffic Management Costs	• 10% reduction in traffic management costs compared to recent South East Queensland projects – traffic management costs on the POBM constituted 2.3% of construction costs, compared to an average of 2.6% across similar projects
Lost Time Injury Frequency Rate (LTIFR)	• 40% improvement in the LTIFR, which for the Alliance package on POBM was 3.5, compared to an average rate for Leighton's civil projects of 5.9 over the past three years – this result has been assisted by innovations such as 3-dimensional GPS, which reduces the rate of injury to 'stringers' interacting with earthmoving machinery
Direct Bridge Costs	• saved up to 30% in direct bridge costs compared to industry averages
Earthworks/Drainage/Pavements	• all delivered at the lower to mid-region of the range of costs associated with a sample of major urban road projects in South East Queensland

These measured benefits sit alongside a number of other significant project achievements flowing from the innovative alliance structure, many of which are difficult to quantify. For example, the project was completed with no residual contractual issues or risk of litigation and no requirement to allow further contingencies for these issues. This meant less dependence on programming resources for activities other than those focussed on 'getting the project built'. This outcome was despite the emergence of several construction related issues which, under a traditional delivery method, would most likely have led to extra cost and/or delays.

Another key benefit of the Alliance was the integration of the alliance works on the POBM with other POBM works packages being conducted around the same time. The incentive structures within the Alliance were linked to the successful completion of all four POBM works packages. One of these (Package 1, the early works) was delayed, potentially impacting the overall project. Under normal circumstances, with a hard dollar contract for the main works (Package 3 – the Alliance), problems with the early works would have resulted in contract variations. However, the alliance structure encouraged a flexible 'best for project' response. The Alliance agreed (without variation) to manage the pre-load settlement process, giving it freedom to optimise the placement of surcharge fill and use excess fill as required elsewhere on the project, thereby freeing up the flow of works with no need for the pre-load team on-site. The early works package and the Alliance (in association with extra scope works at a new interchange) utilised polystyrene fill to minimise settlement in difficult areas. This was the first use of polystyrene fill in Queensland.

Other Alliance benefits included:

- negotiation of several 'win/win' community/project trade-offs, including innovative noise amelioration treatment at a local school;
- negotiation of financial win/win outcomes between Alliance participants;
- excellent stakeholder relations, which will assist in expediting related works planned for the future;
- supporting Queensland Government Priorities;
- safety auditing of traffic control plans;
- savings achieved through negotiation of performance incentives with major suppliers; and
- private and public sectors working together and dispelling some myths regarding the calibre, capability, attitude and commitment of government employees.

5.5 The Implementation Process

Generally speaking, alliances are driven initially by clients. DMR and QML chose an alliance contract to deliver the POBM in view of the need for improved delivery performance on road projects, especially complex ones, to address concerns about poor cost/time outcomes, unsatisfactory quality, high rates of rework, poor stakeholder/community relations, and dissatisfied clients, designers and contractors. Their choice was driven by their knowledge of potential benefits, given their first hand experiences on smaller alliance projects and their research into alliances in other industries. The initiative was in keeping with senior management commitment to innovative project delivery.

Further, there was recent advice from government auditors in the UK and Australia suggesting that public sector accountability concerns are not compromised by alliances as a form of project delivery. Indeed, it is likely that alliances will be employed with increasing frequency, as best practice public sector clients turn their attention away from hard dollar project delivery models toward more effective 'value-for-money' approaches. Implementation of alliances is also being facilitated in Australia by the lead taken by major contractors in championing the approach.

The above factors help explain the choice of an Alliance contract for the POBM. Within that structure, the team was keen to maximise outcomes, so DMR provided the opportunity to 'challenge' their Standard Specifications and established construction procedures and practice, through a detailed peer review process, value management workshops and joint problem-solving exercises. This resulted in key initiatives which underpinned project benefits, such as co-location of designers and geotechnical staff on site with construction personnel. Consultants were then easily accessible, enabling timely responses to constructability issues. Indeed, in order to deliver under the TCE, the Alliance '…recognised the need for a high level of design input, and more importantly, a significant integration of design, planning and construction activities.'

The Alliance also appointed an in-house Culture Manager to champion the alliance approach and assist in maintaining harmonious relationships and encouraging project integration, in part by providing coaching and support services. The emphasis on strong integration of project functions and building trust through effective relationships is reflected in the significant investment made in the design process and site management/facilities. The Alliance considers that this investment in integrated design, planning and construction was a major factor in achieving the project benefits outlined above.

5.6 Overcoming Difficulties

The Alliance encountered a number of significant difficulties during the project. Many of these involved relationships with the community, including community irritation with the ‘start/stop’ nature of the project in its planning and development stages; serious noise concerns from a local school; road closures resulting in loss of access; and construction across floodplains and wetlands, with associated environmental problems. The project’s full-time Community Liaison Officer was a key resource in addressing these problems. The Officer promoted community ownership of the project, coordinating initiatives such as painted noise barriers, community events, site tours and a community hotline. These activities assisted in securing community support.

Nevertheless, the floodplain/wetland problem around the Bulimba Creek Oxbow was particularly difficult for the Alliance. Rehabilitation of the area was an objective of the Alliance from the outset of the project (following ministerial commitments and advice contained in an earlier Impact Assessment Statement). The TCE included an allowance for a feasibility study. However, environmental groups were keen to see a fuller commitment to rehabilitation of the Oxbow area as part of the POBM project. Indeed, the area was already significantly degraded and the motorway works could easily have exacerbated the problem. The Alliance took the lead in developing a Memorandum of Understanding between key stakeholders and securing a commitment of funds to carry out the rehabilitation. The Alliance framework accommodated the increase in scope that a full rehabilitation involved and facilitated the excellent results that have been recognised by several environment awards.

The ‘virtual organisation’ represented by the Alliance structure was able to draw on the collective skills of its team to find a best practice solution to the Oxbow problem. Initially, it appeared that $11m in bridges and culverts would be required to meet the "hydro-ecology" objectives of environmental groups. However, through the adoption of advanced flood modelling software, the Alliance was able to demonstrate that $250,000 in strategically placed earthworks and drainage structure would achieve similar environmental outcomes. The modelling software helped convince all stakeholders, through quantitative analysis, that the outcome being proposed was optimal. This solution was adopted thanks to a well structured team approach, which effectively integrated the often separate skills of design and construction.

There were other difficulties, which were internal rather than external. Firstly, there were challenges in adopting the Alliance ‘best for project’ culture. Although participants directly related with the project were well supported in making the required mind-shift from hard-dollar contracts, those at more junior levels and those further removed from the project adapted less well to the new delivery system. This caused some relationship problems between the Alliance and some DMR groups not directly involved with the project. However, during the course of the project, these problems became less frequent as the level of exposure of DMR officers to the Alliance culture improved.

Secondly, the preliminary design (horizontal and vertical geometry) of the Port Motorway presented some challenges and needed to be optimised in the detailed design stage. This included adjustments to the geometry to achieve the required design speeds in a very constrained site at the Gateway Motorway interchange. Leighton and Parsons Brinckerhoff came up with an innovative structural arrangement, involving a portal beam assembled in two parts, which spanned the Gateway Motorway. Adjustments to the design were also required to minimise the embankment heights on the soft foundation soils, while still maintaining flood protection. The optimum design was achieved with the designers (Parsons Brinckerhoff, Coffey Geosciences and DMR staff) working closely with the builder Leighton.

Thirdly, the design brief specified a 6.6 metre clearance height to bridge structures. However, Parsons Brinckerhoff challenged this and, in consultation with DMR, it was agreed to reduce clearances to 6.1 metres consistent with the adjoining motorway network, given that an alternative route for excess height vehicles was available. This adjustment delivered significant cost savings.

Fourthly, exclusive use of DMR's standard (generally prescriptive) specifications for traditional delivery could have hampered the flexibility of the Alliance to pursue innovative solutions. Therefore, the Alliance and DMR adopted a 'fit-for-purpose' approach to the design and construction activities, enabling a more effective and efficient outcome.

Finally, the Alliance structure and the large scope of the project encouraged the team to put aside their risk aversion and trial a range of new technologies, including slip-formed, reinforced bridge barriers. Initially, DMR had some reservations about the bridge barrier technology being proposed by Leighton, concerned that it would not produce a fit-for-purpose result. Often, that would be the end of an innovation; however, in a collaborative alliance context and with many bridges to construct, Leighton and DMR had sufficient incentive to undertake some tests. The results justified the use of a concrete paving machine, instead of formworkers, providing project benefits in safety, labour costs and time.

5.7 Lessons Learned

The Alliance reviewed project performance and noted key learnings, including:

- building sound relationships with project stakeholders provides a solid platform for the resolution of issues which, under a traditional contract, could be insurmountable barriers to project completion;
- preparedness to trial and implement new technology results in excellent project outcomes in terms of cost, innovation and quality;
- involvement of designers in all phases of the project alliance is critical to producing infrastructure that is fit-for-purpose and meets quality and safety requirements;
- peer review of the design process is very effective in ensuring 'value-for-money' outcomes; and
- external review of quality assurance and key performance indicators is particularly necessary under alliances to ensure good project governance.

At a more detailed level, DMR and QML advise that, in relation to project alliances, clients should:

- develop a sound budget before entering into a project alliance, because budgets set expectations about TCEs;
- be informed buyers so they can make informed decisions – having designers and other technical experts as alliance members helps in this regard;

- show leadership to ensure that design changes intended to result in value improvements do not lead to reduced standards;
- conduct a financial audit of the Alliance proponent, rather than seeking financial information from all alliance project offerers in the initial stages of the selection process, in order to minimise the cost of tendering and improve value-for-money;
- conduct thorough workshops with offerers to help establish the effectiveness of relationships between various teams and the client;
- encourage the use of value management workshops and joint problem-solving exercises by the alliance team to help develop an appropriate scope of work to achieve needed functionality at acceptable cost;
- be involved in development of the TCE to avoid the perception that the TCE is a quasi-tender bid; and
- exercise care in the adoption of fit-for-purpose standards, and involve peer reviewers in the development of the TCE, to ensure that the drive to reduce cost is appropriately balanced against operational suitability, durability and whole-of-life costs.

6. INNOVATION CASE STUDY NO 4: Performance-Based Building Codes and Fire Engineering Yield Innovative Design Solution

The use of fire engineering tools, particularly cutting-edge quantitative risk assessment techniques (QRA), reduced construction costs for the National Gallery of Victoria (NGV)-Australian Art Building by 4-5%.

Development and application of these innovative tools was driven by introduction of the performance-based Building Code of Australia (BCA), and resulted in the use of unprotected steel for the structure of the building, thereby saving approximately:

- $3 million in construction costs; and
- several thousand dollars per year in on-going maintenance costs.

6.1 The Project

The NGV-Australian Art Building is a centrepiece of the Federation Square development in Melbourne. Federation Square is one of Australia's civic and cultural icons, incorporating multi-media, art, museum and office buildings.

The NGV-Australian Art building was constructed by a private sector managing contractor and was completed in 2002 for approximately $65 million.

Table 6.1 Selected Project Participants

Client	Victorian Department of Infrastructure – Office of Major Projects /Federation Square Management Company
Managing Contractor	Multiplex
Architects	Lab Architecture Studio in association with Bates Smart
Fire Engineers	Arup Fire

Organisations consulted in preparing this report: ARUP and Federation Square Management Company

6.2 The Achievement

Part way into the project's design and planning stage, the managing contractor decided to pursue steel alternatives to the intended concrete and masonry building design. This decision was mainly driven by doubts about the capacity of a concrete deck to withstand the proposed constructional loads.

As time and budget issues were beginning to cause concern when the switch to steel occurred, a solution that minimised cost and time was imperative. The design team, which included the architects, the building surveyor, the fire engineers and other consultants, explored a number of options, with unprotected steel emerging as the best solution. If the steel did not have to be protected, it would aid in meeting the objectives of reducing cost and time, as the process of applying fire protective coatings to steel is expensive and time-consuming.

As well as demonstrating that the use of unprotected steel would not increase the cost of the project or delay its completion, the design team needed to demonstrate that it would not:

- endanger the occupants of the building if there was a fire; and
- increase the expected level of property damage if there was a fire (property damage was a critical consideration, given the value of the intended contents of the NGV-Australian Art Building).

The team had to show that unprotected steel would perform at least as well as the generally accepted construction materials of masonry and concrete. The comparison was necessary to comply with relevant building regulations. Under the BCA, buildings could be designed to meet certain performance requirements by either:

- following the prescriptive, 'deemed-to-satisfy' requirements set out in the BCA itself (i.e. a design based on concrete and masonry construction – Type A construction); or
- demonstrating that a solution equivalent to the deemed-to-satisfy case could be adopted, even if arrived at in a different way or with the use of different materials (e.g. the use of unprotected steel based on the application of fire science and engineering).

The team was ultimately successful in demonstrating time and cost savings with comparable fire safety outcomes.

6.3 The Innovation

The innovation on the NGV-Australian Art Building examined by this study has three main elements:

- use of the performance-based BCA;
- use of QRA; and
- use of unprotected steel.

The innovation was in the adoption of these approaches and their combination to achieve project benefits. Globally, since the early 1990s, there has been a shift to performance-based building codes, with the BCA making the change in its 1996 edition. Performance-based codes have made it easier to develop alternative building designs.

On the NGV-Australian Art Building project, the performance-based BCA allowed the design and approval process to be completed at least twice as quickly as it would have been under the pre-1996 BCA. This speed – 3 months compared to 6-12 months under the old system – was a key driver of the unprotected steel innovation.

Unprotected steel emerged globally in the early 1990s, but has been used for very few large buildings (where fire safety is particularly challenging). The fire engineers on the NGV-Australian Art Building noted that they 'knew of only three previous examples of unprotected steel use in large building developments in Australia. Its rate of use is expected to rapidly increase in the future as designers and computer technologies catch up with the new opportunities and as clients adjust to new approaches.

The use of unprotected steel was also facilitated by QRA which allows building owners and developers to evaluate the risks of fire against their corporate objectives and make optimal decisions consistent with their risk management policies. QRA techniques are commonly used in the building and construction industry, for example by transportation and environmental engineers. However, the use of QRA to assess the fire resistance of structural steel is a new field globally, which emerged in the mid-1990s in conjunction with performance-based building codes, and large increases in computer power that are necessary for modelling and testing. Indeed, there are only 30-50 experts in fire and steel safety worldwide, attached to a handful of universities, research centres and private companies.

6.4 The Benefits

Using QRA, the fire engineers were able to show that unprotected steel would deliver fire damage outcomes equivalent to those of protected steel. An exercise modelling fire damage showed that if unprotected steel was used, in all but the three key support columns (which were protected for risk management reasons), the overall cost of fire would be $8500 per year, averaged over the 25-year design life of the building.

By contrast, if the building had been constructed using the BCA's deemed-to-satisfy concrete method (Type A construction), the overall cost of fire would be $8700 per year. Therefore, unprotected steel (including the fire safety systems for contents protection) was shown to offer a fire cost projection broadly equivalent to the BCA Deemed-to-Satisfy compliant concrete. Without the need to apply expensive fire protection finishes to steel, approximately $3 million was saved in construction costs.

Although maintenance benefits of unprotected steel were not fully quantified, the fire engineers also considered that 'several thousand dollars per year were likely to be saved, because unprotected steel does not require monitoring or re-coating.' The inspection process for protected steel would have been very costly on the NGV-Australian Art Building, as 60-70% of the steel is fairly inaccessible, being behind wall cavities and in ceiling spaces. Further, all of the steel would have been inspected gradually over a 5-10 year period and parts of the building would have been shut down during many of the inspections, due to the requirement for a dust-free environment within the galleries.

The use of structural steel also eliminated numerous difficulties associated with construction using concrete. A concrete structure would have required complex propping and temporary structural support that would have created problems in accessing the NGV-Australian Art Building site. Eliminating the need for these works saved the project an additional $1 million. Also, the lightweight nature of steel meant that smaller cranes could be used, and structural elements were more manageable on site.

Finally, the use of steel rather than concrete provided architectural and functional benefits, with more flexibility in the architectural layout, more effective use of space and increased size of fire compartments.

6.5 The Implementation Process

The key to the benefits achieved by the use of unprotected steel was the QRA, which, in turn, was particularly useful because of the possibilities opened up by the performance-based BCA. The managing contractor drove the design shift from concrete to steel, based on their experience of the benefits of steel. The design team drove the use of *unprotected* steel, reaping time and cost benefits, principally by employing QRA.

Risk assessment techniques, such as QRA, are used to evaluate the frequency and probability of threatening events such as fires. Once risks are assessed, options to reduce the risks can be examined and costed, and the most effective option adopted.

There are a number of approaches to risk assessment for fire safety decision-making. One of the most complex of these approaches is QRA based on fault and event scenarios. Fault scenarios can be used to identify mechanisms of failure leading to fire starts. Event scenarios can then be drawn up and evaluated to identify the probability of the fire going from ignition to various stages of fire development and the levels of threat to occupants and property. In Australia, this approach is known as an Evaluation Extent 3 or System Risk Evaluation approach, as defined in the Australian Building Codes Board Fire Safety Engineering Guidelines.

In the case of the NGV-Australian Art Building, the concept of five states of fire growth was used in the risk assessment in order to assess the probability and consequences of various times to activation of the fire safety systems and human intervention. Further, a number of events and factors were incorporated into the analysis and the associated probabilities enumerated in order to determine the overall probability of fire development and damage to property. These three features – the five fire states, the application of QRA to property and the method of probabilistic analysis – are cutting-edge. They have been used only rarely globally, and were adopted by the fire engineers on the project through their linkages with international experts, such as engineers with the National Research Council of Canada.

6.6 Overcoming Difficulties

One of the primary challenges in the adoption of the fire engineering/unprotected steel innovation was addressing the safety concerns of a number of stakeholders, including the client, about the new approach. Members of the design team were able to effectively use fire engineering tools, and a cooperative approach, to educate the stakeholders about the relative risks and allay their fears.

One of the key reasons for concern, particularly for the client, was that the QRA approach to fire safety engineering is an analytical process, as opposed to a physical testing-based approach. Acceptance of the QRA results requires understanding its theoretical underpinnings, and appreciating the logic that leads to the outcomes. These can be more conceptually difficult than results based on physical testing of materials.

QRA is a significant departure from *prescriptive, rule-based* approaches to building construction, and this may also have been a reason for concern. Despite the capacity of QRA to arrive at what are, in many cases, safer and less expensive construction methods, there is still a residual tendency for many stakeholders to prefer uncomplicated rules prescribing conventional building materials and methods. Put simply, QRA is harder to understand than prescriptive rules and this can result in risk-averse responses to its adoption. However, as this case study demonstrates, it is possible to reduce this problem using education and a cooperative approach.

6.7 Lessons Learned

- Performance-based building codes promote innovation.
- Innovation is enhanced by international linkages with global experts.
- Computer advances can be crucial to innovation in other areas.
- Risk aversion needs to be addressed within the Australian building culture, as it continues to act as an impediment to novel innovation.
- Education and a cooperative approach can help overcome objections to innovation.
- Performance-based approaches to fire engineering have the potential to deliver design/structural innovation which results in more functional buildings, equal or better levels of fire safety, increased cost effectiveness in construction and through-life performance, and more flexibility in design.

7. INNOVATION CASE STUDY NO 5: Australia's First Fibre-Reinforced Polymer Bridge Deck on the Road Network

In February 2003, the first fibre-reinforced polymer (FRP) (fibre composite) bridge deck was installed on the Australian road network, at Coutts Crossing, New South Wales. The new bridge deck design offered substantial benefits over traditional bridge deck design, including the following estimates:

- installation in only 5 days, instead of 8 to 10 weeks;
- 90% saving on traffic control costs; and
- 75% saving on bridge transportation costs.

7.1 The Project

The bridge at Coutts Crossing spans the Orara River, in northern New South Wales. The FRP bridge deck was installed in 2003 to replace a timber span constructed in the 1930s. The Coutts Crossing bridge is 90 metres long and 7 metres wide. The FRP deck replaced 12 metres of the bridge length. It was commissioned by the Roads and Traffic Authority of New South Wales (RTA), and was constructed and installed by Wagners Composite Fibre Technologies Pty Ltd (WCFT). The FRP bridge deck was designed by Connell Wagner, drawing on an earlier WCFT -University of Southern Queensland (USQ), Fibre Composites Design and Development (FCDD) prototype design.

Table 7.1 Selected Project Participants

Client	RTA
Diagnostic testing and consulting	Queensland Department of Main Roads (DMR)
Consulting engineers	Connell Wagner Pty Ltd
Prototype designers	WCFT FCDD
Manufacturer and installation	WCFT

Organisations consulted in preparing this report: RTA, WCFT, DMR, FCDD

7.2 The Achievement

Coutts Crossing is Australia's first FRP bridge deck on a road network. It is also one of the first such bridge decks in the world. Although many fibre composite pedestrian bridges have been built as technology demonstrators overseas, the development of the FRP fibre composite bridge at Coutts Crossing pushed the boundaries of conventional bridge construction methods and materials as well as current fibre composite technology worldwide. The main achievement of the technology at Coutts Crossing was that bridge members were far bulkier and more robust than those found in existing FRP bridges worldwide, making them suitable for Australian conditions and carrying vehicular traffic. This achievement relies on the modular construction method pioneered in WCFT/FCDD's prototype bridge beam and applied at Coutts Crossing.

The Coutts Crossing bridge is the result of close collaboration between RTA and WCFT, which saw the parties share costs: RTA paying for the cost of a conventional bridge and

WCFT making up the difference to pay for the FRP bridge, which was an extra 50%. The Coutts Crossing FRP bridge is a hand-made prototype and therefore was relatively costly to build. Research by the manufacturer, however, suggests that the installed cost of its FRP bridges will match that of conventional bridges when it commences full-scale manufacture early in 2004 and begins to reap economies of scale.

7.3 The Innovation

'tomorrow's infrastructure will not be built using today's technology'

The innovation lay in the modular construction of the FRP bridge deck and the hybrid engineering of the material usage. There are three basic shapes that make up a FRP beam – a hollowed-out glass square shape, a long carbon strip, and a rectangular concrete shape. These shapes are adhered with special adhesives to make a beam. The hollowed-out glass squares are adhered together to create a box section. The carbon strip is glued along the bottom of the box section and the concrete is then adhered on top of the glass box to complete the beam section. These beams are then glued together to make a deck section. A number of decks go to make up a complete bridge deck. Because the system is modular, if bridge length increases, more modules are used; if bridge length decreases, fewer modules are used.

The above components, and their mechanical interaction, constitute the particular composite mix (the FRP) employed at Coutts Crossing (and in the prototype bridge). This composite design has never before been used, and was developed specifically for bridges, to mimic a conventional concrete bridge deck, which is accepted best practice.

7.4 The Benefits

In general terms, composite fibre structures have a number of features that make them attractive for use in bridge structures, including high strength-to-weight and stiffness-to-weight ratios, corrosion and fatigue resistance, and tailorability. Replacement of heavier concrete and timber decks by lighter fibre composite decks also allows for an increase in traffic load, without an overall increase in load on the supporting structure. Fibre composite decks also have potential for use in areas where longer spans are necessary or where lower weight would translate into increased seismic resistance.

Additionally, fibre composites have significant benefits when used in so-called 'aggressive' environments, such as on the coast or in environments with snowfalls and de-icing salts, because the product is completely inert, i.e. non-corrosive and non-conductive. FRP bridges are expected to have much lower ongoing maintenance costs when used in such environments (while this is unproven at this stage, parties involved in the project believe this has enormous potential), and offer a similar, if not longer, lifespan to alternative bridge designs. Indeed, unlike the alternative bridge types (1) to (5) listed below, FRP bridges can be factory produced and therefore should be of higher quality.

At this stage, composite materials are still quite expensive, largely because of the costs of resins. However, costs are expected to fall as mass production is undertaken. Current research is looking at ways to optimise the design to bring costs down even further.

Looking at the Coutts Crossing project in particular, several forms of superstructure replacement could have been used, including:

1. Doolan timber concrete composite decking;
2. M-Lock decking;
3. NSW conventional PSC planks with *in situ* concrete overlay;
4. Queensland conventional PSC planks without *in situ* concrete overlay; and
5. Other, less used proprietary decking systems.

Options (1), (2), and most of (5) could have been installed over much the same timeframe as an FRP deck; quicker than options (3) and (4). Hence, FRP savings in traffic management costs would have been marginal when compared with options (1), (2) and (5). However, the major advantage of the FRP structure over all the listed alternative superstructures was its light weight and the associated reduction in transportation and foundation costs this could deliver.

For the conditions associated with the Coutts Crossing project, (3) was considered the next best alternative to the FRP bridge and is the comparator used to derive benefit estimates. Time required to install (3) was estimated to be 8 to 10 weeks, while the FRP bridge was installed in 5 days, translating to substantial traffic management savings of approximately 90%. The lighter deck weight of the FRP bridge (55 tonnes compared to 114 tonnes) also saved 75% in transportation costs.

Normally, there would also have been an associated reduction of 27% in foundation costs; however, as the Coutts Crossing bridge was a demonstration project, the loading for a relatively heavy conventional prestressed concrete plank deck was used in design to reduce risks. It is expected that this measure will prove unnecessary in the future. Indeed, the design at Coutts Crossing was conservative, since it was the first project of its kind, and it can be expected that weight and related cost savings will be greater on future projects.

7.5 The Implementation Process

‘… innovation is a constant effort to stay outside your comfort zone’

The installation of the bridge deck at Coutts Crossing in February 2003 represented the culmination of more than five years of extensive collaborative research and development by a number of enthusiastic individuals and organisations, including state and federal government departments, private sector firms and the university sector. The Coutts Crossing project would not have been possible without this background research and development.

USQ’s FCDD Group started research into fibre composite bridges in 1996. Shortly afterwards, Connell Wagner consulting engineers joined the research effort, with DMR becoming involved in 1998, contributing important practical design information. The bridge design moved away from the initial lightweight ‘thin walled’ approach to a slightly heavier, but more robust, bridge structure. Through the development of an innovative casting technology, a far more economical and practical solution was obtained in mid-2001.

In 2000, the Cooperative Research Centre for Advanced Composite Structures, in conjunction with RTA and the Commonwealth Department of Industry, Science and Resources, instigated a feasibility study to evaluate the suitability of advanced composite materials for Australian civil infrastructure applications. A generic design exercise established which particular technologies should be encouraged. This involved the generation of a performance specification that met RTA requirements and the submission of two conforming preliminary design concepts.

One of these was a concept developed by an Australian FCDD-led team. RTA selected this solution as the preferred alternative for demonstrating the appropriateness of the materials for Australian conditions. The economics of the design were potentially comparable with those associated with bridge construction using conventional materials. RTA also considered that the polymer composite design had other through-life advantages that increased its attractiveness.

In 2001, a project team consisting of WCFT, FCDD, RTA and DMR completed the development of the concept and installed the first prototype on a quarry site at Wellcamp, near Toowoomba in Queensland, owned by Wagners Investments Pty Ltd (Wagners). WCFT played a key role in both the prototype bridge and the Coutts Crossing bridge. WCFT is a trading division of Wagners, a Toowoomba-based company with interests in concrete, quarries and transport. A relatively young company (formed in 1989), Wagners had a strong background in research and development, pouring millions of dollars a year into research activities. Wagners management sums up its approach to innovation as ‘a constant effort to stay outside our comfort zone’ and ‘its belief that tomorrow’s infrastructure will not be built using today’s technology’.

Wagners first learned of fibre composites technology when USQ, which had placed a graduate engineer with the company, asked it to look at the feasibility of a lightweight semi-trailer as part of the graduate engineer’s project. Wagners quickly saw the potential for other applications of fibre composite technology, including for rail sleepers, cross arms, power poles and bridges and beams. A research and development project on fibre composite bridges was launched and WCFT contributed significant up-front funding to develop the prototype bridge beam, which was matched dollar-for-dollar by an AusIndustry grant. WCFT (and Wagners) did not expect to make an immediate return on its investments in research, but could see a longer-term commercial return. Indeed, WCFT is planning to start operation of a production line early in 2004, which is expected to deliver the first fibre composite profits for the company. To date, WCFT has put many millions of dollars into research on fibre composite bridges.

DMR was also an important contributor to the prototype development project, contributing the time of one of its bridge engineers, as well as testing equipment and a small cash payment to FCDD. The DMR engineer’s role was two-fold. First, she contributed technical expertise to the project. Second, and very importantly, she ensured that the prototype was one that could later be transformed into a product commercially available to DMR for use on Queensland’s road networks. The engineer ensured that the prototype met DMR’s design, safety and environmental criteria and that it was constructed in a way that delivered a suitable cost structure for later use.

The prototype was completed in early 2002, and an extensive series of field tests followed, revealing that the concept exceeded expectations of its technical performance. The prototype bridge is still in use at Wagner’s quarry, with an estimated 150 quarry trucks passing over it every day. ‘Health’ monitoring is ongoing. The prototype bridge project was awarded a ‘Highly Commended’ by the Institution of Engineers in September 2002.

The success of the prototype led to the proposal to place an FRP bridge on the road network. After initial project development by RTA, WCFT, and FCDD, a site was selected and it was decided to replace an existing timber span bridge at Coutts Crossing. Connell Wagner was engaged by WCFT to review and modify FCDD’s fibre composite bridge concept to suit the site-specific requirements (essentially, however, the design was the same as the prototype). The new Coutts Crossing bridge is an innovative combination of fibre composite and conventional materials constructed and installed by WCFT. FCDD assisted

RTA in its superintending responsibilities. Initial site testing shows that the bridge is performing well, and this will be periodically monitored by RTA over coming years.

WCFT treated the installation of the bridge at Coutts Crossing as a research and development project, largely because the RTA budget would only allow for the cost of an equivalent bridge constructed from traditional materials. WCFT has, however, been able to apply the experiences learned during the project, and expects that mass production will lead to profitable sales to road and traffic authorities in the near future. WCFT has a patent over the design cross-section of the individual beams as well as the manufacturing process used for construction of the bridge deck. WCFT believes that the collaborative history of the project involving DMR, RTA, FCDD and others has been invaluable in the commercial development of the technology. These partners steered WCFT in directions it might not have otherwise gone, and also provided essential technical and moral support.

The partners continue to conduct individual research projects on fibre composites, as exploring the full potential of the technology remains an on-going priority for them.

7.6 Overcoming Difficulties

Manufacture of the fibre composite bridge prototype proved to be a challenging task. The fibre composite industry is not new – it sells to the aerospace, marine and other industries – however the construction industry is a new market for fibre composites. Accordingly, material uniformity and product stability were still being developed during the prototype process. There are thousands of resins and fibres, all with different structural properties, that could have been used.

The first batch of pultrusions supplied to make the prototype bridge was rejected, as the product did not meet DMR and WCFT standards for bridge components. Another problem was encountered with the adhesive to connect the pultrusions. The heat distortion temperature was meant to be 100 degrees Celsius, but a chemical manufacturer up the supply chain had changed the chemical properties of the adhesive, so that the heat distortion temperature was only 60 degrees Celsius. The design team was, however, able to out-engineer this concern and accommodate the difference.

The DMR engineer involved in development of the FRP bridge describes the challenges in her USQ Masters thesis, which observes that the design of the fibre composite deck units evolved through several phases during the prototype development process. The use of combined modular sections to make bridge beams was a constant theme, however the type of modules, materials and design philosophy changed dramatically, as difficulties were encountered and overcome. In all, five designs were trialled.

Another difficulty – or perhaps more a challenge than a difficulty – was that so many parties were involved in the development and construction of the prototype bridge. These parties were from different backgrounds – academia, the private sector and government. At times, differences in objectives became apparent, particularly when the costs or quality of materials to be used were at issue. It appears that tensions were overcome by overwhelming goodwill and trust established between the parties during the development stage. Another element in the successful resolution of conflicts was the interest that the parties had in successful completion of the project – for example, WCFT in future commercial sales of its product, DMR in the future application of the technology to Queensland's bridges, and materials suppliers in supplying to manufacturers like WCFT in the future. Individuals interviewed for the case study indicated that the involvement of all the collaborators was essential to the success of the project.

7.7 Lessons Learned

- Innovations are fostered by collaborations between industry, academia and government.
- Companies believe that investing money in research and development can reap significant commercial benefits.
- Involvement of clients in the early stages of innovation development can improve outcomes.
- Linkages with university research bodies can yield commercial benefits for far-sighted companies.
- Goodwill and trust are essential in collaborative innovations.
- Public sector research and development grant schemes can yield tangible commercial benefits.
- Successful innovation often requires commitment, perseverance and a willingness to sacrifice short-term gain.

8. INNOVATION CASE STUDY NO 6: Ground Penetrating Radar Finds Defects in Bridge Beams

Use of Ground Penetrating Radar (GPR) has reaped significant savings in redressing problems with defective bridge beams on the Cattle Creek Bridge project located in Mackay, north Queensland. Fifty per cent of the cost of completely replacing the defective beams was saved because GPR provided the ability to reliably locate the defects in the beams and repair them *in-situ.*

This is believed to be a world first – use of latest generation high-frequency GPR to identify if movement of purpose-made voids had occurred during manufacture of prestressed concrete bridge deck beams.

Perhaps more importantly, the project created the conditions for refinement and demonstration of advanced technology that more efficiently allows for rapid, non-destructive, and non-invasive inspection of the internal structure of concrete.

8.1 The Project

The original timber bridge over Cattle Creek was constructed in 1941. It was replaced in 1999 by a concrete bridge, which was constructed by a private sector contractor under a Schedule of Rates agreement. The bridge opened in May 2000, following the cooperative and innovative resolution of problems with defective concrete bridge beams, using GPR.

Table 8.1 Selected Project Participants

Client	Queensland Department of Main Roads (QDMR)
Head Contractor	Abigroup
GPR consultant	Georadar Research Pty Ltd

Organisations consulted in preparing this report: QDMR and Georadar.

8.2 The Achievement

In 1999, at a very late stage in the construction of the Cattle Creek Bridge, when the last of the prestressed concrete bridge beams were being installed, the suppliers of the bridge beams discovered that some of them were defective. The supplier alerted QDMR to the problem, but was not able to identify the extent or precise location of the defects.

QDMR was faced with the choice of completely reconstructing the bridge on the assumption that all the beams were defective, or finding a way to identify the defective beams for selective repair and replacement. At that time, there was no accepted method for identifying or analysing defective beams without damaging them further.

An ‘innovation champion’ at QDMR’s Central Queensland Regional Office who was active in knowledge networks suggested that GPR may be an option. Consequently, QDMR commissioned a private consulting firm, Georadar Research Pty Ltd (Georadar), to undertake initial testing. The results were good, with Georadar proving that GPR could efficiently solve the problem. Georadar was then commissioned by the supplier of the concrete beams to inspect all the beams on the bridge deck and jointly develop a solution for repair of the defective beams.

8.3 The Innovation

GPR is an imaging technology that uses electromagnetic waves with frequencies typically from 25 MHz to 2 GHz to obtain information on the structure of sub-surfaces. Since the introduction of the first commercial system in the 1970s, which measured the thickness of ice, GPR has been successfully applied to a wide range of tasks. GPR was introduced to Australia by Georadar in 1984 and has since been used in mining, civil engineering, geology, archaeology, telecommunications, and gas and water industries.

The innovation on the Cattle Creek Bridge project was in using high-frequency GPR to investigate the interior of prestressed concrete beams in a precisely calibrated way. This latest generation of GPR technology is only just beginning to be used globally for structural applications, and the Cattle Creek Bridge application was a very early, and successful, test of the technology in this field.

The improvement in image accuracy obtained by the latest generation GPR represents a quantum leap in clarity. GPR was able to provide accurate images of internal defects in the Cattle Creek Bridge beams to within five millimetres. This accuracy was confirmed by drilling small percussion holes in selected beams and using a wirehook test to check that the thickness of concrete around the voids corresponded to the GPR images. Blind tests gave a mean difference of 1.6 millimetres between GPR measurements and core hole measurements. The technology is now earning the trust of engineers, which earlier more blurry GPR results had failed to do.

Georadar was a key international player in recognising the advantages and facilitating the development of the latest generation GPR antennae and control units. The company has also developed unique software for transforming radar results into accessible engineering images. The software was custom built for the Cattle Creek Bridge project and has been applied to a number of subsequent road and bridge projects.

GPR was used to image 180 prestressed concrete bridge beams on the Cattle Creek Bridge. The beams analysed are of a standard design used throughout Queensland. In this design, large polystyrene blocks (called ‘voids’) are cast internally within the deck beams to reduce the weight of the beams. At Cattle Creek, GPR was used to determine the final location of these voids within the beams and identify any defects caused by movement of the voids during their construction.

The results indicated that over 90 per cent of the beams were ‘out of tolerance’ due to significant movement of the voids, creating thin top or bottom flanges and air cavities between the lower steel stressing strands, resulting in soffit cracking.

Instead of entirely replacing every beam, with very high associated removal and transportation costs, the defective beams were repaired by cutting a narrow slit into the underside of the beams and pumping grout into selected locations.

8.4 The Benefits

Had GPR not been used, it is unlikely that QDMR or the suppliers of the beams would have been able to identify the location, or the extent, of the defects in the beams. Drilling and coring was not a feasible option as it would have been necessary to drill every part of each beam to obtain, with sufficient certainty, an understanding of the nature of the defects, while causing significant damage in the process. The only other solution was to rebuild the bridge deck units, which QDMR estimated would have cost about $2 million (probably borne by the supplier).

In contrast, the cost of GPR analysis, and repair and replacement of defective bridge beams, cost $1 million (primarily borne by the supplier), roughly half the cost of a total rebuild. Because this was the first time GPR had been used for such a problem and extensive validation trials were required, the costs to validate the method were higher at Cattle Creek Bridge than they will be for similar projects in the future.

Unquantified benefits have also flowed to QDMR as a result of using GPR on the Cattle Creek Bridge project. For example, the technology has been successfully used to identify termite damage in a timber bridge and was recently applied to examine historical scour events (caused by debris during flooding) at the Cattle Creek bridge.

Further, QDMR believes that GPR can be used more widely to identify defects in concrete structures in Queensland, estimated to be worth about $15 billion. Already, GPR has been used by Georadar in 2000 in an audit of bridge decks and to assess portions of new concrete road pavements on the Pacific Motorway Construction Project. The results indicated that some sections of the concrete road pavements contained defects. These were remedied by the project contractors during the warranty period, probably saving significant maintenance costs.

8.5 The Implementation Process

‘…luck favours the well-prepared mind’

The decision to use GPR to identify the location and number of defects in the beams of the Cattle Creek Bridge involved a commitment to trial the technology for this type of application. Georadar was willing to spend research and development funds to demonstrate the benefits of the technology before project stakeholders committed to a more comprehensive testing of the beams.

Since its establishment, Georadar has internationally pioneered many surface and underground applications of GPR. As noted above, an ‘innovation champion’ at QDMR’s Central Queensland Regional Office persuaded his colleagues to consider using GPR and Georadar to identify the defects in the Cattle Creek Bridge project. This champion had become interested in radar technology after his involvement in addressing the problem of collapsed trenches at Rockhampton Airport in 1975. The solution was to drill at 750 millimetre intervals along the length of the runway to identify the location of the sub-surface collapse zones. The inefficiencies of the approach encouraged his interest in non-invasive, non-destructive methods of identifying hidden defects. He began to read widely across scientific literature and later encountered Georadar, commissioning them to perform several survey projects using low-frequency GPR to investigate deep geological targets.

Georadar had been working to develop the more challenging high-frequency GPR technology for over nine years before the Cattle Creek Bridge project. They consider the Cattle Creek Bridge a fortuitous opportunity for real-world application and testing of new technology, noting however, that 'luck favours the well-prepared mind'. They first used pre-cursors of the high-frequency GPR technology to test the concrete shell structures of the Opera House in 1992. They realised then the need for significantly improved resolution to increase the accuracy of defect identification. Over subsequent years, several individuals and organisations, including international scientists and antennae manufacturers, worked with Georadar to develop the technology.

The Cattle Creek Bridge problem presented a timely opportunity for testing and refining Georadar's latest advances. All parties committed to a cooperative approach to the problem. Georadar deployed their technology under an Intellectual Property (IP) agreement with QDMR. In turn, QDMR's willingness to commit funds to trial the technology facilitated their access to the benefits of GPR for the Cattle Creek Bridge, and to subsequent testing work, subject to an IP agreement. Significant funds were also committed by the supplier of the bridge beams, which was keen to arrive at a cooperative and efficient solution to the defect problem. Additionally, the experience led quickly to improvements in the supplier's manufacturing processes.

8.6 Overcoming Difficulties

The most important difficulty associated with the use of GPR to audit the Cattle Creek Bridge beams was the risk of failure, because the technology had not previously been used that way. All key stakeholders – the client, consultant, contractor and supplier – agreed to trials of the new technology because they accepted the need for judicious risk taking. They championed the innovation: QDMR Head Office was very keen to find an efficient solution to the beams problem and created the organisational conditions for innovation to succeed; QDMR Central Queensland Regional Office had networks in place that pointed to the potential value of GPR; and Georadar was the technical expert, with an international reputation for championing developments in GPR.

Having decided to test GPR, the parties needed to cooperate during the trial and investigation period. This was assisted by a history of good relationships, which were maintained throughout the project's uncertainties. The networking of key individuals had previously built the inter-business relationships upon which an efficient solution to the Cattle Creek Bridge problem depended. QDMR believes that without these good relationships, a more costly solution would have been necessary. In particular, QDMR and Georadar have independently noted that the positive attitude of the supplier was crucial in ensuring the positive outcome.

8.7 Lessons Learned

- Problems are strong innovation drivers.
- Problems can create opportunities for learning and future benefit.
- Investment in problem-solving on a particular project/application often reaps flow-on/spill-over benefits across a number of projects/applications.
- Fine-tuning of new technology to suit specific applications depends on opportunities for testing in real-world situations.

- The presence of ‘innovation champions’ is often crucial to the adoption and development of innovative technologies.
- Organisations willing to invest in research and development can reap significant benefits over time.
- A culture of cooperation is often necessary for identification of innovative solutions to problems.
- Innovation is not a short-term endeavour – persistence is required.
- Involvement in knowledge networks is a good insurance policy against uncertainties of the future.

9. BRITE CASE STUDIES SUMMARY

This summary was prepared as a stand-alone booklet for industry participants.

9.1 Introduction

In 2003, the BRITE Project of the Cooperative Research Centre for Construction Innovation undertook six case studies of innovation in the Australian building and construction industry. The case studies showed that businesses reap substantial benefits from adopting and extending innovations developed by others; a process known as adoptive or incremental innovation. This is in keeping with the findings arising from the Prime Minister's initiatives to map Australia's science and innovation capacity, which show that incremental innovation is a key driver of business success across a range of industries.

The studies demonstrate that incremental innovation is driven by 'market-pull' factors, which can require non-technological activity, such as linkages with global experts (1, 2 & 4)[1]; relationships with manufacturers and clients (2 & 5); or building trust between project stakeholders (3 & 6). This is in contrast to revolutionary innovation, which tends to be driven by 'technology-push' factors. The distinction underlines the relative importance of organisational skills, compared to technical skills, for the majority of innovation undertaken in the Australian building and construction industry.

Although the case studies undertaken by the BRITE Project illustrate the long-term benefits to flow from large-scale formalised research and development (R&D) programs (5 & 6), more significant is the evidence that non-R&D innovation activity can also provide considerable benefits (1 & 3). This finding is in keeping with growing evidence nationally and internationally, across industries, that R&D and non-R&D innovation activities are equally important in improving business performance. It suggests the need for a rethinking of the Commonwealth Government's R&D tax concession, with its narrow definition of eligible expenditure.

The case studies focused on innovation in the context of building and construction projects. The project-based nature of production within the building and construction industry adds a complication which is absent from other industries – although an innovator may see an opportunity to improve project performance, benefits flowing back to the innovator may be harder to see. This can reduce innovation in the industry. However, the case studies (2 & 3) have shown that innovation history is increasingly taken into account by clients in awarding work, potentially leading to less industry concern about the distribution of project benefits and greater long-term reward for 'best-for-project' thinking.

This document outlines the lessons learnt from the six case studies, suggests approaches to improve business innovation performance, provides a checklist for business managers to gauge their innovative capability, and identifies potential innovation resources.

9.2 Lessons Learnt

A number of common themes emerged from the six innovation case studies:

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[1] Numbers in brackets refer to BRITE case study numbers which most clearly demonstrate the point being made.

Key Participants in Innovation Processes

- small regional firms can be important innovation drivers because of their knowledge of local conditions (1, 2, 5 & 6)
- manufacturers play a key role in promoting innovation on projects because they are more likely to be undertaking formal R&D than contractors or consultants (2 & 5)
- informed clients, with high levels of technical competence, are an important 'market-pull' factor in driving innovation (1, 3, 4, & 5)
- universities play a key role in innovation networks, especially where innovation relies on formal R&D (2, 4 & 5)

Key Dynamics in Innovation Processes

- many successful innovations are based on access to international expertise (1, 4, 6)
- standards act as another strong 'market-pull' factor encouraging the industry to improve performance (1 & 4)
- borrowing ideas from related industries is a useful innovation strategy, underlining the importance of adoptive innovation, compared to original innovation (2, 3, 5 & 6)
- the type of contract employed by clients on projects has a big impact on the ability of stakeholders to try new approaches and hence innovate (2 & 3)

Overall, the experiences of innovators in the BRITE case studies highlight the highly interactive nature of successful innovation processes and the importance of robust business networking. Although R&D activities are shown to be important, the success of each innovation has been ensured by high level organisational expertise. Innovation then relies on technical advances *and* people skills.

9.3 How to Innovate Successfully

The findings of the case studies, together with a survey of the literature undertaken by the BRITE Project, indicate that innovation in the building and construction industry can be usefully leveraged through:

Building Relationships with Key Players

- active use of innovation brokers to facilitate efficient access to technical support providers, and other external players with complementary knowledge bases;
- building robust relationships with manufacturers supplying the industry, in view of their involvement in R&D programs;
- building-up long-term relationships with clients in view of the shift towards more cooperative approaches to project delivery;

Streamlining Activities

- mobilising integrated approaches to construction projects, in response to the fragmentation of the industry arising from the 'one-off' nature of most projects and the proliferation of small players;
- improving knowledge flows by developing more intensive industry relationships to offset the disadvantages of production based on temporary coalitions of firms;
- integration of project experiences into continuous business processes to limit the loss of tacit knowledge between projects;

Growing an Appropriate Internal Business Environment

- building-up a culture supportive of innovation, including encouraging staff to share ideas, enhancing in-house technical competence, supporting innovation champions, appreciating the opportunities represented by problems; encouraging prudent risk-taking; and establishing recognition programs;

Effective Client Leadership

- maintaining high levels of technical competence, advanced demand patterns, and a positive approach to prudent risk-taking;
- promoting innovative procurement systems, including partnering or alliancing, to enhance cooperative problem solving, the adoption of non-standard solutions, and equitable allocation of risk; and
- strengthening performance-based standards, through the enhancement of technical knowledge, and through the formulation of simple enforcement strategies.

9.4 Innovation Checklist for Businesses

The Innovation Checklist is based on case study findings and follows a format developed by the Construction Best Practice Program in the UK. The Checklist assists business managers identify where they are and where they want to be. Business managers are invited to mark each item as appropriate, assuming that they might be asked to demonstrate the basis for their response.

Table 3 Innovation Checklist

	I haven't thought about it	I am thinking of doing something	Yes	Yes, and we are constantly improving	Yes, we represent best practice
	Level 1	Level 2	Level 3	Level 4	Level 5
1. Do you have robust relationships with key industry participants e.g., clients, manufacturers and universities?					
2. Do you actively monitor international best practice in your field?					
3. Do you actively monitor advances in related industries that might be applicable to your business?					
4. Do you have a formal system for transferring project learnings into your continuous business processes?					
5. Do you view problems or failures as opportunities for learning and growth?					
6. When you make changes, do you measure how well the changes have worked?					
7. Are staff rewarded for maintaining networking linkages with other industry participants with complementary skills?					
8. Are staff encouraged to share ideas?					
9. Do you have a strategy to keep the loyalty of key experts within the business?					
10. As your business changes, are you bringing in the necessary new skills and competencies?					

Business managers can look at the pattern of their responses and ask themselves:

Level 1: Is it in our interests to ignore these activities?

Level 2: Am I putting in the effort or resources needed to support these activities?

Level 3: Which of these activities should I make even better?

Level 4: How can I identify the strengths on which to build and improve even more?

Level 5: How can I capture and share these successes?

Additional Resources to help businesses move ahead are available from the BRITE Project (www.brite.crcci.info); the Cooperative Research Centre for Construction Innovation, Australia (http://www.construction-innovation.info); the Commonwealth the Department of Industry, Tourism and Resources, Australia (http://www.industry.gov.au/); and the Construction Excellence program in the UK (http://www.cbpp.org.uk/), which currently provides the widest range of practical tools for building and construction organisations seeking to improve performance.

10. CONCLUSIONS

The case study program was completed successfully in 2003 thanks to a combination of hard work, team cooperation and good fortune. To a large extent, the success of the project depended on our ability to encourage cooperation and timely responses from our interviewees. The most challenging process was that of moving from the first case study draft to a fully approved draft suitable for publication. This involved complex and time consuming deal-brokering activities, and for two of the case studies, management of conflict between project participants. Careful management of these issues ensured publication of the studies and protected the integrity of the content.

Overall, the case studies reflect the key innovation influences to emerge from our review of the academic literature, namely industry relationships, procurement systems, clients, regulations, organisational resources, structure of production, and industry culture. One of the key benefits of the case studies is that they demonstrate the *dynamics* of these influences in *local* real world examples.

Key stakeholders in the project are very enthusiastic about the content, format and educational potential of the case study booklets; distribution of which will be pursued into 2004 by CRC HQ, with a formal launch planned for February.

Finally, it is the impression of the researchers that the very act of undertaking the case study program has, in itself, led to increased awareness of the importance of innovation. It is also expected that the booklets will continue to create interest over 2004 and that this will encourage strong industry participation in the 2005 program.

11. REFERENCES

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Appendix A - Papers Completed by the BRITE Project in 2003

Survey Preparation

Innovation Surveys: Design Issues and Recent Experiences
Statistical Overview of the Australian Construction Industry
BRITE Survey Scope and Sub-Population Identification

Case Study Preparation

BRITE Framework for Identifying Case Studies
BRITE Framework for Analysing Case Studies

Literature Review

Influences on Construction Innovation: A Brief Overview of Recent Literature

Article in Refereed Journal

Frameworks for Understanding Interactive Innovation Processes

Refereed Conference Papers

Innovation Rates and Drivers in the Road Industry: The Case of Queensland, Australia

Knowledge Flows in the Road Industry: Queensland's Experience

Innovation Adoption Behaviour in the Construction Sector: The Case of the Queensland Road Industry

Workshop Paper

Innovation Processes: A case study of the Queensland Road Industry

Innovation Case Studies

No 1: Outstanding Whole-of-Life Gains Without Higher Up-front Costs

No 2: Concrete Planking Innovation Saves over $300,000 on Major Sports Stadium

No 3: Motorway Alliance Drives Performance Improvement

No 4: Performance-Based Building Codes and Fire Engineering Yield Innovative Design Solution

No 5: Australia's First Fibre-Reinforced Polymer Bridge Deck on the Road Network

No 6: Ground Penetrating Radar Finds Defects in Bridge Beams

Summary Booklet 'What's in it for me?'

Appendix B - Confidential Interviewee Details

Case Study Number and Full Project Title	Short Case Study Title	Case Study Interviewees	Title/Address	Email	Phone (include any mobiles)
1 Outstanding Whole-of-Life Gains Without Higher Up-front Costs	McCormack Place and Reduced Energy Costs	Graham Messenger	*Acting Manager* – Portfolio Branch Building Division, Qld Dept of Public Works GPO Box 2457, Brisbane QLD 4001	graham.messenger@publicworks.qld.gov.au	07 3224 6580 07 3225 8122
		Graeme Standfield	*Director* – MGF Consultants (NQ) PO Box 797N, North Cairns QLD 4870	graeme@mgfnq.com	07 4051 0999
2 Concrete Planking Innovation Saves over $300,000 on Major Sports Stadium	Clever Planks	Hossein Shamsai	*Managing Director* Quickcell Technology Products Pty Ltd Lot 3 Beaudesert-Boonah Rd, Bromelton QLD 4285	manager@quickcelltechnology.com quickcell@hotmail.com	07 5541 4838
		Stephen Davies	*Structural Engineer* – Arup Cairns Suite 6, 111 Spence St, Cairns QLD 4870	stephen.davies@arup.com	07 4052 1445
		Ian Ainsworth	*Manager Building Structures* – Arup Brisbane Level 4, Mincom Central 192 Ann Street, Brisbane QLD 4000	ian.ainsworth@arup.com	07 3023 6061
3 Motorway Alliance Drives Performance Improvement	Port of Brisbane Motorway Alliance	David Wright	*Project Director* – Port of Brisbane Motorway Queensland Department of Main Roads Level 2, Dickens St, Spring Hill QLD 4000	david.wright@mainroads.qld.gov.au	07 3834 2361
		Dave Rankin	*Transport Engineering Executive* Parsons Brinkerhoff Australia Limited Level 12, 348 Edward St, Brisbane Q 4000 GPO Box 2907 – Brisbane QLD 4001	drankin@pb.com.au brisbane@pb.com.au	07 3218 2285 07 3218 2222

		Darren Weir	*Construction Manager – Civil* – Northern Region Leighton Contractors Australia PO Box 288, Toowong QLD 4066	darren.wier@leicon.com.au	07 3215 4400
		Roger Olds	*Managing Director* – Coffey International Ltd 16 Church Street, Hawthorn VIC 3122	roger_olds@coffey.com.au	03 9853 3396 0403 242 470
		Lydia Czosnowska	*Project Manager* Queensland Department of Main Roads Level 2, Dickens St, Spring Hill QLD 4000	lydia.e.czosnowska@mainroads.qld.gov.au	07 3218 2810 0417 607 141
4 Performance-Based Building Codes and Fire Engineering Yield Innovative Design Solution	Fire Engineering	David Barber	*Associate* – ArupFire, Risk & Security Level 17, 1 Nicholson Street, Melbourne VIC 3000	david.barber@arup.com.au	03 9668 5446 0407 050 497
		Ian Moore	*Group Leader – ArupFire Senior Associate* ArupFire, Risk and Security Level 17, 1 Nicholson Street, Melbourne VIC 3000	ian.moore@arup.com.au	03 9668 5456 0416 043 463
		Tjip Faber	*Manager* – Operations and Development Federation Square Management Pty Ltd Corner Swanston & Flinders Sts, Melbourne 3000	tjip.faber@fedsq.com	03 9655 1903 03 9655 1900 0428 345 605
5 Australia's First Fibre-Reinforced Polymer Bridge Deck on the Road Network	Coutts Crossing FRP Bridge	Louise McCormick-Chandler	*Engineer* – Bridge Design Queensland Department of Main Roads GPO Box 1412, Brisbane 4001	louise.a.chandler@mainroads.qld.gov.au	07 3834 5974 0418 237 200
		Neil Wagner	*Company Director* – Wagners PO Box 151, Drayton North QLD 4350	neil.wagner@wagner.com.au	0418 716 431
		Rod Oates	*Manager* – Bridge Rehabilitation Projects Bridge Section, RTA Technical Services Roads and Traffic Authority, New South Wales PO Box 3035, Parramatta NSW 2124	rod.oates@rta.nsw.gov.au	02 8837 0830 0407 298 646
6 Ground Penetrating	Cattle Creek Radar Bridge	Tony Elgar	*Principal Engineer* – (Contracts) Mackay Queensland Department of Main Roads, Mackay	tony.r.elgar@transport.qld.gov.au	07 4951 8578 0418 870 146

Radar Finds Defects in Bridge Beams		Alan Carse	*Principal Engineer* (Concrete Technology), Structures Division Queensland Department of Main Roads Floor 8, Spring Hill Office Complex 477 Boundary Street, Spring Hill QLD 4000	alan.h.carse@mainroads.qld.gov.au	07 3834 2502 0418 759 632
		Richard Yelf	*Managing Director* – Georadar Research Pty Ltd 412 Eastbank Road, Coramba Coffs Harbour, NSW 2450	georadar@midcoast.com.au	02 6654 4162 0428 662 399
		Lex Van Der Staay	*Regional Advisor* – Technical Services Central Queensland Regional Office Queensland Department of Main Roads	lex.g.vanderstaay@transport.qld.gov.au	07 4931 1657 0418 989 115
		…… Regional SMEs			

12. AUTHOR BIOGRAPHIES

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