Sustainable
Built Environment
National Research Centre

2012
Annual Report

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Executive Summary

Our Centre aims to be an enduring world-class research and knowledge broker in sustainable infrastructure and building design, construction and management. In 2012 we came closer to achieving our mission, thanks to our members support, program and project leaders and the collaborative research teams involved in our three programs of activity:

- Program 1: Greening the built environment, led by Professor Peter Newman, Curtin University
- Program 2: Developing innovation and safety cultures, led by Professor Russell Kenley, Swinburne University of Technology
- Program 3: Driving productivity through procurement, led by Professor Robin Drogemuller, QUT.

The valuable research outcomes our projects delivered have largely been due to our strong focus on industry, government and research collaboration. Our Centre would not be able to continue growing without the commitment and support of our core partners and we thank you wholeheartedly: Curtin University; John Holland; NSW Roads and Maritime Services; Parsons Brinckerhoff; Queensland Departments of Transport and Main Roads, Housing and Public Works, and Local Government and Planning; Queensland University of Technology; Swinburne University of Technology; Western Australian Government agencies: the Department of Commerce (Building Commission), the Department of Treasury (Strategic Projects), the Department of Finance (Building Management and Works) and Main Roads WA.

Additionally, international participation (formally through Constructing Excellence UK; VTT Technical Research Centre of Finland; BRANZ in New Zealand; CIB – the International Council for Research and Innovation in Building and Construction; and informally through a variety of leading university and other research institutions) provides important global perspectives on our research as we share information and ideas to improve the quality of our research.

Centre highlights of 2012 include:

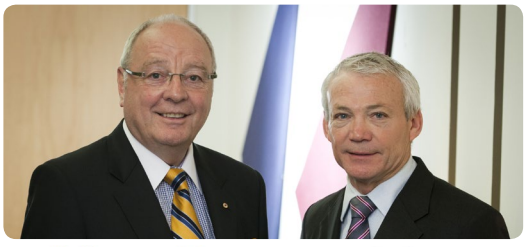
- We facilitated three successful ARC Linkage funding applications, and these projects are now underway:
  - Greening procurement of infrastructure construction (Russell Kenley, Swinburne) - $340,000
  - Leveraging R&D for the Australian Built Environment (Keith Hampson, QUT) - $235,000
  - Diffusion of manufactured high performance green houses (Karen Manley, QUT) - $198,000
- Partnering with industry groups such as Built Environment Industry Innovation Council (BEIIC), buildingSMART, Australian Constructors Association (ACA), Australian Green Infrastructure Council (AGIC), Australian Procurement and Construction Council (APCC), Austroads, Civil Contractors Association (CCF), Engineers Australia (EA), Green Building Council of Australia (GBCA), Master Builders Australia (MBA), The Australian Workers Union (AWU), Construction, Forestry, Mining and Energy Union (CFMEU), the Office of the Federal Safety Commissioner and the Warren Centre for Advanced Engineering to ensure industry-focussed research outcomes and convene dissemination seminars.
- The project The Future of Roads has provided a valuable contribution to industry around 'sustainable road infrastructure', providing an extensively researched context to inform future innovation. The key findings include: capacity building to identify short term options to 'reduce greenhouse gas emissions' during design, construction, maintenance and operation on existing and future road projects; enhancing 'sustainability reporting' efforts; and on-going strategic consideration of the 'risks and opportunities' associated with current and future trends. These provide many benefits to industry and government including: improving strategic positioning; informing policy and management decisions; providing guidance on areas of specialisation; and understanding market gaps and arising business opportunities
- The project Safety Impacts of Alcohol and Other Drugs in Construction has been the first scientific evaluation, at a national level, of the use of alcohol and other drugs (AOD) in the construction industry. The findings have fundamentally contributed to a greater understanding of AOD consumption rates, patterns of use and the associated levels of risk within the Australian construction industry. With a stronger grasp of the extent and severity of the problem, we are better equipped to understand the causes, impact and consequences of AOD within the cultural and operating context of the construction workplace – and importantly, how to respond effectively. A cultural change management program and implementation plan has been developed by the project team in consultation with project partners and industry stakeholders.
- The goal of the project Collaborative Object Libraries Supporting the Facility Lifecycle, in conjunction with industry partners Queensland Government Project Services and Natspec, was to provide a software implementation of an on-line product library that would provide the basis for a future national product library. The business case behind the project is that if there was a national product library that was on-line and free for users, then many of the issues with collaboration would be reduced. A solution to the technical problem of sharing library objects between software from different vendors is a method used in software engineering called 'software transformations'. This method provides an automated system of mapping data and structures between different representations. Once established as a National Object Library this project will provide benefits across a range of industry participants.

Our challenge for our next three year phase, from 2013-2015, is to grow the value and impact of our applied research more deeply and broadly across Australia. We are pleased to announce we have been given a significant growth injection from our partners in Western Australia. Consequently our headquarters will relocate to Curtin University in Perth, Western Australia. Keith Hampson will maintain continuity as CEO and relocate to Curtin University, and John McCarthy will remain as Chair of the Board. Lauren Gubbin will also maintain important corporate administrative leadership for our Centre.

This move provides us with greater opportunities to grow by servicing the resources infrastructure sector, which will complement our existing activities in roads and building infrastructure – in which we have traditionally been acknowledged as a national and international leader.

We would like to take this opportunity to acknowledge the SBEnrc team who have contributed enormously over the last three years. In particular, Rick Darroch, who has provided financial management prudently and effectively. Also thanks to Sandy Cheung, Jo Waddell and Hana Nepia. I wish you well in your future endeavours.

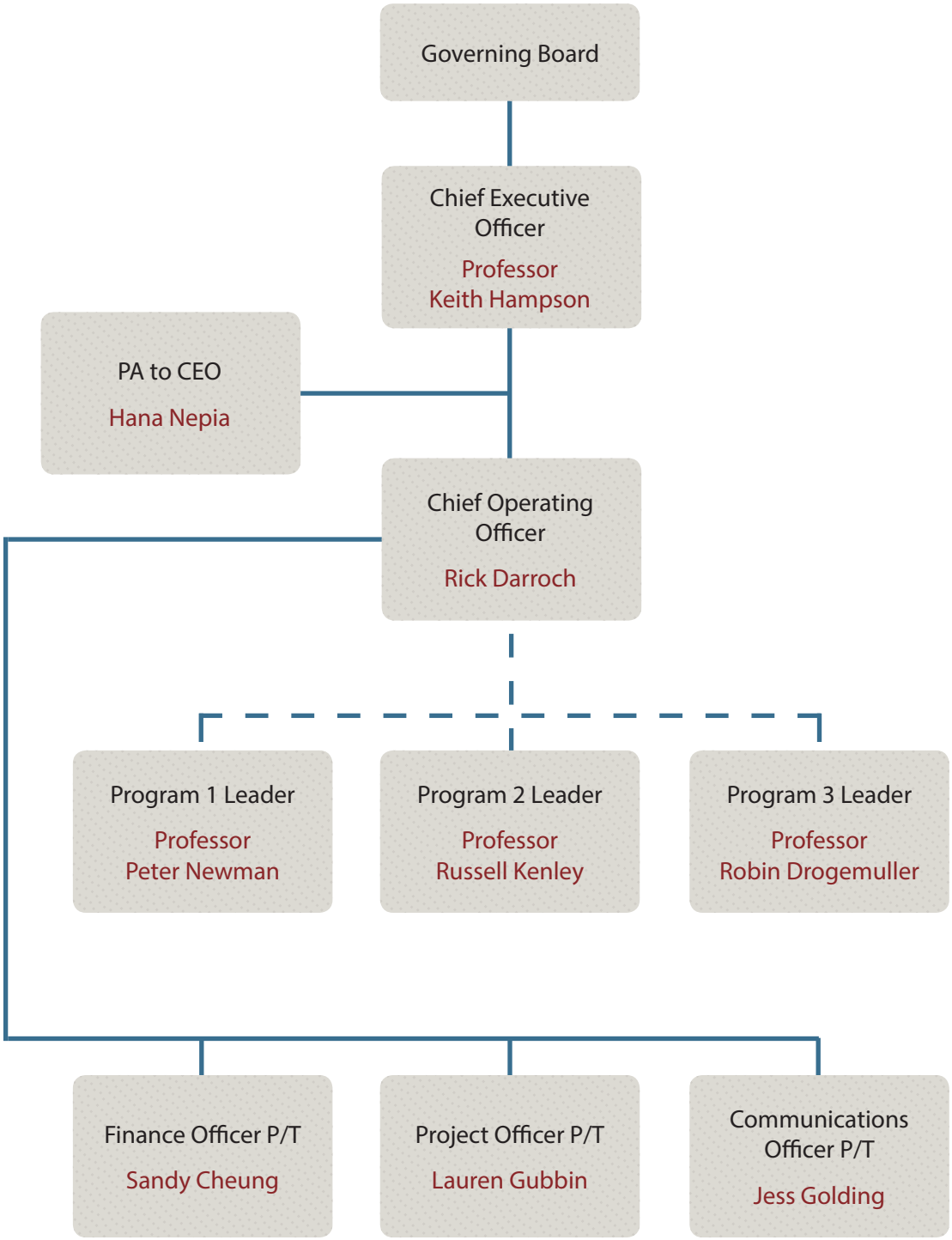
As we move into our next phase, we look forward to maintaining our joint commitment and working with core members, project partners and other industry stakeholders growing the value of SBEnrc research for our national partners and our industry well into the future.



John V. McCarthy AO, Chairman

Keith D. Hampson, Chief Executive Officer

Organisational Chart for 2012



Team Members

SBEnrc Board

1. John V. McCarthy AO (Chair)
2. Graham Atkins, Queensland Department of Housing and Public Works (to 22 August 2012)
   Ross Guppy, Queensland Department of Transport and Main Roads (from 19 September 2012)
3. Angelo Conte, John Holland
4. Richard Mann, Western Australia Department of Treasury
5. Charlie Thorn, Curtin University
6. Shaun Nugent, Parsons Bricknerhoff (to 29 March 2012)
   Jim Mantle, Parsons Bricknerhoff (30 March 2012 to 23 May 2012)
7. Matthew Bailes, Swinburne University of Technology (to 23 May 2012) Alternate: Bruce Whan
   George Collins, Swinburne University of Technology (from 22 August 2012)
8. Martin Betts, Queensland University of Technology
9. Michael Veysey, NSW Roads and Maritime Services (from 22 August 2012)
10. Keith Hampson, CEO, SBEnrc
11. Rick Darroch, COO, SBEnrc (Secretariat)
12. Lyn O'Connell, Australian Department of Infrastructure and Transport (Observer)

Research and Utilisation Committee

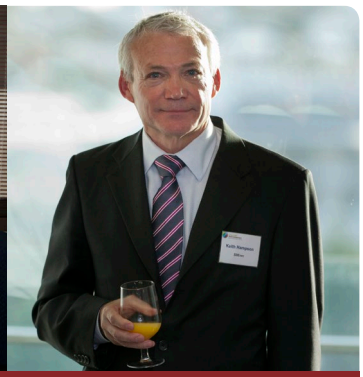
1. Ross Guppy, Queensland Department of Transport & Main Roads (Chair)
2. Shaun Nugent, Parsons Bricknerhoff (to 1 May 2012
   Alan Hobson, Parsons Bricknerhoff (2 May 2012 to 8 November 2012)
3. Angelo Conte, John Holland
4. Carolyn Marshall, Western Australia Department of Finance -
   Building Management and Works
5. Angela Heymans, WA Department of Commerce (from 6 August 2012)
6. Michael Veysey, NSW Roads and Maritime Services (from 6 August 2012)
7. Program 1 Leader: Peter Newman, Curtin University (Alternate: Charlie Hargroves)
8. Program 2 Leader: Russell Kenley, Swinburne University of Technology
9. Program 3 Leader: Robin Drogemuller, Queensland University of Technology
10. Keith Hampson, CEO, SBEnrc
11. Rick Darroch, COO, SBEnrc

Finance and Audit Committee

1. Charlie Thorn, Curtin University (Chair)
2. Richard Mann, Western Australia Department of Treasury
3. Graham Atkins, Queensland Department of Public Works
4. Martin Betts, Queensland University of Technology

Remuneration and Performance Committee

1. John McCarthy AO (Chair)
2. Angelo Conte, John Holland
3. Martin Betts, Queensland University of Technology
4. Charlie Thorn, Curtin University

Team Members

John V. McCarthy AO

Chair, Sustainable Built Enviornment National Research Centre

FRICS, FAPI, FREI, FREAV

John is a recognised industry leader, with a breadth of experience across various commercial and industry disciplines. He served as inaugural Chair on the Australian Sustainable Built Environment Council (ASBEC), as Chair of the Australian Construction Industry Forum (ACIF), President of Property Council of Australia (PCA) and member of the Australian Building Codes Board (ABCB). He is Australia's first industry representative on the Board of the International Council for Research and Innovation in Building and Construction (CIB) - an organisation he now serves as global President.

Graham Atkins

Queensland Department of Public Works

BASc (Quality Surveying), AssocDip Bldg

Graham brings with him over 30 years experience in the building and construction industry. He is committed to building strong relationships with key stakeholders and departmental clients to ensure that DPE provides responsive and flexible client focussed services. Graham held senior roles in the Department of Education and Training (DET) being responsible for all infrastructure planning and delivery. During his 10 years with DET he was instrumental in leading the delivery of record capital and maintenance programs.

Richard Mann

Western Australia Department of Treasury and Finance

BE, CPEng, FIEAust

Richard is a civil engineer with more than 20 years experience in building and infrastructure projects throughout Western Australia. He heads Treasury's Strategic Projects division and oversees the delivery of a $8 billion portfolio of 18 major projects, including the $2.0 billion Fiona Stanley Hospital, $1.2 billion New Children's Hospital and $550 million Perth Arena indoor entertainment and sports stadium.

Keith Hampson

CEO, Sustainable Built Environment National Research Centre

BEng (Hons), MBA, PhD, RPEQ

FIEAust, FAICD, FAIM

Keith Hampson is an energetic senior leader with a blend of strong technical and management skills and formal qualifications gained through international experience in industry, government and university environments. He is committed to building an internationally competitive Australia by promoting access to better education, technology and innovative practices. At the industry level, Keith is a registered civil engineer and project manager with extensive experience in operating in multi-disciplinary environments in planning, design, construction and maintenance.

Angelo Conte

John Holland

BE (Civil) (Hons), FIEAust, RPEQ

Angelo is the Strategic Development Director at John Holland and has had over 30 years experience in the construction industry. He has been involved in numerous projects throughout Australia in the civil, structural and mechanical disciplines. Angelo provides strategic advice to assist the Managing Director and Executive Management Team to formulate the strategic direction of the Company.

Charlie Thorn

Curtin University

BSc (Agric) (Hons)

Curtin University recently appointed Australian Sustainable Development Institute (ASDI) Director, Charlie Thorn to the position of Director Research and Development. Charlie has more than 30 years experience in research management, commercialisation and technology transfer in agriculture, fisheries and University research institutions. During his time as ASDI Director he led, developed and grew Curtin's sustainability research in the areas of energy, climate change, water, sustainable resources, urban and regional development, sustainable communities and food.

Team Members

Shaun Nugent

Parsons Brinckerhoff
BE (Civil), GAICD, CPEng, RPEQ

As Director for Operations and Capability, Shaun has been instrumental in the prosperity of PB's Business Groups within Australia and New Zealand. He brings 21 years of hands-on engineering experience in civil infrastructure, structural, materials handling, coastal, ocean and systems engineering.
He has extensive experience in the design and delivery of power and industrial sector projects. Shaun has been involved in some of Queensland's most notable engineering projects as a member of alliance leadership teams and project boards.

Michael Veysey

NSW Roads and Maritime Servicesy
BEng (Mech)

Mike is an experienced senior traffic management, transport planning and road safety professional who has worked in NSW State and Local Government for over 30 years. He has worked extensively on strategic transport and traffic planning, the traffic impacts of major developments, conflict resolution and multimodal transport planning.

He is regarded as a specialist on how to manage the difficult challenges presented by the Sydney Central Business District and its planned major development activities over the next few years.

Rick Darroch

COO, Sustainable Built Environment National Research Centre
BEc, GradDipAcc, MBA, GAICD, FCPA

Rick Darroch joined the SBEnrc in June 2010 after serving as the Business Manager for the CRC for Irrigation Futures for its seven year term, with primary responsibility for the everyday functions of the Centre. Prior to working in the University / Research Management sector Rick held senior Finance Manager positions at Grainco Australia and Defiance Mills Limited. Rick has a Bachelor of Economics, Grad Dip in Accounting, MBA and is a Fellow CPA.

George Collins

Swinburne University of Technology
B.Sc.(Hons I), Ph.D., Certified Materials Professional, Materials Australia F.Inst.P., MAIP, GAICD

George began his appointment as Deputy Vice-Chancellor (Research & Development) in August 2012. In this capacity, he is driving Swinburne to become Australia's leading university in research innovation by creating a distinctive Research and Development environment that focuses on the application of research.
George has more than 30 years experience in research and research management.
He has significant experience and a long list of achievements across the Australian research sector with a strong focus on the promotion of excellence in research and innovation.

Martin Betts

Queensland University of Technology
BSc (Hons), PhD
CNAA, FCIOB, FRICS, FIEAust, CPEng, FRSA

Martin is Executive Dean of the Built Environment and Engineering Faculty, QUT. He is Fellow of numerous institutions and societies including the Royal Institution of Chartered Surveyors and was recognised by Engineers Australia in 2007 as one of Australia's 100 most influential engineers. Martin was founding director of the Construct IT for Business Centre of Excellence in the UK, which he received the Queen's Anniversary Prize for Further and Higher Education in 2000.

Peter Newman

Curtin University
PhD, Dip.ES&T, BSc (Hons), FTSE

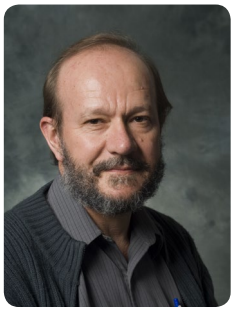
Peter Newman is the Professor of Sustainability at Curtin University and is the Leader of the Greening the Built Environment Program. He was appointed as a Lead Author for Transport on the next Intergovernmental Panel on Climate Change Report. He is on the Board of Infrastructure Australia and has published more than ten books and 200 academic publications. In 2011 he was awarded the Sidney Luker medal for his contribution to the science and practice of town planning.

Team Members

Russell Kenley

Swinburne University of Technology
BBldg (QS) (Hons), PhD, MAIB, AAIQS

Russell is Professor of Management at Swinburne University of Technology and Visiting Professor of Construction at Unitec, NZ. His research interests involve the built environment including: project financial management; lean management of production in construction; and strategic management of property portfolios. He has co-developed the location-based management system and is working with industry to introduce new model-based production systems to improve productivity.



Robin Drogemuller

Queensland University of Technology
BArch, BAppSc (Maths&Comp)

Robin is Professor of Digital Design, QUT. He leads a multidisciplinary team who examine the use of information technology to support decision-making within the built environment. Together they developed national and international standards for the exchange of information for building and infrastructure; and commercial and prototype software to support integrated design, construction and operation of constructed facilities.

Ross Guppy

Queensland Department of Transport and Main Roads
BEng, RPEQ

Ross leads Queensland Department of Transport and Main Roads' liaison with industry bodies including Australian Asphalt Pavement Association (AAPA), Consult Australia, Civil Contractors Federation, Queensland Major Contractors Association and Institute of Public Works Engineers Australia Queensland Division and is chair of the TMR Prequalification committee. Ross was a Board Member of the CRC for Construction Innovation, currently Chair for SBEnrc's Research & Utilisation Committee and on the Austroads Project Delivery Panel. Ross also manages the Strategic Alliance with the ARRB Group.

Carolyn Marshall

Western Australia Department of Treasury & Finance, Building Management and Works
Architect, MA World Heritage

Carolyn Marshall is Assistant Director of the Building Research and Technical Services team in Building Management and Works, WA Department of Finance. Carolyn is a registered architect with post graduate qualifications in building sustainability and heritage, and a Green Building Council of Australia Green Star Accredited Professional.

Hana Nepia

PA to the CEO

Sustainable Built Environment
National Research Centre

Lauren Gubbin

Project Officer

Sustainable Built Environment
National Research Centre

Sandy Cheung

Finance Officer

Sustainable Built Environment
National Research Centre

Core Partners

Queensland Government

GOVERNMENT OF WESTERN AUSTRALIA

QUT

SWINBURNE UNIVERSITY OF TECHNOLOGY

Curtin University

PARSONS BRINCKERHOFF

John Holland

Project Partners/Affiliates

Greening the Built Environment

The first three years of SBEnrc has seen Program One deliver a range of valuable outputs that support improvements in sustainability performance across the built environment sector. The program has focused on responding to industry and government needs across its various areas of focus. In working with such partners, researchers have built a framework upon which to continue this work in the second stage of the SBEnrc.

During this initial stage, Research Program One has targeted the following outcomes for the built environment sector:

- Commercial buildings: a) Cost savings for industry and government, through the development of a comprehensive tool for capturing vital data on how to maximise the broader value of energy efficiency initiatives; b) Increased worker productivity from improved design, through the delivery of the tool to allow occupant experiences to inform energy efficiency initiatives in office buildings; c) Reduction in costs for green retrofits of infrastructure and buildings, through the tool streamlining building management systems, legal agreements and organisational culture as part of energy efficiency initiatives in office buildings
- Biophilic urbanism: a) Increased productivity from sustainability designers, through the provision of evidence to demonstrate that a range of natural features can be used to deliver tangible direct and in-direct benefits; b) Reduced water consumption and waste, by demonstrating the value of the use of green walls and green roofs in storm water management.
- Mass Haul: Finance savings on major infrastructure and building projects, through the development of methodologies such as a practical procurement system based on mass-haul planning and associated work to reduce fuel consumption on road projects.
- Future of Roads: a) Decreased greenhouse gas emissions in the built environment industry, achieved by specifying verified methods of greenhouse gas emissions reduction in road construction; b) the opportunity to reuse waste in road construction; c) Increased sustainability skills capacity in the road industry, achieved through industry education and training initiatives such as workshops to collaborate on the development of the research across sub-projects.

The projects completed in Program 1 are described in the Brochures following.

by Dawn Easterday Flickr

Understanding the Performance of Existing Office Buildings

to inform Energy Reduction Initiatives

The purpose of this project was to provide a low cost, low complexity tool that can be used across the sector and around the world, to assist efforts to improve the energy performance of existing commercial buildings and foster a productive workplace.

Efforts to reduce carbon emissions in the building sector have in the past focused on encouraging green design, construction, and building operation. The business case is not very compelling if considering energy cost savings alone, even with a carbon price, so it is necessary to ensure these savings are associated with broader productivity improvements. There has also been little attention paid to existing commercial buildings, with such buildings making up the majority of the commercial building stock. Furthermore, complexities involved in reducing energy use in existing commercial buildings are not well understood, involving a set of complex and interdependent factors.

Responding to the need for existing buildings to significantly improve in this operating environment, this report presents the key findings of an investigation of factors contributing to whole of building performance, particularly: green design elements; internal environmental quality; occupant experience; agreements and culture; and building management. The resultant 'Performance Nexus' tool has been developed through research, stakeholder workshops, and trials with project partners.[1] The project suggests that the Nexus tool is a low cost, low complexity tool which can be used to encourage the greening of existing commercial buildings through a focus on enhanced productivity.

The research

As part of the Sustainable Built Environment National Research Centre's (SBEnrc) focus on industry-led research, two stakeholder workshops were held in the early stages of the project, hosted by SBEnrc Core members, the Western Australian Department of Finance in Perth, and the Queensland Government Department of Public Works in Brisbane. The workshops involved the research team presenting the key findings of the literature review and working with a total of 35 key stakeholders to identify areas of interest for the project to develop. The workshop format was based on a methodology where participants were asked to articulate a vision of their ideal green buildings and then consider the enablers and disablers to achieving them.[2] The workshops were followed by a series of working sessions with partners to identify key areas of interest that were seen to be areas that would provide clear benefits to industry and government.

1 The 'Productivity Nexus' can be downloaded from the SBEnrc and CUSP website.
2 Based on the work of Emeritus Professor Valerie Brown

Sustainable Built Environment National Research Centre

Aims

Based on industry engagement the project focused on:

1. Investigating '*leading efforts*' in Australia and internationally to improve the performance of existing commercial buildings and extract valuable lessons.
2. Identifying '*key performance areas*' of existing commercial buildings to be considered in efforts to improve the energy performance of the building in a manner that supports a productive workplace.
3. Developing a '*framework for collecting data*' in a building to inform low cost, low complexity strategic interventions that capture multiple benefits through more holistic approach.

Key findings

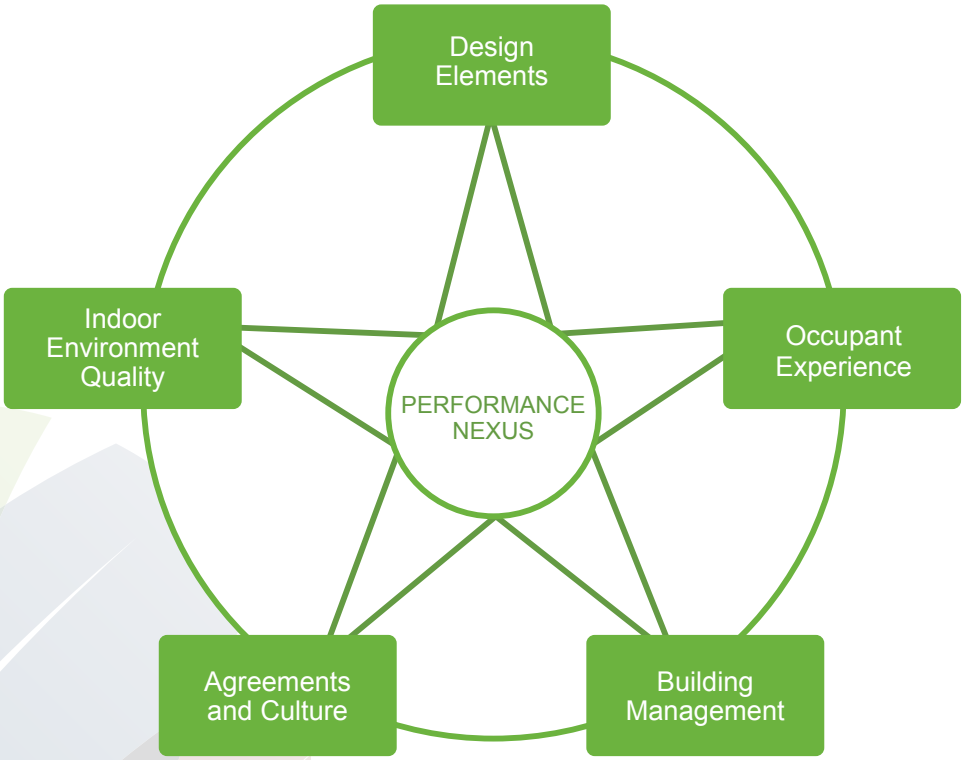
Energy and maintenance costs equate to around 4-5 per cent of total costs over the life-cycle of a building, and occupant salaries equate to around 85 per cent. In the US, productivity losses from poor indoor environmental quality are estimated to be costing as much as US$22.8 billion per year, and only 14 of the 561 NABERS rated office buildings in 2012 have been rated for indoor environment. Clearly, to reduce energy demand, indoor air quality and other productivity-related factors need to be a focus of any greening activity.

Within the building industry there is a lack of mainstream knowledge and skills in 'green building'. In addition, the industry typically operates in silos meaning that many sub-contractors have set responsibilities with limited collaboration. Furthermore, for multi-tenanted buildings tenants traditionally have relatively little interest in energy related costs, and little knowledge of the ancillary benefits from improving the efficiency of a building. In order to achieve an improvement in both energy performance and productivity, a more holistic approach is needed that involves communication between the many stakeholders and sub-contractors involved in operating buildings. Such an approach challenges standard industry practices and requires a new framework that goes beyond simply energy management.

A tool for whole of building performance evaluation

The 'Performance Nexus' for commercial buildings (Figure 1) provides such a framework. The design elements section of the Performance Nexus can act as an anchor point with each element being examined across the other nodes. Structuring the Nexus in this way enables building stakeholders to assess what design elements are in place, how these are being managed and maintained in the building, and how effective this is through Indoor Environment Quality (IEQ) and occupant experience components.

Figure 1: The 'Performance Nexus'



The '*Performance Nexus*' can be used to identify links between the key performance areas to uncover potential strategies for improvement. As an example, Table 1 suggests key questions across the Nexus for the case of lighting.

Table 1: Example of application of each node of the Nexus to 'lighting'

Design Element	Indoor Environment Quality	Occupant Experience	Building Management	Agreements and Culture
Is the lighting system energy efficient?	Are the lighting levels suitable for tasks?	How satisfied are occupants with light levels and controls?	Is there a maintenance schedule for lighting?	Is there a fit out guide in place for lighting systems?

Table 2: Typical responsibilities for 'Performance Nexus' nodes in commercial buildings

AUDIENCE	Design Elements	Building Management	Indoor Environment Quality	Occupant Experience	Agreements and Culture
Base Building	Building Owner	Building Manager	Building Manager	N/A	Building owner
Tenancy	Representative	Manager	Representative	Occupants	Representative

The 'Performance Nexus' tool focuses on five key areas of performance:

- **Design elements**: This node focuses on identifying *key existing energy efficient design elements* within a building and identifying retrofit technologies that could be considered. These includes: monitoring and control technology; lighting; heating, ventilation and air-conditioning; plant and equipment; building fabric; and the tenancy design and fit out.
- **Building Management**: This node considers *the way design elements are used and maintained*, and how information from the other nodes is used in decision-making processes. This includes: operation and management practices; reporting and evaluation; maintenance and cleaning; commissioning and tuning; management personnel; communication and education; and procurement.
- **Occupant satisfaction**: This node considers *how to identify potential problem areas and systems* that are contributing to dissatisfaction in order to rectify the situation. This includes: perceived productivity; communication and reporting; training, education and guidance; and use of controls.
- **Agreements and Culture**: This node considers opportunities for 'hard' and 'soft' agreements affecting building performance. They include: lease agreements; ratings, mandates and incentives; commitments and targets; organisational culture; and communication and education initiatives.
- **Indoor environment quality**: This node considers how key IEQ parameters can provide valuable guidance for improving conditions as part of efforts to improve energy performance. It includes: basic IEQ monitoring; advanced IEQ monitoring; IEQ management programs; Health and well being; and reporting and communication of results.

Results of trialling the 'Performance Nexus' tool

The tool was developed across the five areas by considering global literature, stakeholder workshops, and several trials in Perth and Brisbane with SBEnrc Core Partners. The tool has been designed to target both the base building and tenancies through the use of checklists, questionnaires, and interview questions, designed for particular areas of responsibility, as shown in Table 2.

After adjustments were made to the tool it was then trialled in its final form in several City of Fremantle buildings by the research team. The result is a tool that guides users through a more holistic approach to the building evaluation process and ensures that key metrics and considerations are included in the process. The 'Performance Nexus' is particularly valuable as a pre- and post-retrofit evaluation tool that can effectively highlight the impacts of retrofits to a workplace and identify areas that may need improvement, and where relationships between areas could be strengthened to support improved building performance. The tool is complemented by a series of case studies that investigate how such metrics and considerations are used in practice to improve performance across multiple dimensions. The results show that the tool provides a low-cost, low complexity approach that provides a structure to achieve buy-in from a range of stakeholders involved in the building.

Benefits to government

The key findings provide valuable insight about the range of benefits associated with a more holistic approach to building performance improvement:[3]

- *Informing legislation and policy development*: The key findings highlight legislation and policy opportunities for government to support a more holistic approach to improving the energy performance of existing commercial buildings. This includes building codes; planning requirements; incentives for existing buildings to undertake retrofit initiatives; workplace agreements (for employees); procurement arrangements (as owners and tenants); and clarity around current and future carbon tax implications for the building industry.
- *Identifying key reporting metrics and areas*: The database review has highlighted a lack of readily accessible data for benchmarking building performance in order to learn from other building examples. This project has highlighted a set of key metrics and considerations that could become part of mandatory reporting requirements.
- *Providing government with succinct capacity building materials*: The deliverables of the project provide materials for capacity building staff with regard to low-cost, low-complexity options for improving energy performance in ways that also improve work conditions and streamline management practices.
- *Informing procurement policies*: The Performance Nexus tool framework provides valuable guidance for procuring services and requiring performance enhancement in existing building retrofits.

3 See Industry Report for further details

Benefits to industry

This project has focused on identifying a set of key criteria to inform efforts to improve the energy performance of existing commercial buildings while also supporting a productive workplace. Industry benefits of this research include:[4]

- *Providing a succinct tool to collect key performance data*: The 'Performance Nexus' provides a valuable tool to identify key performance data and inform efforts to improve the energy performance in a manner that supports a productive workplace.
- *Providing precedent of a more holistic approach to performance improvement*: The 10 Australian case studies investigated provide industry with examples of efforts that take a more holistic approach and consider a range of performance factors.
- *Providing industry with succinct capacity building materials:* The outputs provide a clear and structured set of materials to be used for capacity building including an indication of industry perceptions about taking a more holistic approach to building evaluation.
- *Supporting an expansion in focus from new builds to existing buildings*: The deliverables will support industry to expand into a focus on existing buildings, representing the majority of Australian building stock.
- *Improving strategic positioning*: The Performance Nexus tool enables detection of opportunities across multiple dimensions of a building's operation. This allows building owners to plan for future retrofits with an improved understanding of financial and non-financial implications. It provides a process that enables building managers to focus on how all relevant building occupants can help improve energy performance.

4 See Industry Report for further details

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. The SBEnrc is a key research broker between industry, government and research organisations servicing the built environment.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the economic, social and environmental sustainability areas in programs respectively titled: Driving Productivity through Innovation; People, Processes and Performance; and Greening the Built Environment.

This research wouldn't be possible without the ongoing support of our industry, government and research partners:

Queensland Government
GOVERNMENT OF WESTERN AUSTRALIA
NSW Government Transport Roads & Maritime Services
John Holland
PARSONS BRINCKERHOFF
Curtin University
QUT
SWINBURNE UNIVERSITY OF TECHNOLOGY

Project partners:

- WA Department of Finance
- QLD Department of Housing and Public Works
- Parsons Brinckerhoff
- John Holland
- Curtin University
- Queensland University of Technology
- Townsville City Council
- QED Environmental Services
- HFM Assets
- Green Building Council Australia

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QUT
hfm asset management BUILDING EFFICIENCY
QED
John Holland
City of Townsville
green building council australia

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The Future of Roads

Reducing Environmental Pressures, Managing Carbon, and Considering Future Scenarios

Australia's road network and transportation infrastructure faces increasing pressure from a range of factors, including: population growth and urbanisation; changes to weather patterns; increases in energy and resource prices; road material resource shortages; and the changing usage and expectations of roads and transport. There is a growing imperative for road agencies to address such pressures with informed and transparent approaches. SBEnrc's research has found that significant sustainability gains are feasible in design, construction, maintenance and operation. They focus on three specific needs:

1. To reduce greenhouse gas emissions related to road construction;
2. To identify reporting frameworks and key reporting areas for roads; and
3. To identify potential trends and future risks affecting roads.

The key findings inform a range of actions for moving forward, namely: capacity building to identify short term options to 'reduce greenhouse gas emissions' during construction, design, maintenance and operation on existing and future road projects; enhancing 'sustainability reporting' efforts, such as to AGIC and the GRI; and ongoing strategic consideration of the '*risks and opportunities*' associated with current and future trends.

Benefits to industry include: Improving strategic positioning; providing guidance on areas of specialisation; and understanding market gaps and arising business opportunities.

Benefits to government include: informing policy and management decisions; providing insight into changing roles and leverage points for action; providing a scenario planning framework; and informing further research areas.

Both will need transparent and strategic reporting mechanisms to show how the new challenges for road delivery and operations are being addressed.

The research

As part of the SBEnrc focus on industry-led research, two stakeholder workshops were held in the early stages of the project, and two more in the later stages, hosted by SBEnrc partners, Main Roads Western Australian and the Queensland Department of Main Roads and Transport. The initial workshops involved the research team presenting the key findings of a literature review and working with key stakeholders to identify areas of interest for the project to develop. A wealth of evidence and precedent was produced to show that road projects can improve sustainability outcomes through design, construction, maintenance and operation. The result of the workshops was a project scope that investigated key areas of interest to partners and that were seen to be areas that would provide clear benefits to industry and government. Following the initial workshops a series of meetings were held with SBEnrc partners to refine the scope in light of the key findings of the research team. The second stage of stakeholder workshops focused on trends and future risks affecting roads; and involved a run through of a new methodology for undertaking trend assessments that will be the basis of the next stage of the project.

Sustainable Built Environment National Research Centre

Aims

Based on industry feedback the project focused on:

1. Providing a '*clear description*' of a range of options for reducing the carbon intensity of roads in the design and construction phases, in particular considering aggregates and asphalt as key areas with concrete and road lighting also topics of interest.
2. Investigating how '*sustainability reporting*' applied to road projects and identifying relevant assessment and rating tools. This focused on understanding the level of sustainability reporting in road projects in Australia and Internationally.
3. Developing a '*strategic process to consider future trends*' to provide government and industry with a tool to consider future trends, consider the likely intensity of such trends over time, identify risks, identify interactions, and brainstorm strategies that can minimise risk and delivery with multiple benefits across key trends.

Key findings

In a September 2012 edition of the Economist, a lead article examined the emerging global awareness that car use has peaked in the world's developed cities.[1] It quotes an Australian Government report examining the phenomenon and speculates on what may be causing it and what it could mean for government policy—especially on roads. The factors considered to be significant were those impacting many other areas of the economy, including: the use of digital communications instead of travel; internet shopping; changing demography with younger people more urban and less oriented to the attractions of the car; and increased fuel costs due to oil scarcity and climate policy.

While road agencies are digesting what this may mean for their priorities and approaches to road building and management, they are also under increasing pressure to provide solutions to congestion and the political cycle of promised new roads. This SBEnrc project identifies three key needs that are becoming pressing priorities for road agencies that are facing such a conflicted future.

1. The need to reduce greenhouse gas emissions related to road construction

One of the most immediate pressures is the need to respond to climate change, and in particular the need to reduce carbon intensity through options such as: reducing automobile fuel consumption through the design of road alignments (vertical and horizontal); adapting roads for multiple users; reducing embodied energy of aggregates, cement and asphalt; reducing and avoiding fossil fuel use in hauling and onsite transport of materials and water; and reducing energy requirements of route and signal lighting.

Table 1: Impacts of Climate Change on Road Infrastructure

Issue	Implication for Roads
Costs of greenhouse gas emissions	• Reducing automobile fuel consumption through the design of road alignments (vertical and horizontal) • Reducing energy intensity of aggregates, cement and asphalt • Reducing and avoiding fossil fuel use in hauling materials and water • Reducing energy requirements of route and signal lighting • Adapting roads for multiple users
Temperature increase & severe droughts	• Increasing road maintenance of surface cracking due to changing landscape topography caused by evaporation • Increasing maintenance due to wear and tear of road surfaces from higher temperatures • Increasing rehabilitation of road surfaces due to surface cracking, warping and asphalt bleeding (flushing)
Increased extreme rainfall events & flooding	• Increasing road maintenance due to potholes from water entering the road surface • Increasing road rehabilitation due to flooding events affecting large expanses of roadways • Decreasing ability for maintenance and rehabilitation to take place due to extreme wether events affecting construction days and access • Increasing pressures on road network and drainage systems due to road flooding
Sea Level Rise	• Increasing salt-water corrosion of roads due to higher water tables from flooding and sea level rise. • Increasing regularity of storm surge and wave impacts on coastal and low-lying areas
Increased Cyclones	• Increasing road damage and traffic hazards due to debris on roads • Increasing regularity of storm surge and wave impacts on coastal and low-lying areas

Five key focus areas for reducing greenhouse gas emissions and other environmental pressures are: road design, aggregates, asphalt, concrete, and road lighting.

For example, in Australia there are now a number of states with specifications and guidelines that regulate the use of recycled materials in roads. Such efforts in construction and other areas are providing a wealth of experience and knowledge in innovative approaches to road construction and maintenance, including: road bases that reuse previous pavement layers; road surfaces that use scrap tyres, plastic bags and plant based bitumen alternatives; and lighting designs that achieve radical energy and cost reductions by implementing new lighting and signal technology.

1 Economist (2012) The future of driving, Seeing the back of the car, In the rich world, people seem to be driving less than they used to, 22 September 2012

Key areas for reducing environmental pressures related to roads

DESIGN

Route design
Pavement design
Material specifications
Alternative road users
Knowledge transfer

CONCRETE

Materials
- Use of alternative aggregate material.
- Use of cement alternatives including sulfo-aluminate, magnesium-phosphate, and alumino-silicate cements.

Processes
- The potential to achieve carbon storage in concrete, in particular magnesium-phosphate cements.
- Innovations in methods and techniques for cement placements.

AGGREGATES

Placement
- Saline or non-potable water stabilisation.
- Non-potable water for dust control.

Alternative Materials
- The use of waste products-concrete, tyres, glass, bauxite residue, and waste building materials.
- Plant based bitumen alternatives.
- The use of in-situ stabilisation techniques such as foamed bitumen to reduce the need for aggregate.

LIGHTING & SIGNALS

Potential to reduce consumption of electricity and associated greenhouse gas emissions through lighting choices, such as using energy efficient route lighting using LEDs, and demand management.

ASPHALT

Materials
- The use of alternate materials such as rubber crumb and recycled asphalt.
- Opportunities to innovate bitumen mix design.

Processes
- The use of warm mix technologies.
- The use of cold mis applications.
- Innovations in methods and techniques for bitumn placement.

2. The need to measure and report on the sustainability of roads

Road agencies in Australia are experiencing an increasing focus on reporting on the performance of projects. Beginning with an initial focus on '*environmental reporting*', focused on ecological impacts and disturbances of road construction, the focus of reporting has broadened to '*sustainability reporting*'. Much of the data that is required to fulfil the new generation of project reporting is already being collected across many road construction projects. However, it is clear that the data is not systematically presented in a way that encourages use or transparency in reporting. There is an increasing focus on appropriate sustainability metrics for reporting performance that capitalise on measurement and reporting already undertaken. This includes identifying the effective use and implementation of recycled materials, ameliorating in-situ materials, and using industrial by-products. In addition, metrics are increasingly being used to monitor the environmental and carbon performance across a number of factors.

Developed and administered by the Australian Green Infrastructure Council (AGIC), the 'Infrastructure Sustainability' (IS) tool uses a framework of 15 categories within six broad themes, developed in collaboration with industry. The categories '*Energy and Carbon*' and '*Materials*' directly focus attention on carbon reporting through prioritising reducing greenhouse gas emissions, minimising energy demand, recognising the use of greenhouse gas emissions offsets, and considering material life cycle impacts. Fourteen pilot trials for the rating tool were undertaken nationally and showed how useful the tool could be if mainstreamed, especially if aligned to the tender stages of the project.

The Global Reporting Initiative (GRI) was developed by the US non-profit organisations the Coalition for Environmentally Responsible Economies (CERES) and the Tellus Institute. This tool provides a comprehensive sustainability reporting framework that is widely used around the world, including by road agencies. The framework enables all organisations to measure and report their economic, environmental, social and governance performance. Based on the outcomes of this project the next phase of the research will inform a process by the *Global Reporting Initiative* to explore important topics in the transport sector to enhance their important organisational sustainability reporting process. It is a significant achievement for SBEnrc to be invited to contribute to this process.

3. The need to identify potential trends and future risks affecting roads

Future environmental, economic, and social trends associated with roads will have a significant impact on their associated costs and impacts. The project considered a short list of 10 potential trends, their interactions and implications for future risk.

1. Increase in the cost of road maintenance;
2. Increase in extreme weather events;
3. Oil based road surfacing unfeasible;
4. Trips by walking, cycling and public transport increase;
5. Aggregate shortages;
6. Freight vehicles increase in size and quantity;
7. Funding constraints on new projects and on maintenance of existing infrastructure;
8. Transport infrastructure reaches capacity;
9. Electric and alternative fuel vehicles are mainstream;
10. City planning requires intensification along rail lines & infill development.

When looking at such trends the project considered how their intensity might change over time through 'trend profiles', providing a structure to consider associated risks and opportunities for road agencies. This project then distilled a number of strategies that could underpin transport agencies to prepare for the future risks associated with key trends, in particular strategies that are able to address multiple trends. These included:

- Road pricing mechanisms
- Government action to support change
- Investment in research and development
- Analysing investment priorities
- Incentivising preferred practices
- Increasing the efficiency of existing infrastructure
- Creating adaptable design standards
- Sharing knowledge and building capacity
- Investing in carbon management
- Transit oriented development.

These strategies highlight the changing role of road agencies, and importantly, the structural shift that is occurring within organisations, focusing less on new infrastructure and more on maintenance and enhancing the efficiency of existing roads.

Benefits to industry and government

Industry Benefits: This research project seeks to contribute to industry conversation around 'sustainable road infrastructure', providing an extensively researched context to inform future innovation. Specifically:

- *Understanding emerging options to reduce greenhouse gas emissions associated with road construction*: Clear guidance on what these options are and how they can be realised, with precedents from around the world.
- *Improving strategic positioning*: Insight into future areas for risk management through considering global population, resource and climate trends.
- *Providing guidance on areas of specialisation*: To focus resources into areas that will provide the largest reduction of environmental impacts during road construction.
- *Understanding market gaps and arising business opportunities*: Targeting new business opportunities and strategic areas for research and development collaborations.

Government Benefits: This research creates a clear platform for government to consider emergent opportunities for addressing environmental impacts, and future risks to be addressed in managing road infrastructure in a changing climate. Specifically:

- *Informing policy and management decisions for a resilient road network*: Innovations to incorporate into road management planning, tenders, and reporting.
- *Providing insight into changing roles and leverage points for action*: informing a shift to focusing on maintenance and enhancing the efficiency of existing roads.
- *Providing a scenario planning framework to stimulate responses*: Unique scenario planning process to identify emerging trends, risks and strategies impacting road networks.
- *Informing Further Research Areas*: Understanding of critical areas to invest government research funding, and specific design and technical solutions requiring further development.

Both industry and government will need transparent and strategic reporting mechanisms to show how the new challenges for road delivery and operations are being addressed.

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. The SBEnrc is a key research broker between industry, government and research organisations servicing the built environment.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the economic, social and environmental sustainability areas in programs respectively titled: Driving Productivity through Innovation; People, Processes and Performance; and Greening the Built Environment.

This research wouldn't be possible without the ongoing support of our industry, government and research partners:

Queensland Government · GOVERNMENT OF WESTERN AUSTRALIA · NSW Government Transport Roads & Maritime Services · John Holland · PARSONS BRINCKERHOFF · Curtin University · QUT · SWINBURNE UNIVERSITY OF TECHNOLOGY

Project partners:

- Main Roads WA
- QLD Department of Transport and Main Roads
- Parsons Brinckerhoff
- John Holland
- Curtin University
- Queensland University of Technology
- Australian Green Infrastructure Council

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Harnessing the Potential of Biophilic Urbanism

In Australia, an Economic and Policy Investigation

As Australia's cities grow to accommodate a burgeoning urban population it is increasingly important to find innovative ways to reach a balance between the levels of nature necessary for health and well-being, and the performance demands of infrastructure. 'Biophilic urbanism' will be a critical part of urban change as the economic need for large, dense cities and particularly dense centres, continues to grow. Such elements range from green roofs, green walls, and indoor plantings, to green verges, green islands, green corridors, urban farming, and regenerated waterways.

Biophilic urbanism is delivering a range of benefits in cities, such as: reducing the urban heat island effect; reducing heating and cooling loads in buildings; improving air quality; allowing urban food production; and improving stormwater management. Such elements can provide aesthetically pleasing surroundings that have been shown to enhance urban liveability, reduce crime and violence, reduce depression, and encourage greater community connectivity. Biophilic urbanism has also been linked to reducing stress, improving health and well-being, increasing cognitive abilities, improving productivity, and enhancing early childhood development.

This project focused on three key industry needs expressed by project stakeholders, namely: 1) providing a clear description of a range of biophilic urbanism options; 2) investigating the costs and benefits of various biophilic urbanism programs; and 3) investigating actual biophilic urbanism policies and programs to inform efforts in Australian cities. The mainstreaming and development of metrics on biophilic urbanism outcomes appear to be the next phase in this new phenomenon.

The research

As part of the SBEnrc's focus on industry-led research, two stakeholder workshops were held in the early stages of the project, hosted by SBEnrc core members, the Western Australian Department of Finance in Perth, and Parsons Brinckerhoff in Brisbane. The workshops involved the research team presenting the key findings of the literature review and working with a total of 25 key stakeholders to identify areas of interest for the project to develop. The result of the workshops was a project scope that investigated key areas of interest to partners and that were seen to be areas that would provide clear benefits to industry and government. The workshop format was based on the methodology of 'Collective Social Learning', created by Emeritus Professor Valerie Brown, which guided participants through a process to consider a vision for a 'nature loving city' and the aspects that both enable and disable achieving such vision.

Sustainable Built Environment National Research Centre

Aims

Based on industry engagement the project focused on:

1. Providing a 'clear description' of a range of biophilic urbanism options.
2. Investigating the 'costs and benefits' of various biophilic urbanism programs.
3. Investigating 'actual urban greening policies and programs'.

Key findings

The imperative to respond to climate change, increasing costs of energy, and steadily growing urban populations means that companies and governments must take innovative approaches. The popularity of biophilic urbanism is rapidly growing as it provides a proven innovative approach to urban development that can deliver a range of benefits. Developing an evidence base, however, can be complex. At some point, it requires adopting some level of risk to trial and demonstrate new tools and techniques. The key findings of this project will contribute to managing risk, by providing a foundation of evidence for the application of biophilic urbanism. Table 1 highlights a growing number of cities developing regulations and incentives to support biophilic urbanism that are delivering multiple benefits.

Table 1: Examples of requirements and incentives for biophilic urbanism in cities

Location	Name of Policy	Key Policy Requirements
Linz, **Austria**	*Linz Green Space Plan*	New buildings with area of over 100m^2 and a slope of up to 20˚ require a compliant green roof with a subsidy available.
Port Coquitlam, **Canada**	*Zoning Bylaw, No 2240 and 3569*	All new commercial and industrial buildings of greater than 5000m^2 require a green roof of at least 75% of the roof area.
Toronto, **Canada**	*Toronto Bylaw No 583, 2009*	All new developments above 2000m^2 require 20-60% green roof. (Except residential buildings of less than or equal to the greater of six storeys or 20 metres.)
Faenza, **Italy**	*Municipal Structural Plan*	Subsidies offered to encourage developments to maximising ground permeability and water and include green areas and appropriate landscaping, by offering greater building sizes and tenant use types.
Berlin, **Germany**	*Development Code: Biotope Area Factor*	New residential structures require 60% ecologically effective area and new commercial structures 30%. (Only mandatory in areas with legally binding landscape plans.)
Cologne, **Germany**	*Cologne Green Roof Policy (Flood Mitigation)*	A 50% stormwater fee subsidy is offered to compliant green roofs.
North Rhine Westphalia, **Germany**	*Initiative for Ecological and Sustainable Water Management*	Offers a subsidy for green roofs with either a minimum depth of 15 cm or certification of a runoff coefficient of less than 0.3.
Singapore, **Singapore**	*'Green Mark' certified*	All new public buildings and those under retrofitting above 5,000 m^2 are required to be 'Green Mark' certified after 2007.
Basel, **Switzerland**	*City of Basel's Building and Construction Law*	All new and renovated flat roofs require a compliant green roof with native vegetation.
Chicago, **USA**	*Stormwater Management Ordinance*	Requires developments that are over a certain size and density to manage the stormwater falling on the site.
Portland, **USA**	*Stormwater Management Manual*	New developments and redevelopments with over 500ft^2 of impervious surface are required to manage stormwater onsite through replicating as much as possible the pre-development hydrological conditions.
	Building Code Floor Area Ratio Bonus	Developers offered an extra 3ft^2 per foot of green roof without additional permits, along with a *grant* of $5/ft^2 for stormwater retention.
New York City, **USA**	*New York State Law*	Subsidy offered for a green roof of more than 50% of available roof space.
Seattle, **USA**	*Seattle Green Factor*	Requirement for 30% landscaped area for commercial developments.

Economic assessment key findings

The project distilled a number of economic considerations for urban greening, highlighting the emergent stages of the field and the need for further inquiry to support mainstreaming of urban greening practices:

- *Understand the opportunity cost of biophilic urbanism*: Governments and citizens rarely understand the full cost of urbanisation challenges and are therefore often unaware of the need to address these challenges, or the scale of the benefits possible through urban greening.
- *Find the balance of economic argument versus social and environmental obligation*: Berlin, Singapore, and Chicago have shown that an economic argument is not always a strong driver for biophilic urbanism, as it can be marketed on platforms of innovation and world-leading practice, urban beautification, and enhanced liveability. A partial cost-benefit analysis can be sufficient to justify action, particularly when it is recognised that other benefits will result.
- *Generate data on financial costs and benefits of urban greening*: A lack of an economic study of the costs and benefits of urban greening may prohibit a holistic approach and consistent support. Economic reporting can support benchmarking, demonstrating how effective biophilic elements are and fostering knowledge-sharing between cities worldwide. Elements can be used to boost revenue in avenues such as property and sales tax, stimulate real estate development, improve the standard of living and enhance tourism.
- *Provide financial incentives*: Meaningful financial incentives can encourage private property owners to integrate nature into their property, especially for more costly biophilic elements such as green roofs and green walls.
- *Communicate the competitive advantage that urban greening provides*: Visionary and innovative approaches to urban planning have given cities like Germany and Singapore a competitive advantage in various green technology markets, as well as lead the global environmental sector workforce. The head of Singapore's Lee Kuan Yew Public Policy Centre Dr Balakrishnan said at the World Cities Summit in 2012 'cities that provide a green and welcoming environment soothe their citizens and gain a competitive advantage…people want to stay and invest in your economy'.
- *Implement creative funding systems that respond to local context*: A creative financial scheme that attracts private and public funding is particularly important to ensure a consistent source of funding for a project (such as an urban park) and to minimise the cost to tax payers.

Policy and program key findings

The project distilled the following key considerations for policy and program design:

- *A focus on specific outcomes from biophilic urbanism*: Biophilic urbanism can provide a range of benefits including: improving stormwater management; increasing urban amenity; economic revitalisation of derelict urban areas; enhancing international competitiveness; countering the loss of biodiversity and ecosystem services; and mitigating the urban heat island effect. Tailoring projects to areas that are of specific relevance to a given city can be more effective than concurrently promoting all possible benefits.
- *The need for a high level champion*: Cities that have successfully encouraged biophilic urbanism have typically had a political champion, such as Mayor Daley in Chicago and Prime Minister Lee Kuan Yew in Singapore. This can drive trial and demonstration projects and help overcome barriers surrounding a lack of experience and evidence.
- *Begin with demonstration and evaluation*: Government supported demonstration projects that test and evaluate techniques and technology provide evidence and experience necessary for public and industry support. As many benefits of biophilic urbanism are difficult to quantify, personal experience and interaction through demonstration projects can build broader understanding and awareness of these benefits. Outcomes of demonstration projects should be measured where possible and widely communicated across government, industry and the community.
- *Overarching policies or visions*: High level governance frameworks, such as the German and Berlin Nature Conservation Acts, provide a central focus for issue-specific policies, plans and programs. Multi-departmental advisory boards, or instituted mechanisms for cross-departmental communication and collaboration such as the Chief Sustainability Officer and Bureau of Environmental Services in Portland, maintain consistency and enable synergies between governance areas.
- *Provide incentives for private property owners*: A range of financial incentives have been shown to encourage the use of biophilic elements, and can address the issue of split incentives. Several cities investigated as part of this project charged property owners separately for stormwater, providing a discount where it was managed onsite, principally through the use of biophilic elements. These schemes generally raise awareness about the costs of stormwater management, and engage property owners as partners of the city to manage the issue together.
- *Develop mandatory, performance-based requirements*: For new and renovated properties, performance based requirements for biophilic elements enable innovation. Evaluating outcomes can help communicate benefits and drive continual improvement. Some examples include Portland's stormwater and drainage management policies, and Berlin's Biotope Area Factor.

Benefits to industry and government

Industry Benefits: Governments and citizens alike are increasingly demanding smart, sustainable, sophisticated urban design solutions to meet the pressing challenges facing cities today. Biophilic urbanism provides such an approach and the outcomes of this project are of benefit to industry in the following ways:

- *Building Demand for Biophilic Urbanism*: Benefits of biophilic urbanism to encourage a greater requirement in urban development proposals and tenders.
- *Forecasting Future Requirements*: The current level of requirements for biophilic urbanism in cities around the world to inform forecasts of future such requirements in Australia.
- *Improving Strategic Positioning*: Guidance to industry on current and future opportunities for harnessing biophilic urbanism to strengthen project and service offerings.
- *Increasing Capacity Building*: A clear and structured understanding of how key elements of biophilic urbanism can be practically applied along with the associated benefits.
- *Reporting Industry Perceptions*: An indication of the perceptions of biophilic urbanism held by the industry.

Government Benefits: The key findings provide valuable insight on the range of benefits associated with biophilic urbanism that will enhance government programs. As such the outcomes of this project are of benefit in the following ways:

- *Benefits to Government*: Enhanced stormwater management; reduced urban energy demand; reduced urban temperatures; reduced impacts of heat waves; and increased tourism and sales tax revenue.
- *Benefits to the Community*: Enhanced liveability in cities; increased health and well-being; improved productivity; increased real estate value; and reduced crime and violence.
- *Informing Policy Design*: Evidence of the current level of requirements for biophilic urbanism in a number of cities around the world to inform policy development.

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NSW Government Transport Roads & Maritime Services

John Holland

PARSONS BRINCKERHOFF

Curtin University

QUT

SWINBURNE UNIVERSITY OF TECHNOLOGY

Project partners:

- WA Department of Finance
- Parsons Brinckerhoff
- Curtin University
- Queensland University of Technology
- Townsville City Council
- PlantUp
- Green Roofs Australasia

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Sustainable Infrastructure Procurement

Reducing greenhouse gas emissions (GHGE) from consumption of fossil fuels in road construction is an essential step in meeting Australia's Kyoto Protocol obligations. GHGE reduction is an important driver to change procurement processes for both road authorities and contractors.

The overarching aim of the project has been to provide both the client-side and the provider-side of infrastructure construction with a methodology and measure, based on mass-haul planning, which can be applied to an integrated GHGE reduction procurement protocol to reduce GHGE.

The haulage of mass materials (mass-haul) around, as well as to and from a road construction site, has been identified as a major producer of GHGE. High volumes of GHGE are produced during the earthworks cut and fill operations when large quantities of fuel are consumed building the road to its designed alignment.

Industry problem:

Industry needs a method to encourage reduction of GHGE arising from mass-haul operations during the construction of major roads.

Proposed solution:

An effective and practical procurement system based on an alternative method for calculating, estimating, evaluating and monitoring GHGE using the principle of calculated 'work' derived from a mass-haul plan.

A small but effective change is recommended for procurement processes related to mass-haul/ earthworks operations. This practical system for motivating GHGE minimisation is presented as a series of interventions in the procurement cycle of major road projects. Recommendations for all procurement phases are based on reducing the effort/work required for mass-haul activities. Hauls planned using a contractor's preferred methods can be used to calculate comparative GHGE reductions by using the planned effort/work involved in the physical movement of loads.

This small change to existing procurement methods has the potential to deliver a major reduction in GHGE on major road-works and other infrastructure projects.

Green public procurement

In Australia, state transport authorities are 'greening' their procurement processes to meet declared GHGE targets. For example, Main Roads Western Australia has a 2020 target of 5-15% reduction in GHGE from 2010 levels and NSW Roads and Maritime Services has committed to becoming carbon neutral by 2020.

Sustainable Built Environment National Research Centre

Proxy for GHGE

Current construction industry practice is to use fuel consumption as a proxy for GHGE. Using this proxy, measuring the GHGE produced from road construction activity is difficult for two reasons: fuel consumption can only be calculated after the project is completed, and the data is aggregated for all phases of the construction project. This retrospective approach does not assist in the development and management of pro-active fuel reduction strategies.

One significant contributor to GHGE *during* road construction is the handling and movement of mass materials (soils, aggregates, rock). Representing on average almost 30% of overall project costs, the negative environmental impact of the physical effort to move men, machines and materials during earthworks is an even higher percentage of fuel consumption for a project, leading to the consumption of millions of litres of diesel across all projects.

An alternative method of calculating GHGE

Focus on fuel reduction during project planning is a better method to proactively reduce GHGE. An alternative method has been developed as a practical and feasible solution to planning and controlling the negative environmental impact of GHGE from mass-haul/earthworks operations. This method is based on work or effort as a *relative proxy* for GHGE.

The alternative method is based on four assumptions:

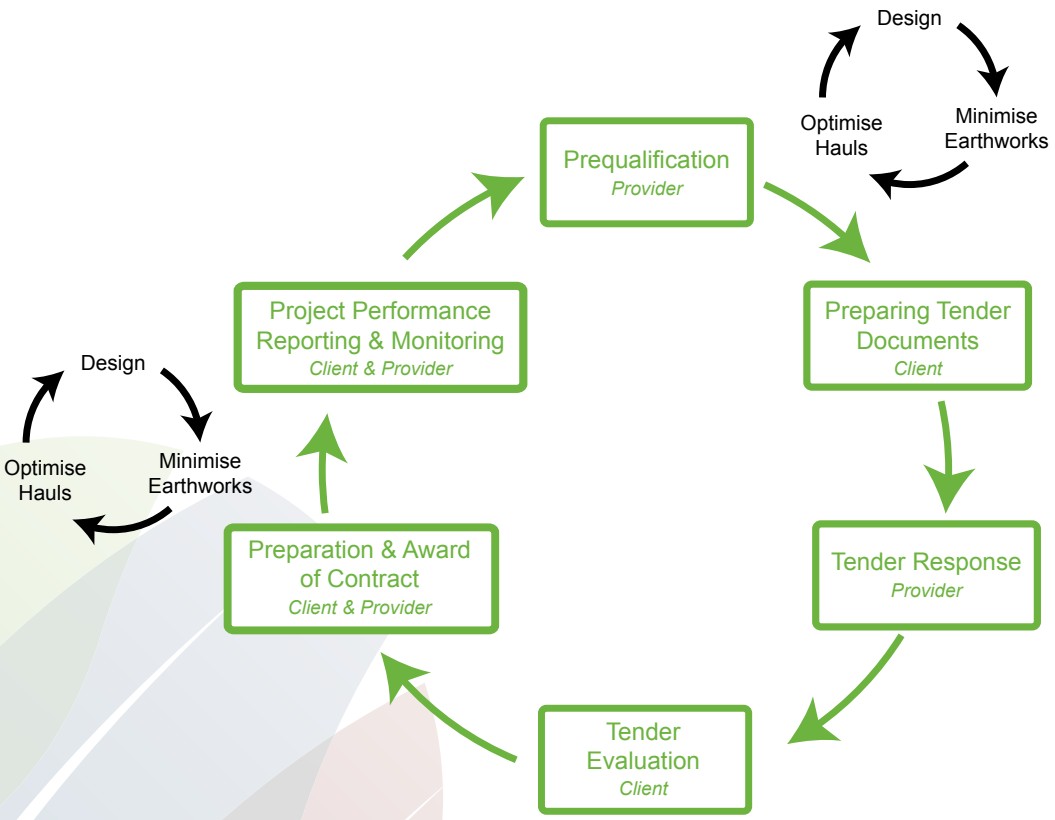
1. Fuel consumption from the fleet engaged in mass-haul operations is an indicator of GHGE.
2. The effort required to move mass is an indicator of fuel consumption.
3. Effort can be reduced if the amount of material moved, the distance travelled or the height lifted can be reduced.
4. GHGE can be reduced if the amount of mass-haul effort can be reduced.

The three advantages of using the work/effort principle are:

1. Calculations are simple
2. Requires only tables of hauls
3. Takes quantity, distance and gradient into account.

Using physics principles, the amount of work can be used as a tool when comparing different mass-haul plans for relative fuel consumption and relative cost. The summation of the amount of work for individual hauls becomes the total amount of work for the table of hauls. This amount is **a unique figure for non-price comparison**. This **unique figure** can be used as an indication of the amount of fuel used and GHGE, and can serve as a tool for comparing different mass-haul plans.

Figure 1 GHGE reduction opportunities in the procurement of major road-works



A model for greening road construction procurement

There are six primary functions in the road construction procurement cycle (Figure1). This closed-loop includes the National Austroads Prequalification Ranking System, now an important addition to traditional major works procurement.

Each procurement phase provides an opportunity to change process and influence changes to industry practice. The GHGE reduction intervention points collectively provide an effective and alternative method for calculating, estimating, evaluating and monitoring GHGE using the principle of 'work' calculated from a mass haul plan. Further, there are two opportunity points for design intervention to minimise earthworks and haulage. The first opportunity is before the tender documents have been developed. The second opportunity is once the contractor has been selected.

1. Contractor pre-qualification scheme

Contractor pre-qualification is the outcome of a process that evaluates the ability of organisations to complete a contract satisfactorily before they are admitted into the tender bidding process. This motivates contractors to improve their performance.

Two recommendations for clients to consider as pre-qualification criteria.

- Require contractors to have management systems with the capacity to create, monitor, report and adapt constrained and unconstrained optimal mass-haul plans.
- Require sustainability credentials, such as AGIC membership.

Four capability recommendations for providers.

- Have the means and methods for preparing unconstrained and constrained optimal mass-haul plans.
- Have systems in place for monitoring, controlling and reporting against a constrained mass-haul plan.
- Have expertise in calculating, monitoring and reporting GHGE.
- Have sustainability credentials.

2. Preparing tender documents

There are two opportunities to maximise 'value for money' during the preparation of tender documentation.

- Early contractor involvement in design.
- Requiring tender submissions to include mass-haul method statements and plans (constrained and unconstrained) as tables of hauls.

3. Tender response

Recommendations for inclusion in the contractor's detailed analysis of the project requirements.

- Creation of a mass-haul method statement.
  The method statement is the opportunity for the contractor to demonstrate understanding the specific nature of the project as well as the project constraints.
- Development of mass-haul plan (unconstrained) as table of hauls as the ideal solution without time-related impacts.
- Development of mass-haul plan (constrained) as table of hauls that includes resource issues, task sequencing and project priorities.

4. Tender evaluation

Tender evaluation, including non-price criteria, aims to achieve 'best value for money'. Reducing GHGE is one non-price criterion currently required by a number of state road authorities.

It is recommended that clients use work/effort as a *relative proxy* for GHGE as a non-price criterion to facilitate tender evaluation.

- To compare different haul solutions presented in tables of hauls.
- To assess the practicality of mass-haul plan methodology statements.

5. Preparation and award of contract

Contractor selection using the non-price criterion of work/effort provides the opportunity for design changes to be made to minimise effort/work in mass haul to reduce GHGE.

6. Project performance monitoring and reporting

It is critical for the contractor to monitor the movement of earthworks and compare and report actual hauls against planned hauls. Deviations can be identified and corrective action taken.

Recommendations for accurate monitoring and reporting: client requirements and capacity.

- Require contractors to monitor hauls and report against the constrained mass-haul plan.
- Require contractors to report using a table of actual hauls.
- Client capability to calculate the **unique figure of work** calculated from the table of actual hauls and compare performance with the constrained plan.
- Client capacity to assess performance data that can feed back into the contractor's pre-selection profile.

Benefits to industry

The benefits of this project are that it provides infrastructure clients and construction service providers with a a practical procurement system based on mass-haul planning and associated work/effort that can be applied to an integrated GHGE reduction procurement protocol to reduce GHGE on road projects. SBEnrc 1.8 is just one of a number of Australian initiatives focused on ensuring a sustainable built environment. These include the AGIC Infrastructure Sustainability Rating Tool, VicRoads INVEST (Integrated VicRoads Sustainability Tool) and TAGG Greenhouse Gas Assessment Workbook & Carbon Gauge for Road Projects. These GHGE reduction tools focus on the total road construction or the life-cycle of the road. However, such tools are not intended to examine in depth high levels of GHGE produced by mass-haul.

The study proposes a new procurement system that can deliver additional value to these existing tools. As such, it may be readily implemented practical with only minor change to existing construction practices and delivery strategies. An effective and practical method for calculating, estimating, evaluating and monitoring GHGE using the principle of work calculated from a mass haul plan is provided. The alternative method introduces GHGE reduction procurement process changes for all phases of road procurement.

This will provide an alternative to the current reliance on post-hoc measuring of fuel consumed, by instead motivating contractors to target fuel reduction through better planning of and control of mass haul. The use of non-price criteria in a structured procurement system has the capacity to significantly reduce one of the major contributors to GHGE in road construction and practical, thereby reducing the environmental impact of infrastructure construction.

The application of the complete alternative method summarised in this brochure is explained in the industry report titled *Mass-Haul Environmental Impact Minimisation: A Practical Method for Greening Road Procurement.*

Available online: www.sbenrc.com.au

The *Practical Method for Greening Road Procurement* developed during the study will make a significant contribution toward Kyoto Protocol obligations to reduce GHGE by 2020.

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This research wouldn't be possible without the ongoing support of our industry, government and research partners:

Queensland Government

GOVERNMENT OF WESTERN AUSTRALIA

NSW GOVERNMENT Transport Roads & Maritime Services

John Holland

PARSONS BRINCKERHOFF

Curtin University

QUT

SWINBURNE UNIVERSITY OF TECHNOLOGY

Project partners:

- QLD Department of Transport and Main Roads
- Main Roads WA
- Swinburne University of Technology
- Queensland University of Technology

Queensland Government

mainroads WESTERN AUSTRALIA

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SWINBURNE UNIVERSITY OF TECHNOLOGY

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Developing Innovation and Safety Cultures

The primary aim of Program Two during the initial phase of the centre has been to deliver improved economic and social outcomes for the built environment through increased uptake of sustainable practices.

Greater levels of innovation for the built environment sector offer the most significant flow-on benefit to the national economy of all Australian industries. A better understanding of the interplay between innovation and risk mitigation at the individual, organisational and institutional levels of this industry has clear relevance to the industry to improve sustainability outcomes, increase productivity rates, and decrease personal and industry costs. Application tools for innovation through use of new technologies, new models of focused investment for industry research, and culture change activities based on increasing the understanding of workplace safety will enable stakeholders to provide a sustainable built environment.

For Research Program Two, the past three years of work have targeted the following outcomes for the built environment industry:

- Increased GDP from increased adoption of sustainable technologies.
- Increased turnover for innovation research.
- Reduced national GDP lost due to workplace injury.
- Reduced direct costs of construction workplace injuries.
- Reduced costs from drug and alcohol-related injuries.

This entire project suite has provided both public and private organisations with tools to enable innovation change activities that ensure enhanced economic and social outcomes for the construction sector. These tools are specifically designed to increase sustainable construction practices. The suite of tools includes:

- A cultural change management program and implementation plan for industry employers nationally to manage the safety impacts of alcohol and other drugs. A key component of the implementation plan is an online educational tool that has been specifically developed for managers and supervisory/safety staff.
- The OSM Project Team Evaluation Tool (V1.0), which aids construction project teams in rating their off-site manufacture (OSM) capability and capacity. The indicative number can be used to evaluate: a) appropriateness of OSM project team members' experiences; b) level of risk based on availability of project OSM requirements; and c) OSM project readiness.
- A strategic research and development roadmap based on the Construction 2030 report. An assessment of the likely future landscapes for research and development investment outlines responses to anticipated futures for the Australian built environment. This tool provides guidelines for aligning funding and research priorities for both public and private sector organisations.

The projects completed in Program 2 are described in the Brochures following.

Safety Impacts
of Alcohol & Other Drugs in Construction

The impact of alcohol and other drugs (AOD) consumption continues to be a significant issue for workplace safety and performance in Australia—particularly within the construction industry. While most Australian jurisdictions have identified this as a critical safety issue, limited information is available about the extent or effect of AOD usage on the workplace, or how employers can effectively and efficiently address the issue.

To address such a scarcity of information, this project set out to evaluate the use of AOD within the Australian construction industry and work with employer and employee groups across the infrastructure and building sectors to develop an appropriate industry policy. The aim was to have the policy adopted across construction workplaces nationally, with the ultimate goal of generating broad cultural change across the industry.

A total of 494 workers across a number of Australian worksites were surveyed about their general use of AOD. 58% of respondents scored above the cut-off for risky or hazardous alcohol consumption, while 15% of these scored above the cut-off for being significantly at risk. Only 7% of respondents indicated that they considered that they might have a problem with their drinking habits. Other drug use was also identified as a major issue.

Results from the national evaluation support the need for evidence-based, preventative and tailored educational initiatives to effect cultural change

Goals

This project sought to evaluate the relationship between the use of AOD and the safety impacts within the Australian construction industry. A national approach across the Australian construction workforce - involving government representatives; employers and employees; unions; and other key industry stakeholders and experts was adopted.The ultimate goal has been to engender a cultural change in the workforce - to render it unacceptable to arrive at a construction workplace with impaired judgement resulting from the use of AOD.

Industry driven

The two-year project was guided strategically by a national industry steering committee that has met on six occasions over the period. The Committee comprised representatives from:

- John Holland
- Australian Constructors Association
- Australian Workers Union
- Austroads
- Civil Contractors Federation
- Construction, Forestry, Mining and Energy Union
- Engineers Australia
- Master Builders Australia
- Office of the Federal Safety Commissioner (observer)

Sustainable Built Environment National Research Centre

The research

Volunteers from construction worksites around Australia were surveyed to gain an assessment of the general use of AOD in the Australian construction workforce. The majority (464) of the 494 respondents were male, with an average age of 35.7 years. Most respondents were employees, with 85 participants employed as contractors. Respondents were spread across a range of organisational roles, with the majority of respondents classifying themselves as a tradesperson (155). Other roles were identified as:

- Labourer (117);
- Plant operator (68);
- Administration or engineering role (53); and
- Supervisor (47).

To ensure a globally accepted measurement tool was used, the World Health Organisation Alcohol Use Disorders Identification Test (AUDIT) was adopted. The AUDIT examines responses to 10 questions which fall into three domains:

- Quantity and frequency of alcohol consumption (screens for possible risk of hazardous consumption);
- Abnormal drinking behaviour (may indicate early or established alcohol dependence); and
- Negative consequences related to alcohol consumption.

In addition to the ten AUDIT questions, four supplementary questions were included in the survey to probe self-rated dependency and past other drug use.

Semi-structured interviews were also conducted across a number of roles within the company to identify major issues and themes. Questions centred on perceptions towards AOD use in the workplace and attitudes and perceptions towards existing AOD workplace policies.

What the research tells us

Fifty-eight per cent of respondents scored within the range for risky or hazardous alcohol use. Of these, 65% returned scores that indicated they were at risk of harmful consumption; 20% returned scores that showed they were at high risk of alcohol problems; and 15% returned a score that warrants further diagnostic evaluation for alcohol dependence.

It is also important to consider the overall scores in the context of the three individual AUDIT domains that specifically examine consumption, dependency and alcohol-related problems (see Table 1).

Table 1: Mean AUDIT scores for each domain

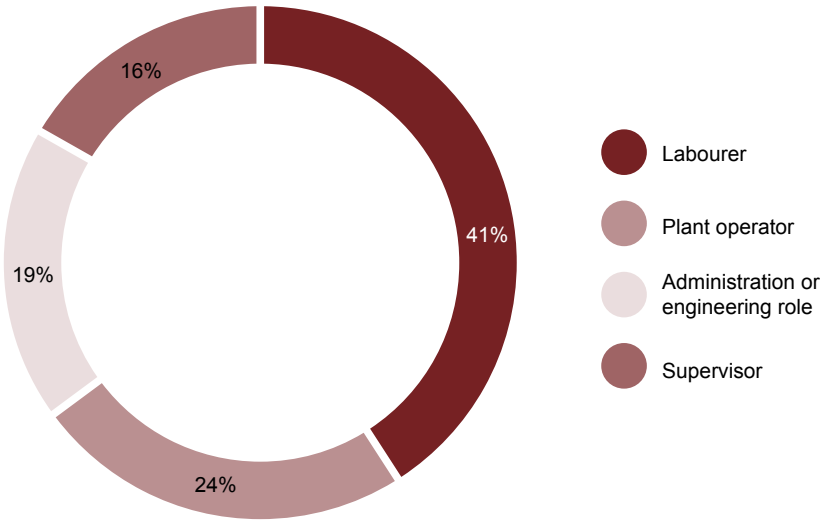
AUDIT Domain	Mean (SD)	No. of respondents (and %) who scored at or above the cut off
Domain 1: Consumption	6.17 (3.1)	300 (61%)
Domain 2: Dependency	1.38 (2.1)	79 (16%)
Domain 3: Alcohol related problems	2.48 (3.1)	291 (59%)

Note: Max score for domain one is 12 (scores ≥ 6 indicating a risk of alcohol related harm). Max score for domain two is also 12 (scores ≥ 4 indicating possible alcohol dependence). Any score in domain three warrants further investigation.

Seven per cent of respondents reported that they either possibly or definitely had a problem with drinking. A further four per cent of respondents reported that they were unsure. Fourteen per cent of respondents reported that it would be either fairly difficult or very difficult to cut down or stop drinking over the next three months.

Of those who scored above the AUDIT score for hazardous alcohol use (58% of the total sample), 74% reported that they do not have a problem with drinking and 55% reported that it would be either very easy or fairly easy to cut down or stop drinking.

In terms of prevalence, 59% of respondents reported they had used marijuana/cannabis in their lifetime, with 15.8% having used it in the last year. Forty per cent had used ecstasy or meth/amphetamine type substances in their lifetime, with 31.6% having used it in the last year.



The interviews

The structured interviews identified a number of important issues.

Links to reduced safety and productivity levels as a result of general use of AOD were confirmed by all of those interviewed in safety advisory positions. Overall, there seemed to be a general lack of understanding and knowledge surrounding the physical and psychological effects of AOD use and how they might impair performance. This was despite the overall attitude that the use of AOD is detrimental to workplace productivity and safety.

In terms of prevalence, AOD use was perceived as a major issue that continues to worsen. It was considered that this decline was of particular concern in relation to other drug use, due to detection being problematic; changes in drug type 'popularity'; and the increased use of synthetic forms of illicit drugs. Prescription medications and other legal stimulants such as energy drinks were also identified by safety staff as a major concern.

While existing policies and programs were generally seen as effective by participants, there was overall support for the development of more comprehensive and tailored educational initiatives for workers within the construction industry. In particular, participants emphasised the need for educational and preventative programs—rather than focusing on the consequences of AOD use after it has become a problem.

A specific need was identified to educate younger employees about coping with the lifestyle that can accompany highly paid, project-to-project work. Acknowledging and understanding the different rationale of "career" workers as distinct from "it's just a job" workers was also highlighted as an important consideration in terms of how to communicate educational messages most effectively to younger employees. Implementing a mentoring type initiative was also suggested as a way of communicating knowledge, experience and advice to younger employees.

In terms of improved communication and education about the effects of AOD use, respondents identified a need for the delivery of clear and simple information via brochures, fact sheets, posters, and videos. Training sessions were also suggested as an opportunity to focus on a particular safety issue in depth. Participants responded positively to the proposed development of a web-based resource.

Fear for job security was highlighted as a common barrier to seeking help or advice about AOD at work.

Other issues included: the importance of management support and maintaining a healthy and open relationship between supervisors and team members, with a strong commitment to preventing harm caused by AOD; and the consistent communication of policies and expectations from day one of the project. Related to this was the importance of ensuring that sub-contractors are subject to the same policies and practices that employees are subject to in their regular practices. Consideration of the culture of specific occupational groups was also identified as being important. Finally, educating therapists and counsellors who are made available to employees about the culture of the construction industry was identified as something that could be of great value.

These results indicate that, as in the general population, a proportion of those sampled in the construction sector may be at risk of hazardous alcohol consumption. As general AOD use does not necessarily translate into workplace AOD use and impairment, these results do not tell us about when those in the 'at risk' group are consuming alcohol. A proportion of those 'at risk' will consume alcohol in their own time, whereby their behaviour has no relevance to their performance at work. For others though, alcohol risk will translate into workplace risk. The evidence from this research does not allow any accurate indication of what this risk might be.

While many in the current sample appear to be at risk of hazardous alcohol consumption, a large proportion of these respondents claimed not to have a drinking problem. Many of these respondents also indicated that it would be fairly easy to cut back or stop their drinking behaviour. These results suggest that those who may be at risk are unaware that a problem may exist, further highlighting the need for educational programs to increase knowledge and awareness of the effects of AOD. Other drug use remains a huge concern.

Benefits to industry

This project has fundamentally contributed to a greater understanding of AOD consumption rates, patterns of use and the associated levels of risk within the Australian construction industry. With a stronger grasp of the extent and severity of the problem, we are better equipped to understand the causes, impact and consequences of AOD within the cultural and operating context of the construction workplace – and importantly, how to respond effectively.

This has been the first scientific evaluation, at a national level, of the use of AOD in the construction industry. The outcomes will be invaluable to the development and delivery of appropriate, up-to-date strategies and tailored materials targeted at the unique needs and characteristics of the construction industry. Importantly, this project has brought together national employer, employee, union and government groups and, within a safety culture framework, has adopted an educative and non-punitive approach to the management of AOD use in this industry. Project outcomes have been coordinated nationally and these aim to contribute to a change in culture towards improving safety in the construction industry—to render it socially unacceptable to arrive at a construction workplace with impaired judgement as a result of AOD usage.

A cultural change management program and implementation plan has been developed by the research team in consultation with all project partners and industry stakeholders. The aim is that this will be adopted by employers nationally. A key component of the implementation plan is the uptake of an online educational tool that has been specifically developed for managers and supervisory/safety staff.

This study is of major significance for Australia within the current context of harmonisation of industrial legislation in occupational health and safety and Federal and State Government investment to improving workplace safety and overall population health.

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- Swinburne University of Technology
- Australian Constructors Association
- Australasian Procurement and Construction Council
- Australian Workers Union
- Austroads
- Civil Contractors Federation
- Construction, Forestry, Mining and Energy Union
- Engineers Australia
- Master Builders Australia
- Office of the Federal Safety Commissioner (observer)

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Offsite Fabrication

and Links to Product and Process Innovation

Off-site manufacture (OSM) is widely recognised as an effective model for improved productivity in commercial and infrastructure construction. The benefits of reduced project duration and improved quality mean total project cost savings. Yet the growth of OSM is hampered by perceptions of high expense and high risk.

Previous research focussed on barriers to implementing OSM. In contrast, SBEnrc proposes a system of OSM enablement. The primary success factor identified for implementing OSM is the approach of the Project Team. So our aim is to enable building a Project Team with skills, knowledge and intent to use an OSM procurement model. To support this process, SBEnrc has developed a toolkit to assist an OSM Project Team from the outset.

The early stage of the study created detailed construction project process and workflows models to support OSM adoption. An extensive report on the models and workflows is available, along with a video demonstrating an operational prototype for a workflow tool. Development of two additional instruments is based on the need to identify available OSM capacity and capability for increasing OSM adoption. The *OSM Project Team Evaluation Tool (V1.0)* is a set of 19 essential OSM questions about OSM expertise and production that is accessed from a project *OSM_KnowledgeBank*. These four enabling tools are available online from SBEnrc.

Industry need

Off-site manufacture (OSM) has been recognised as an effective procurement model for construction in many countries. In Australia, OSM was identified as a key driver for changing the construction industry, but adoption of OSM remains low. Previous research emphasised identifying barriers to uptake. This has been informative, but it has been left to market forces to drive further OSM uptake. The result is sporadic and opportunistic usage. A new approach is needed to assist clients, the ultimate beneficiaries of OSM on their projects, to be proactive in driving the uptake of OSM.

Sustainable Built Environment National Research Centre

Approach

The OSM building model encourages questions of constructability by shifting the resources allocation for both timing of construction and location of production. These changes often mean new management processes and systems are necessary for integrating OSM. This higher level perspective was studied by analysis of construction project phases and related OSM processes.

Construction Project Business Models with Identified OSM Intervention Points

The tool is a comprehensive visual representation of construction processes showing key activities/ resources/ data and stakeholders. The models show OSM intervention points identified by AEC experts for six building construction phases.

OSM Delivery Model Prototype Workflow Application

YAWL automated OSM related activities and tasks are explained in a video. The proto-type tool illustrates a mechanism for a process automation (workflow) system that supports and coordinates OSM-related activities. This workflow system also has the potential to integrate with other IT industry solutions (e.g., BIM, document and project management solutions).

These methods can be used to customise specific projects with specialist OSM components to support OSM adoption by enabling the Project Team to implement an OSM procurement model.

Figure 1: Level of Risk in Relation to Project Process Stage of OSM Stakeholder Engagement

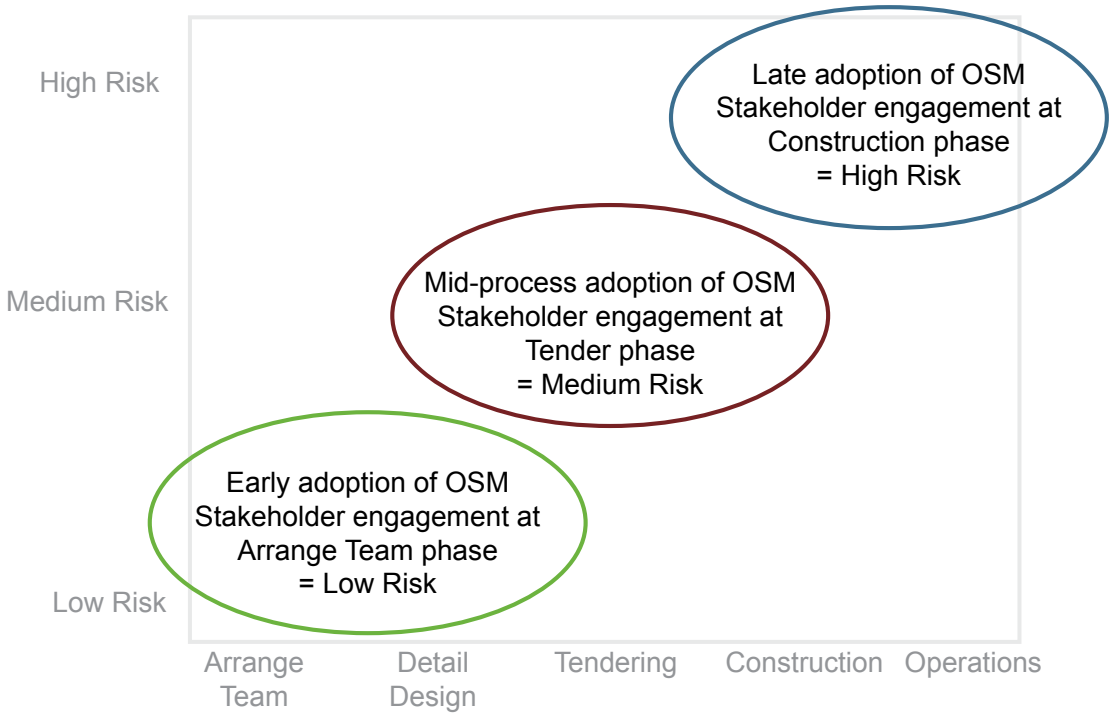


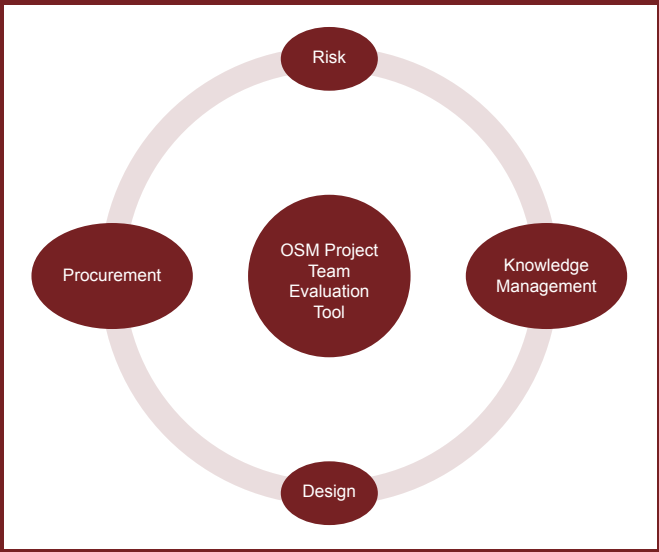
Figure 1 shows that the level of risk for successful project outcomes is related to the project team's OSM experience and knowledge of the OSM procurement model. Early adoption of the OSM procurement model, with input from a wide variety of OSM stakeholders, is considered the low risk option.

The solution

The study found that 'the earlier the better' is an important piece of advice for OSM adoption. This means that all OSM interested parties: the client, the project manager, the architect, the engineering consultants, OSM manufacturers, the construction manager, the builder, the sub-contractors, and the OSM suppliers should be involved with the project from inception. Realistically, the membership of the Project Team will change over time, as the construction progresses.

In this way the OSM procurement model transforms AEC professional relationships by enabling shared OSM expertise. The conventional construction method, Design—Bid—Build, based on task expertise is replaced with an OSM method of production that integrates design, procurement and construction through relationships. The competitive tendering process is replaced with a relationship-based project delivery strategy for increased project productivity.

Figure 2: Key Capability and Capacity Issues for OSM Project Team Evaluation



But not all clients know how to begin using an OSM procurement model. So the SBEnrc developed OSM adoption tools to motivate and enable the development of capability and capacity of OSM project teams because strategic change is necessary when using a new procurement model. The ability to change is centred on OSM capability and capacity in relation to **4 Key Issues**: Risk, Knowledge Management, Design and Procurement.

- Understanding the differences between project **risk** for conventional and OSM procurement models is a priority.
- Identifying the extent of OSM expertise as well as a range of **knowledge management** systems available can advance adopting an OSM procurement model.
- Integrating OSM at the **design** stage requires transition processes for OSM procurement strategy risk minimisation.
- If OSM is a new **procurement** strategy, clients and project teams need support for organisational change processes.

These **4 Key Issues** should be considered *after* the project requirements have been identified **but** *before* the feasibility study is undertaken. Issues of OSM capacity and capability in relation to **building constructability** should be addressed in the feasibility study to ensure that value for money is appropriately gaged.

Adopting an OSM procurement model needs details of OSM capability and capacity as indicted in Figure 2. SBEnrc has designed two tools for this purpose *OSM Project Team Evaluation Tool (V1.0)* and *OSM_ KnowledgeBank (a spreadsheet)*.

OSM Project Team Evaluation Tool (V1.0)

This tool is a device for rating the OSM capability and capacity. The tool uses a set of 19 essential OSM related questions as a framework to capture details of availability of materials, transport, production facilities, standards, codes, etc. All information is connected to a simple scoring system. The scoring system enables the client and project team to assess their knowledge of OSM capacity and capability. The indicative number can be used to evaluate: a) appropriateness of OSM Project Team members' experiences; b) level of risk based on availability of project OSM requirements; c) OSM project readiness.

OSM_KnowledgeBank (a spreadsheet)

Assembling an OSM_KnowledgeBank (spreadsheet) is a mechanism for building an OSM Project Team. This tool is a systematic method for collecting essential types of OSM capability and capacity information using essential question templates. Collection of OSM information about people, projects, products, production and processes provides the foundation for assessing or implementing an OSM project.

Benefits to industry

Off-site manufacture (OSM) is widely recognised as an effective model for improved productivity in commercial and infrastructure construction. The benefits of reduced costs and improved quality are significant. The major advantage of OSM is that the duration of the project can be significantly reduced, due to multi-location production possibilities.

SBEnrc proposes a system of enablement, based on the general acceptance that for OSM to be successful, (a) project teams must have the skills and knowledge to implement and manage it; and (b) that the project must be designed and documented with OSM in mind.

The recommendations are:

1. Ensure OSM Project Teams are organised 'as early as possible', at the Arrange Project Team stage
2. Support early adoption of the OSM procurement model, before the feasibility study
3. Facilitate input from a wide variety of OSM stakeholders before the Detail Design is completed
4. Collect essential OSM capability and fOSM capacity information to make a business case
5. Integrate OSM process and products into the total project.

Clients and projects that adopt these team building strategies will have greater success in implementing OSM and will benefit from the significant productivity gains and quality improvements that OSM can deliver.

A practical guide to the method summarised in this brochure along with the OSM Project Team Evaluation Tool (V1.0) is explained in the industry report titled *Building OSM Capablity and Capacity in Project Teams*.

Available online: www.sbenrc.com.au

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- PrefabNZ

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SWINBURNE UNIVERSITY OF TECHNOLOGY
SurePoint
PrefabNZ The Hub for Prebuilt Construction
John Holland

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Leveraging R&D
for the Australian Built Environment

Australia's infrastructure and building industry has long sought to enhance its commitment to continuous improvement by leveraging the benefits on offer through investment in research and development (R&D). This endeavour has historically been problematic, in no small way due to the complexity of accessing R&D subsidies and negotiating a vast array of funding models and strategies.

This project has set out to determine how to maximise the benefits of R&D to Australia's infrastructure and building industry through improved alignment of funding strategies with industry needs. The research aims to build new understandings and knowledge relevant to: R&D funding strategies; research team formation and management; and how research outcomes are shared and utilised.

Approach

The project has explored the issue from four distinct angles, with each phase feeding into the next:

1. **Audit and analyse R&D investment in the Australian built environment since 1990** – better understand past trends, publically available data relating to Australian R&D investments by both public and private organisations was accessed and examined.
2. **Examine distribution mechanisms of R&D support and how they impact on public and private organisations.** Case studies of specific R&D investments were undertaken to examine the process, including: how research direction is established; how research projects were engaged with by organisations; research outcomes; and pathways to adoption.
3. **Develop a strategic roadmap for the future of this critical Australian industry.** Using the *Construction 2030* report as a basis, an assessment was made of the likely future landscapes that R&D investment will need to respond to and anticipate within the Australian built environment.
4. **Develop policy to maximise the value of R&D investments to public and private organisations** – through working with industry and end user groups to translate the findings of the project into policy guidelines.

Our vision for the future

1. A national industry steering body which defines long-term strategic industry R&D priorities, and funds associated research in public organisations.
2. Government procurement equipped to support construction innovation and supply matching funds for strategic R&D.
3. Research institutions with world-leading interdisciplinary capabilities to provide expertise relevant to the goals of the Australian construction industry.

This vision is underpinned by a culture of self-improvement, mutual recognition, respect and support.

Sustainable Built Environment National Research Centre

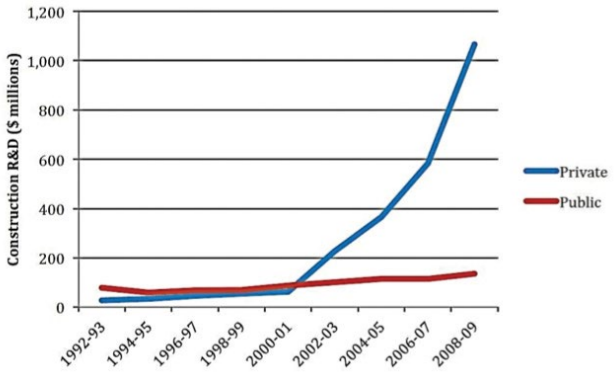
The research

Phase 1: R&D investment 1992-2010

A key outcome of this early phase of work was the report prepared in conjunction with research strategist, Dr Thomas Barlow, entitled ***R&D Investment Study: 1992-2010***. The report drew on data from Australian government sources, the private sector and the Organisation for Economic Co-operation and Development (OECD) to provide a snapshot of R&D investment trends in the built environment.

The data reveals that there was a substantial increase in private sector investment from 1992-2010 (Figure 1).

Figure 1 – Private versus public R&D investment in 'construction'

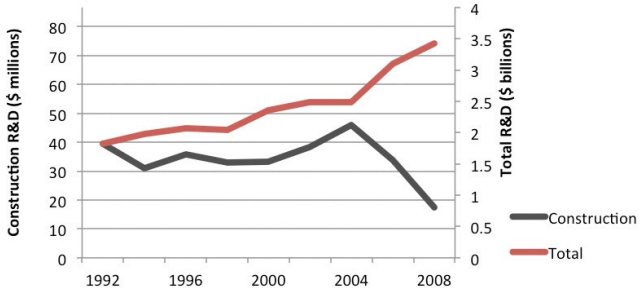


Note: (i) Derived from ABS 8112 and Barlow 2011. (ii) Shows R&D expenditures by sector focused on the socio-economic objective 'construction'. (iii) 'Public R&D' counts R&D from the university sector and from state and federal government agencies.

In the early 1990s, Australian public institutions were spending three times more on construction related R&D than Australian businesses did. Yet by 2008, Australian businesses were spending eight times as much on construction-related R&D as public research institutions.

Australian government R&D agencies have also reduced their emphasis on construction R&D as a proportion of total spending. Between 1992 and 2008, government agency spending on construction R&D fell from 2.2% to 0.5% of total government sector R&D expenditure.

Figure 2 – Government agency R&D focused on 'construction'



Note: Derived from ABS 8109 and Barlow 2011. (ii) Compares government intramural R&D expenditures focused on the socio-economic objective 'construction' (left axis) with total government intramural R&D expenditures across all objectives (right axis). (iii) The right axis has been adjusted so that the growth-rates of both curves from 1992 are comparable.

Phase 2: Pathways to innovation

Researchers worked with government agencies to undertake three case studies of past R&D investment in Australia to illustrate:

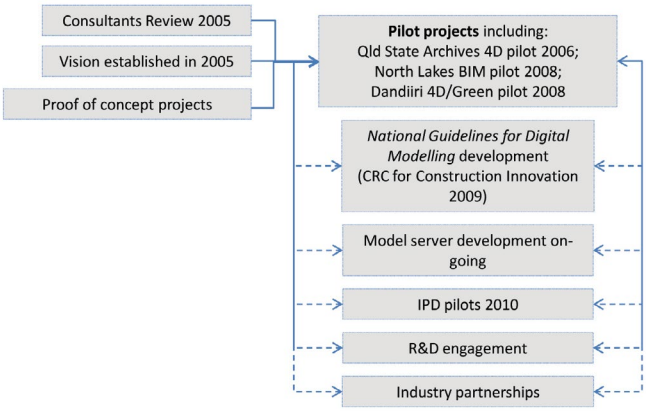
1. The nature of R&D investment by construction organisations.
2. Drivers, successes of and barriers to investment.
3. Organisational capabilities which contributed to outcomes.

Road construction safety with Queensland Transport and Main Roads – investigating three recent initiatives which contributed to safety performance. These projects engaged a formal R&D process that included trials, options analysis and deployment.

Green building case study with the Western Australian Government – This revealed an ongoing focus on policy development, building external relationships, and establishing green targets for commercial building outcomes.

Digital modelling case study with the Queensland Department of Public Works – initiatives spanning from the mid-1980's to more recent implementation of building information modelling (BIM) and moves towards integrated project delivery (IPD) were examined (Figure 3).

Figure 3 – Digital modeling pathway to innovation



Phase 3: Construction 2030

A Roadmap for R&D Priorities for Australia's Built Environment Industry

Industry organisations and government agencies need to consider a realistic vision for the future when contemplating investment priorities and opportunities. Construction 2030 provides an overview of key drivers of the large-scale social environment to which the industry may need to adjust. The report captures the greatest inherent uncertainties of this environment and outlines a broad range relevant emerging trends.

The process was used to generate decision scenarios that incorporate various combinations of likely future uncertainties including: climate change, skills, economy, attitudes, policies/governance, energy and technology. The scenarios were tested with industry representatives in a series of national workshops with participants selecting the possible technology capabilities that best matched the scenario conditions.

This list was then subjected to expert review regarding the timing and likelihood that they would emerge. Outcomes indicated: (1) that some technologies may be expected to emerge from existing research in construction or in other industries; and (2) that others will not, unless the property and construction industry undertakes the research.

Three priority areas for conducting active research were identified:

- Model-based design – business models.
- Intelligent infrastructure and buildings.
- Solutions for a greener built environment.

Further priority areas for research were also identified as: information and communications technology for radical redesign; and biotechnology for tree-based materials.

Phase 4: Built environment industry at a crossroads

Several potential obstacles to investment in R&D by the construction industry were highlighted in the research outcomes. They relate to:

- Drop in government spend.
- Mismatch in R&D activity timeframes between public and private sectors.
- The fragmented nature of the industry (project-based work; lost information as project teams disperse, allowing little capacity for retained information or ongoing organisational learning).
- The SME-based nature of the industry restricting capacity for R&D investment.
- Government risk aversion.
- The level of public sector expertise.
- Lack of incentive for researchers to engage in industry collaborations.

Several models for engagement with R&D organisations have been considered in detail including:

- Industry-sponsored research councils.
- Government-mediated industry R&D.
- Government R&D tax programs.
- Government grants.
- Government agency research.

Specific ***recommendations*** that emerged from this phase include:

- Establishing a national industry steering body to define long-term R&D priorities and their dissemination to help align the research priorities and capacity building activities.
- Provide a new funding stream derived in part from industry sources and distributed directly by this body.
- Establish consistent procurement standards to drive innovation.
- Direct a proportion of state government training levy funds towards long-term strategic R&D.
- Federal funding for Centres of Excellence, CRCs, ARC Linkage funding, and CSIRO should reflect the long-term strategic priorities identified by the proposed national industry steering body.
- Integration of industry priorities and regional industry capability by government agencies and universities
- Build strategic partnerships between research organisations industry which retain a focus on leading-edge practice and transformational change.
- Emphasise interdisciplinary models, including social as well as technical research, to ensure that outcomes are globally connected.

International focus

The International Council for Research and Innovation in Building and Construction (CIB), Task Group 85, is focused on R&D investment and impact and has received significant international interest with 35 members to date from 15 countries. The focus is strongly aligned with that of Project 2.7. The intent is to improve understanding of how public and private sector policy and practice can be enhanced to better leverage investments. The objectives of this task group include:

- Establishing an international network to exchange knowledge and undertake an agreed research agenda to further facilitate discussion and debate.
- Potentially build a consensus of metrics to better enable the ongoing exchange of knowledge and findings.
- Promote publication in this field to enable greater global dialogue regarding R&D investment and its impacts (both academic knowledge-base and industry outcomes). To this end Taylor and Francis have confirmed their interest in publishing TG85 findings in 2013.

The outcomes

This has delivered a number of tangible benefits.

R&D investment 1992-2008 – highlighted the shift in R&D investment in this sector in the past two decades. This emphasises the need to establish new models of engagement to maximise the return on R&D investment.

The Pathways to innovation case studies highlight the importance of external innovation linkages for organisations and the need for timely and practical research available through a range of innovation pathways. In addition, each case study has revealed the beneficial outcomes of past R&D investments such as:

- Thermal imaging cameras being installed in 27 Barrier Trucks across QTMR's fleet in 2011/12; Mechanical Traffic Aids being redesigned for use in Queensland conditions; and Trailer Cameras now approved for implementation throughout the State of Queensland.
- WA Government's Office Accommodation Policy (2004); Liveable Neighbourhoods Policy (2007); Sustainable Non-Residential Buildings Policy (2008); and the Primary School Brief (2012) as outcomes of their R&D focus in this area.
- The integration of BIM related R&D activities into built assets in Queensland with tangible environmental and safety benefits.

Construction 2030 has highlighted three priority areas for active research including:

- Model-based design / business models – to provide a link between the capital asset and more effective asset delivery and management.
- Intelligent infrastructure and buildings – to enable a longer term view of investment and planning with reduced life cycle costs.
- Solutions for a more sustainable built environment – to adapt to changing business conditions including market and regulatory environment.

All these phases have then informed the recommendations contained in ***Built environment industry at a crossroad***, which outlines a vision for the future defined by a long-term strategic focus with appropriate funding; procurement mechanisms which support innovation; and world-leading interdisciplinary capabilities.

Benefits to industry

- Meaningful data about the decline in R&D investment in the Australian built environment, highlighting the need for stronger engagement between construction and R&D organisations.
- Evidence that external innovation linkages along with the timely execution of research can deliver tangible outcomes.
- Identification of priority areas for research globally
- Policy guideline recommendations

Research findings have been actively disseminated through a number of forums including; industry publications and presentations; academic journal papers; and peer reviewed conferences. Full transcripts can be found at: www.sbenrc.com.au/research/developing-innovation-and-safety-cultures/leveraging-rad-for-the-australian-built-environment

The Sustainable Built Environment National Research Centre (SBEnrc) is the successor to Australia's CRC for Construction Innovation. The SBEnrc is a key research broker between industry, government and research organisations servicing the built environment.

The SBEnrc is continuing to build an enduring value-adding national research and development centre in sustainable infrastructure and building with significant support from public and private partners around Australia and internationally.

Benefits from SBEnrc activities are realised through national, industry and firm-level competitive advantages; market premiums through engagement in the collaborative research and development process; and early adoption of Centre outputs. The Centre integrates research across the economic, social and environmental sustainability areas in programs respectively titled: Driving Productivity through Innovation; People, Processes and Performance; and Greening the Built Environment.

This research wouldn't be possible without the ongoing support of our industry, government and research partners:

Queensland Government
GOVERNMENT OF WESTERN AUSTRALIA
NSW Government Transport Roads & Maritime Services
John Holland
PARSONS BRINCKERHOFF
Curtin University
QUT
SWINBURNE UNIVERSITY OF TECHNOLOGY

Project partners:

- QLD Department of Transport and Main Roads
- QLD Department of Housing and Public Works
- WA Department of Finance, Building Management and Works
- John Holland
- Queensland University of Technology
- Swinburne University of Technology
- VTT Technical Research Centre of Finland
- Built Environment Industry Innovation Council
- CIB (International Council for Research and Innovation in Building and Construction)

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Built Environment Industry Innovation Council
VTT
John Holland
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Driving Productivity Through Procurement

The major aim of this program is to deliver economic, environmental and social benefits to the built environment industry through reducing risks and costs and improving productivity on infrastructure and building projects.

The initial three years of SBEnrc included funding for one exclusive research undertaking within this program: Object Libraries Supporting the Facility Lifecycle. The goal of this project has been to facilitate increased efficiency of construction industry practices by reducing duplication of effort, specifically in relation to the development of libraries of products for use with CAD tools in construction projects. The project is relevant to designers, contractors and asset managers.

During this first phase of the centre, the fundamental information technology required to achieve this goal was developed; library definitions for a range of products were defined; and the resulting system has been tested by industry. Phase one has demonstrated the following outputs for the built environment sector:

- Software engineering methods were developed that allow a single definition of a product to be stored, and then mapped across to a range of proprietary software. This reduces the effort required to build and maintain object libraries. This minimises redundancy and the possibility of errors if these processes are done by hand.
- The library mechanism was tested across a range of products and assemblies of products to ensure that the methods used could be applied widely across the built environment sector.
- The storage of data at LOD 200 to 500 (generic product to detailed manufacturer's data) was tested, also adding data from Australian Standards, regulations and NATSPEC.
- Interfaces were developed to existing international object library initiatives to ensure that these efforts could be leveraged to support Australian industry.
- Plug-ins were written to Revit, ArchiCAD and Rhino to demonstrate that a range of client CAD software could be supported over a range of interface types (API and GDL).
- A series of workshops was held around Australia, attracting over 150 attendees across the various sessions. The workshops have received positive feedback from industry attendees, with a number of groups indicating their willingness to financially contribute to stage two of the project.

The benefits to industry from finalisation of this project will be:

- Increased efficiency through reduced errors and elimination of duplicated effort.
- Reduced intellectual property conflicts by making significant amounts of information freely available.
- Improved triple bottom line by ensuring that relevant information is available as and when needed.

The projects completed in Program 3 are described in the Brochures following.

by Alan Levine Flickr

Collaborative Object Libraries

Supporting the Facility Lifecycle

There are over 20,000 design firms within the construction industry in Australia. Each firm maintains its own library of products to use in CAD tools in their projects. Much of the information within each CAD library is developed to support only the processes within the specific firm that maintains it; uses non-standard naming conventions; and becomes out of date. This is an inefficient process in itself and impedes the sharing of data through the design, construction and operation of construction projects. This decreases the efficiency of the whole industry.

An obvious solution is to have a national library that contains objects that meet the needs of entire project teams—regardless of organisational affiliation—and can be embedded directly into current software tools. The contents of such a library would follow nationally agreed naming conventions and would be maintained to suit evolving product specifications, standards and regulatory requirements. It would contain publically available, standardised object definitions that included the ability to attach all of the information that needs to be shared throughout the lifetime of a built asset.

The major stumbling block to this proposal becoming a reality is the lack of compatibility between major software vendors to the construction industry.

A solution to the technical problem of sharing library objects between software from different vendors is a method used in software engineering called ‘software transformations’. This method provides an automated system of mapping data and structures between different representations.

An on-line object library developed by this project stores a generic description of an object that can be accessed from a standard web browser or downloaded directly into Autodesk Revit and Graphisoft ArchiCAD using predefined software transformations. Work is underway to extend this support to Bentley AECOsim Building Designer and downstream software supporting estimating, planning and facilities management.

Background and context

Delivering infrastructure and building projects requires collaboration across multiple disciplines and stakeholders over the duration of the construction project, into handover and through the operation and maintenance of the asset. Current practice, even using modern object-based software does not support smooth collaboration due to the lack of coordination of objects, properties and values through projects. Much of this is due to a lack of motivation to coordinate information sharing, while some of it is concern over protecting intellectual property invested in creating object libraries.

Sustainable Built Environment National Research Centre

How much more efficient would the construction industry be if there were a National Object Library?

The *Collaborative Object Libraries* project has developed such a system. It is currently being tested within Project Services, the Queensland Government's building design and procurement arm. The library is accessible from within software applications and also from standard modern web browsers. An image of the user interface is shown in figure 1.

The main objective for the project is to create a National Object Library (NOL) server to meet the needs of Australian infrastructure and building projects. It is proposed that this will be managed by a single national industry body. The NOL manager would maintain the generic objects and update them to match changes in Australian Standards and legislation. Manufacturers will be able to upload details of their products to the NOL and manage their products over time.
The commercial arrangements underpinning the operation of the NOL are still under discussion, but the key feature will be that access by users is free.

The Collaborative Object Libraries project is being undertaken in stages. The current stage supports a single national library, controlled by a librarian. Users have read-only access to the library, and interfaces have been developed for BIM-based architectural software.

The next stage of the project, to commence in January 2013, will increase the number and range of software that supports interaction with the NOL. It will also add the ability to create a 'project server'. This will enable reading and writing to a library server under user control. This would then update adapted objects from the NOL as necessary.

Figure 1: Object Library User Interface

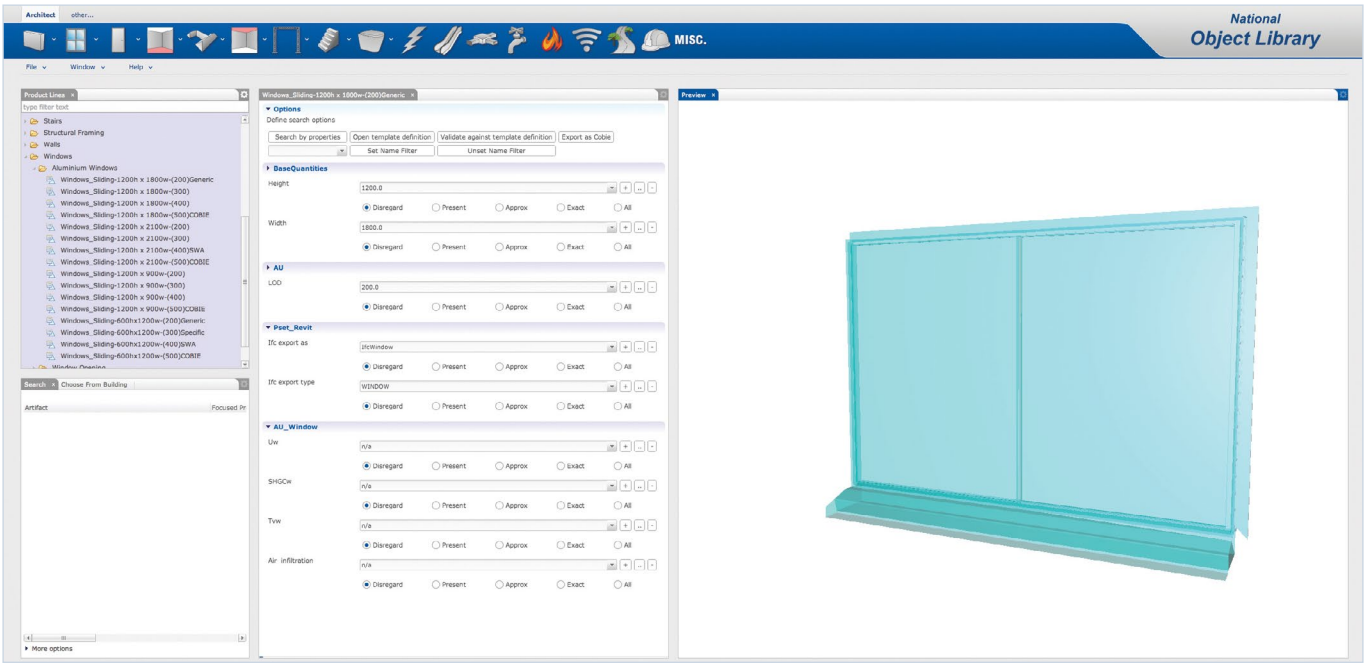
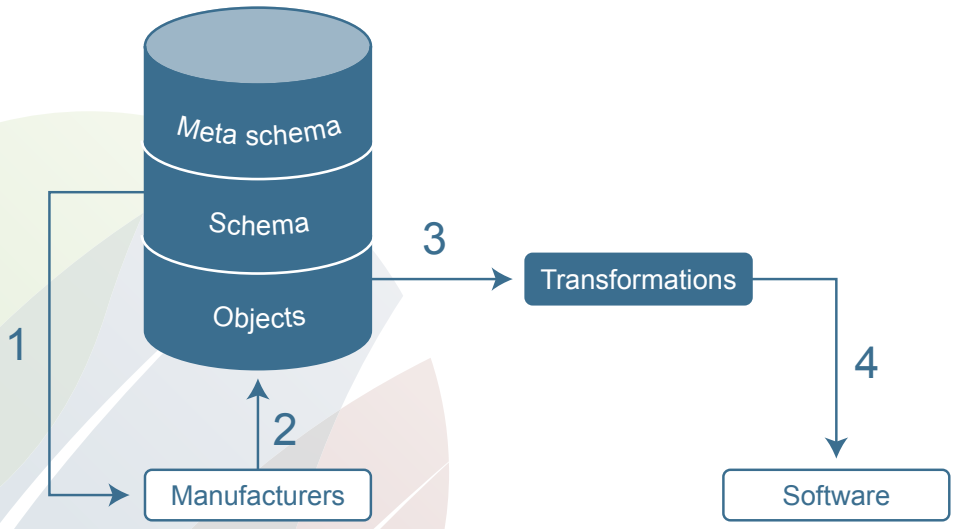
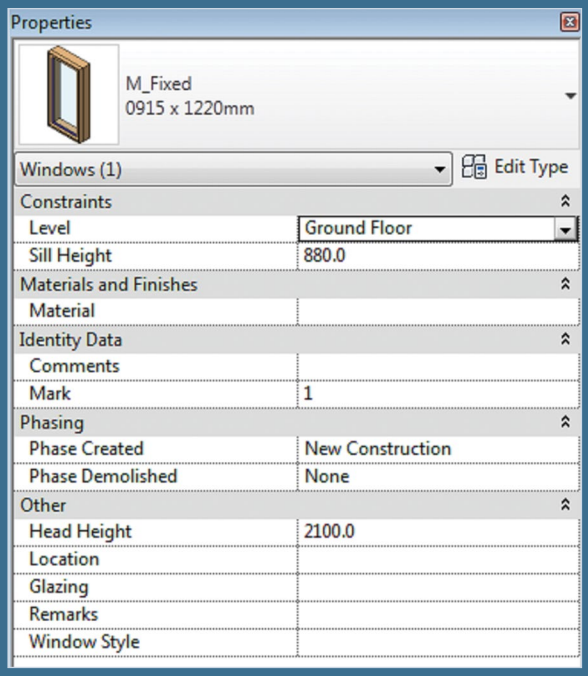


Figure 2: Object Library



Figures 3 and 4 show the properties dialog for a window (a) with standard properties and (b) after bringing in a new window definition. Note the change in geometry as well.

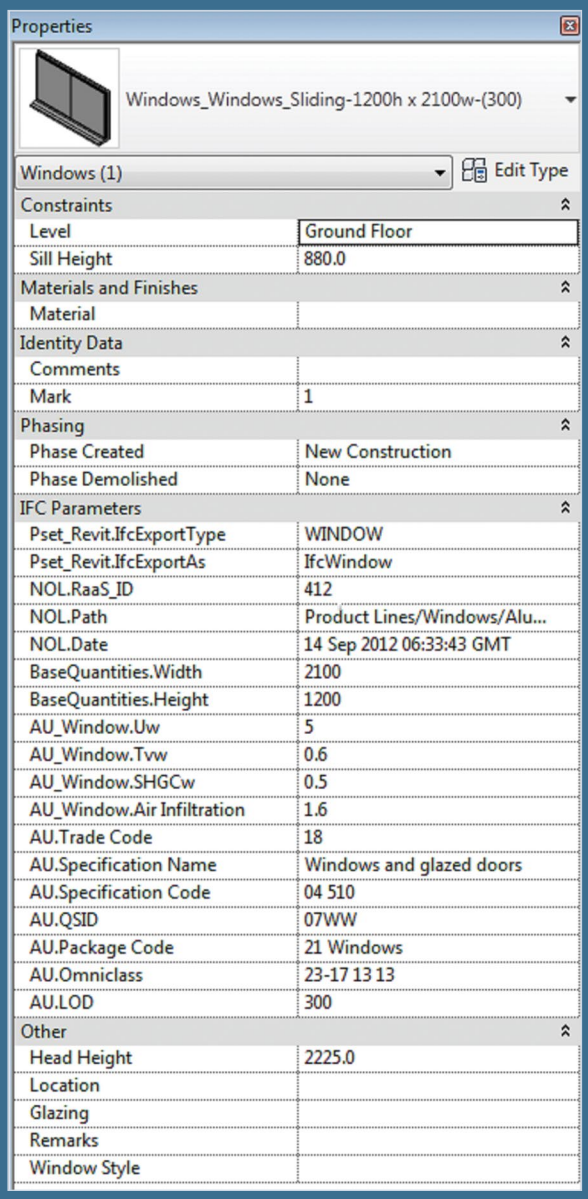


Properties

M_Fixed
0915 x 1220mm

Windows (1) | Edit Type

Constraints	
Level	Ground Floor
Sill Height	880.0
Materials and Finishes	
Material	
Identity Data	
Comments	
Mark	1
Phasing	
Phase Created	New Construction
Phase Demolished	None
Other	
Head Height	2100.0
Location	
Glazing	
Remarks	
Window Style	



Properties

Windows_Windows_Sliding-1200h x 2100w-(300)

Windows (1) | Edit Type

Constraints	
Level	Ground Floor
Sill Height	880.0
Materials and Finishes	
Material	
Identity Data	
Comments	
Mark	1
Phasing	
Phase Created	New Construction
Phase Demolished	None
IFC Parameters	
Pset_Revit.IfcExportType	WINDOW
Pset_Revit.IfcExportAs	IfcWindow
NOL.RaaS_ID	412
NOL.Path	Product Lines/Windows/Alu...
NOL.Date	14 Sep 2012 06:33:43 GMT
BaseQuantities.Width	2100
BaseQuantities.Height	1200
AU_Window.Uw	5
AU_Window.Tvw	0.6
AU_Window.SHGCw	0.5
AU_Window.Air Infiltration	1.6
AU.Trade Code	18
AU.Specification Name	Windows and glazed doors
AU.Specification Code	04 510
AU.QSID	07WW
AU.Package Code	21 Windows
AU.Omniclass	23-17 13 13
AU.LOD	300
Other	
Head Height	2225.0
Location	
Glazing	
Remarks	
Window Style	

Operation of the current Object Library server

The National Object Library (NOL) Server contains three types of information:

1. The 'meta schema' that supports the definition of the transformations between data formats that are the core functionality of the system.
2. The Schema contains the definitions from the industry on what products and components are stored within the system and the properties and values that they should have at particular levels of definition.
3. Then the objects themselves are stored as properties and geometry in the generic format (based on IFCs) that can be mapped onto the target data representations in users' software.

When a manufacturer wants to add a new product to the NOL they will bring up the schema definition for the product (Figure 2: step 1). They will then add required data, possibly add optional data and define the geometry of the product. Manufacturers will be able to request the addition of new properties that they believe are necessary to differentiate their product. The object is then added to the NOL once the object definition is complete (Figure 2: step 2) and becomes available for use by others. When a manufacturer wishes to revise a product description the old description is retained to ensure that links do not become "broken". However, notification that a new version exists will be available for software vendors to support updates.

A user can interact with the NOL in two ways – through a modern web browser; or through software that has been adapted to support the NOL. The current interface is shown on the previous page.

When adding a new object from the NOL from within other software the user selects the command to access the NOL, browses the library and chooses the object. Since the NOL knows which software has generated the request it can feed the object data into the appropriate software transformation (Figure 2: step 3), which then downloads the resulting customised object to the requesting software (Figure 2: step 4) for inclusion in the project.

If an existing object is selected when the NOL is accessed, the type of object is sent to the NOL, which then uses this information to filter the results shown to the user on initial access. If the user selects a more detailed representation of an object than currently exists then the additional data can be added to the existing object. This supports the gradual refinement of design, construction and operation information as a project progresses.

Benefits to industry

Once established as a National Object Library this project will provide benefits across a range of industry participants:

For **Product Manufacturers** – the National Object Library will provide a single point for distribution of 'intelligent content' across multiple software vendors.

Design Disciplines – architects, engineers, and cost planners will benefit through improved sharing of information - for both components (objects) and project data; and improved fit of information with work flows and reduced costs in defining and maintaining internal object libraries. The vendor independent library of objects has the potential to be a national standard. This will contain nationally defined properties and values that correspond to Australian Standards and regulations. These will support consistency across disciplines and through the procurement process.

Constructors - lead contractors, sub-contractors and manufacturers will benefit through improvements in the information flowing into their processes from designers and the ability to link this information (through future work) into their supply chains. This will also improve the quality of as-constructed documentation.

For **Facility managers and Maintenance Personnel** – the NOL will facilitate conformance with standards for the handover of information at completion of construction. It will also offer improved ability to access information about the existing facility and to maintain current information on the facility throughout its life.

Software Vendors - access to localised object libraries that will complement the software they distribute and which will reduce a major cost to their users.

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Queensland Government

GOVERNMENT OF WESTERN AUSTRALIA

NSW GOVERNMENT Transport Roads & Maritime Services

John Holland

PARSONS BRINCKERHOFF

Curtin University

QUT

SWINBURNE UNIVERSITY OF TECHNOLOGY

Project partners:

- QLD Department of Housing and Public Works
- Queensland University of Technology
- Swinburne University of Technology

Queensland Government

QUT

SWINBURNE UNIVERSITY OF TECHNOLOGY

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