Investing for IMPACT

Constructing a Better Built Environment

Keith D. Hampson
Judy A. Kraatz
Adriana X. Sanchez
Naomi A. Herron

International Council for Research and Innovation in Building and Construction

Sustainable Built Environment National Research Centre

The Sustainable Built Environment National Research Centre's collaboration with our partners is adding significant value to the effectiveness and long-term sustainability of Australia's built environment industry.

We thank our partners for their support:

The International Council for Research and Innovation in Building and Construction (CIB) is a global network for exchange and cooperation in research and innovation for the construction industry.

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FOREWORD

The **Sustainable Built Environment National Research Centre (SBEnrc)** is the successor to the CRC for Construction Innovation. Established on 1 January 2010, the SBEnrc is a key research broker between industry, government and research organisations serving the built environment industry.

The three research streams focus on environmental, social and economic sustainability, areas identified by national industry stakeholders as the key areas that will drive productivity and industry development in the built environment industry.

Key to this is understanding how research and development (R&D) impacts on the built environment. Globally, there are a variety of models for industry-government collaboration in R&D that address a range of economic and social contexts. The best outcomes tend to be the result of close collaboration and early engagement of end-users.

This publication, *Investing for Impact,* is a key outcome of Project 2.7 Leveraging R&D Investment for the Australian Built Environment. This information will be included in a more comprehensive book being prepared for publication in 2014 (Taylor and Francis).

It draws together research findings and case studies from CIB Task Group 85 members from across the globe, highlighting their diversity and similarities. The evaluation of international case studies on the role and impact of R&D on national development has allowed us to demonstrate examples from different sectors of the built environment of R&D investment models that provide return on investment and other benefits for companies, governments and the general community.

We sincerely thank the Task Group 85 members who provided us with case studies for this project. Contributions from individuals and organisations who strive to make a difference are essential if we are to deliver the benefits of meaningful R&D over the next decade.

We look forward to working together to better match funding strategies to industry needs for a stronger and more productive built environment industry with our national and international partners.

John V. McCarthy AO
Chair
Sustainable Built Environment
National Research Centre

Keith D. Hampson
Chief Executive Officer
Sustainable Built Environment
National Research Centre

TASK GROUP 85

The International Council for Research and Innovation in Building and Construction (CIB) is a global network for exchange and cooperation in research and innovation for the construction industry. CIB provides support to improve processes and performance in the built environment.

CIB's Task Group 85 (TG85) R&D Investment and Impact was established in Helsinki in October 2011. The Task Group's objective is to establish an international network to exchange knowledge and develop new understandings related to leveraging R&D investment in the construction industry. An active forum has been established to strengthen collaboration between private firms, government agencies and research institutions. Its intent is to inform policies and programs to enhance R&D investment outcomes.

TG85 has 37 members from 18 countries located as shown below. Members from these countries are actively preparing country-based reports on the state of R&D investment in the construction industry. Fourteen reports form the basis for this publication and will be further expanded as contributions to a comprehensive book to be published in 2014.

This publication identifies similarities and differences between Australia, Brazil, Canada, Denmark, Finland, France, Germany, Hong Kong (China), India, New Zealand, Norway, Sweden, the Netherlands, and USA. While these themes and challenges are based on discussions in the book, they are not restricted to these countries alone. We trust that the outcomes will provide guidance to better understand mechanisms for disseminating R&D outcomes and to maximise the impact of R&D investment for the private and public sectors.

TG85 Coordinators are: Aminah Robinson Fayek (University of Alberta, Canada); Keith Hampson (SBEnrc, Australia); and Judy Kraatz (Queensland University of Technology, Australia). The Commission Secretary is Adriana X. Sanchez (SBEnrc, Australia). The Coordinators have recently been acknowledged by a Commendation Award from the CIB Program Committee for having made the most remarkable contribution to the CIB from amongst the commissions and theme groups. This Award recognises the level of ambition of this group and the contributions being made by all members to ensure relevant outputs.

OVERVIEW

KEY THEMES OF PUBLICATION

- Productivity
- Energy efficiency and sustainability
- Information and communication technology (ICT)
- SMEs and R&D
- Collaboration

The level of enthusiasm for **Task Group 85** reflects a developing culture of research and innovation in the global construction industry. Sweden states its ambition to become a prominent research nation; New Zealand identifies research and development as a key driver for innovation, business success and economic growth; Finland is ranked as having one of the best innovation systems in the world; Hong Kong (China) has actively been investing in academic research since the 1960s to enhance the growth of the administrative region as an international metropolis.

Despite this enthusiasm for research and innovation many countries (including Australia, Canada, Finland, France, New Zealand, the Netherlands and USA) report insufficient research funding into the construction industry, especially from private industry. In Australia however, there has been a significant recorded increase in private funding while the public sector's contribution has been declining. This underinvestment is counter to the position of the construction industry as a major contributor to national employment, economic growth, the standard of living and improved environmental sustainability.

Productivity is a major issue affecting the construction industry within Australia, Brazil, Canada, India, New Zealand, Sweden, the Netherlands and USA. The USA and Canada report decreasing productivity levels in recent decades and lag behind other market sectors. The Netherlands attributes this to the slow rate of new technology diffusion impacting standardisation throughout the construction industry. In Australia, national key performance indicators (KPIs) have been identified to address this issue: safety; productivity and competitiveness; economic security; workplace capability; and environmental sustainability/eco-efficiency. The USA has identified five key areas to improve efficiency and productivity including: deployment of interoperable IT applications across the industry; improved interfacing of people, processes, materials, equipment, and information on projects; greater adoption of prefabrication; widespread demonstrations to diffuse knowledge; and targeted **performance benchmarking**. New Zealand has established a partnership between industry and government to examine skills, facts, and procurement and construction systems for industry development.

A common theme for research and innovation is activity across participant countries to **reduce resource consumption and CO_2 emissions** by creating a more environmentally sustainable built environment using eco-friendly technology and construction processes. The German Government challenged researchers and pre-fabrication companies to create model homes that generate surplus energy, which can be transferred to, for example, electric motor vehicles. Norway has a similar program where the non-governmental environmental protection organisation, ZERO, challenged the construction industry to design and build **energy producing buildings**. Finland, Germany and Norway are thinking beyond individual buildings towards the development of **more sustainable communities.**

Information and communication technology (ICT) has been readily adopted to improve productivity and reduce inefficiencies by Australia, Brazil, Canada, Finland, Hong Kong (China) and USA. In Australia, public sector construction projects have been an opportunity to develop **building information modelling (BIM)** and **integrated project delivery (IPD)** (and associated national guidelines) to improve industry efficiency. In the USA, widespread deployment and use of interoperability technologies within the facilities management sector has been identified as having the potential to cut costs by reducing supply chain inefficiencies. In Canada, research into the field of fuzzy hybrid modelling is improving construction project performance to enhance industry competitiveness.

Collaboration between and within government, researchers and industry is key to successful R&D and innovation. Effective **diffusion of research outcomes** is also widely acknowledged as a key issue (Canada, Denmark, Finland, Germany, Hong Kong (China), Norway, Sweden and USA). The USA identifies **public-private partnerships** fostered by federal funds as a key in creating roadmaps for more cost-effective construction and a more productive workforce. Canada identifies more applicable and tangible benefits when an industry-wide approach is taken. Norway highlights the benefit of researchers and industry mutually challenging and inspiring each other to improve and innovate. The Swedish Government has recently brought together public sector and industry leaders to identify innovative projects for R&D funding. Finland describes the need for collaboration between businesses across the value chain and benefits to smaller companies working together and sharing data. Brazil and India cite collaboration between government and industry to develop more efficient and lower cost technologies to solve acute housing shortages. Denmark highlights the need for a systematic effort towards improved **knowledge dissemination** between researchers, the local industry and international knowledge centres.

It is noted that tensions arise between industry, government and researchers due to **different priorities for R&D**. In Germany and USA, **academic funding** flows to basic and applied research, while industry funding is more heavily focused on development and demonstration phases. Germany's R&D efforts are an example of a government's interest in overall national reputation, a concern not always at the heart of industry interests. A further conflict arises with academic objectives having longer **timelines** and with industry requiring a more immediate return on investment (Australia, Canada and USA).

Other challenges identified include:

- **increasing global competition** (Canada, Finland, Germany, Norway and USA)
- **population increases** creating demand for more sustainable housing (Brazil, India and Norway)
- **ageing populations** (Germany and Norway)
- **climatic extremes** (Norway and Sweden)
- **indoor air quality** (Finland, Norway and Sweden).

The **supply of skilled labour** is also a challenge in several countries (Canada, India, New Zealand and Norway). In New Zealand 25 per cent of workers have no qualification, and literacy and numeracy levels are low. In India, until recently, manual construction labour came from rural areas, was often transient, low skilled and poorly educated. The cost of construction workers is now increasing because of a shortage created by employment growth in other sectors. Norway is also facing a problem in its supply of construction workers as it relies on *guest* workers from neighbouring countries.

KEY CHALLENGES FOR THE CONSTRUCTION INDUSTRY

- **Conception and diffusion of R&D and innovation**
- **Tight profit margins and risk aversion curtail private funding**
- The contracting process (design, bid, construct) causes **conflicting incentives** and inhibits application of construction knowledge in the design phase
- Innovation tends to be **ad hoc and project-based**
- Employee knowledge and training is lost because of **cyclical fluctuations of construction industry**

CASE STUDIES

AUSTRALIA
Integrating the Supply Chain through Digital Modelling

The Queensland Government has been widely acknowledged for national and international leadership in the use of digital modelling for improved delivery of public buildings across the state.

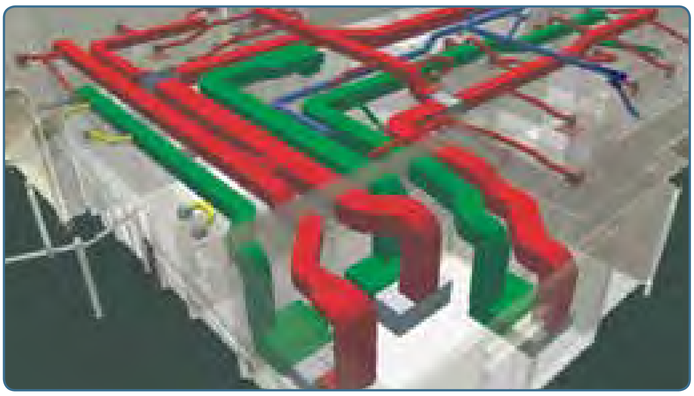
Context

The use of digital modelling in the construction sector has been found to: reduce project team conflict; improve collective understanding of design intent; reduce documentation errors; improve overall project quality; and facilitate faster client approval cycles.

Case

Between 2005 and 2012, the Queensland Department of Public Works (Project Services) developed and implemented a strong vision for the use of digital modelling in integrating the project delivery supply chain. This was achieved through an ongoing, integrated and informal R&D process with the incremental adoption of new technologies and work practices. Internal proof of concept was achieved on a project-by-project basis. This process was complemented by strong industry and research partnerships and engagement. Formal R&D engagement occurred through core involvement with the Cooperative Research Centre (CRC) for Construction Innovation (2001-2009) and subsequently with the Sustainable Built Environment National Research Centre (2010-2012).

The use of digital technologies in project delivery evolved within Project Services from: initial implementation of computer aided design and documentation (CADD) in the mid-1980's; to experimentation with and implementation of building information modelling (BIM) from the mid-2000's; to recent moves towards integrated project delivery (IPD).



The study found that the key driver for Queensland Project Services was developing more efficient delivery mechanisms through the use of new technology enablers coupled with process changes.

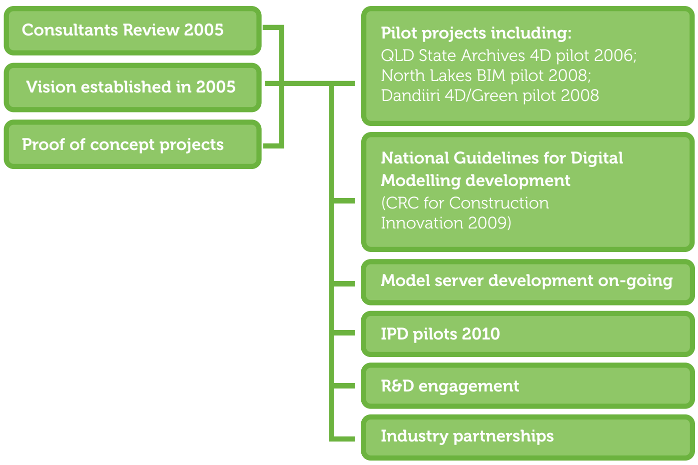
Impacts on the industry include Project Services being acknowledged as a national and international leader in this field with extensive dissemination of improved and integrated work practices to other government agencies, external contractors and consultants, suppliers, vendors and researchers.

Key outcomes include:

(i) Queensland State Archives (2006) for which an advanced 3D technology company (A3D) was novated to the contractor (Laing O'Rourke) and a 4D model was developed (enabling rehearsal and refinement of the construction sequence)

(ii) the Dandiiri Contact Centre[1] (2008) where the use of 4D modelling led to the building being awarded the highest environmental performance of any Australian building at that time

(iii) leadership role in the development of the Australian National Guidelines for Digital Modelling (CRC CI 2009).



(Left): North Lakes Police Station – mechanical services clash detection. Courtesy of QDPW; (Above): Digital modelling pathway to innovation

Authors – Judy Kraatz and Keith Hampson

[1]A consolidated government telecommunications centre

BRAZIL
Mortar Coatings for Residential Construction

This multi-institutional research program is developing product innovations for construction that will save costs and improve the quality of mortar coatings for residential buildings in Brazil.

Context

With the fifth largest population in the world, Brazil has a consistently high demand for residential buildings, especially for the poor. To meet this demand of low-cost housing, there are many large multi-family condominiums that have been built seeking industrialised construction characteristics of low cost and high productivity.

Case

The residential construction demand for products leading to higher productivity, lower production costs and improved quality has led the Industry Consortium for Technological Innovation in Mortar Coatings (CONSITRA) to conduct a two-phase research program to innovate mortar coatings. The research program aims to develop new technologies in mortar coatings that are more reliable, highly productive, durable and competitive for the construction market in Brazil.

The two-phased program undertakes interdisciplinary and inter-institutional research at all stages of mortar coating production, including conception, design, production, application, and technological control. The first research phase (2005-2008) was jointly funded by the private industry (67%) and Finaciadora de Estudos e Projectos (FINEP, Financier of Studies and Projects) with a total BRL670 million (USD335 million). This phase focused on improving the formulation and mechanical characteristics of mortar coating.

The ongoing second research phase (2012–2015) is being funded solely by the private industry with BRL1 billion (USD500 million). This phase focuses on the production chain through process optimisation and cost reduction by improving elements such as production equipment and design guidelines.

The first phase of the program brought significant benefits to the mortar manufacturers, providing an innovative low production cost formulation that in turn reduced the market price and created new market niches. The manufacturers have now embarked on the second phase where greater returns are anticipated through lower construction costs and improved product quality.

(Above): Facade surface conditioning to receive the mortar coating; (Left): Manual application of mortar coating.

Authors - Mercia Maria Semensato de Barros, Francisco Ferreira Cardoso and Lúcia Helena de Oliveira

CANADA
Strategic Construction Modelling

Collaborative industry-led research is using fuzzy hybrid modelling[2] to improve project performance and global competitiveness of the Canadian construction industry.

Context

Between 2012 and 2030 Alberta is set for a non-residential boom with the second highest construction investment in Canada. This is driven in part by a USD360 billion investment by Alberta oil sands. This investment is at risk however because of *large cost and schedule growth of projects, challenges in labour productivity, skilled labour shortages, and international competition.*

Case

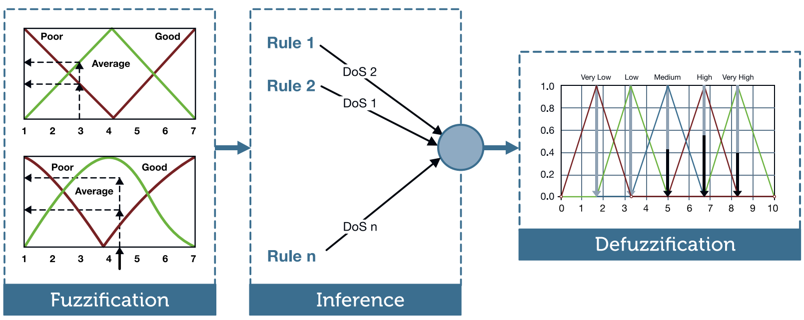
The Industrial Research Chair (IRC) in Strategic Construction Modeling and Delivery (SCMD) program (at the University of Alberta) is helping the Albertan construction industry alleviate labour shortages through: improved labour productivity and efficiency; reducing risk with innovative and real-time decision support systems; and improved project outcomes.

The research team has focused on solving significant and complex construction-related problems in three key areas: labour productivity analysis and modelling; structuring projects and teams for improved performance; and reducing owner and contractor risk through qualification. This is achieved by using fuzzy hybrid modelling which has involved advancing the field of fuzzy logic in combination with other artificial intelligence and simulation techniques to develop advanced decision-support tools and approaches.

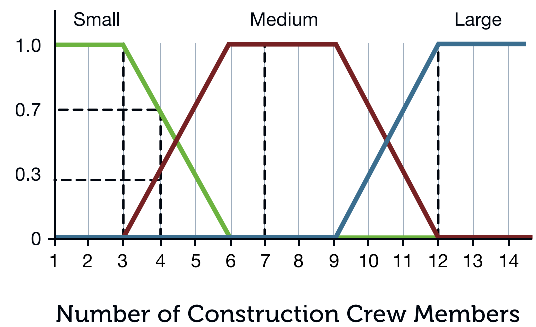
This research is industry-driven with funding from a consortium of Alberta-based construction industry stakeholders, the University of Alberta and the Natural Sciences and Engineering Research Council of Canada (NSERC). The industry partners, who are either involved in or impacted by the oil sands development, are expected to: provide funding; exchange ideas; apply research outcomes; and disseminate research results.

The IRC actively engages with senior management and provides continuous tangible evidence of short-term value to continuing and new personnel, as well as their requirement for short-term return of investment. In a highly competitive market, this close association with private industry also helps to attract and retain high calibre staff.

Collaborative research has succeeded by the mutual benefits for graduate students, researchers, and industry partners. Industry partners are provided with a neutral ground to interact and share perspectives with different members of the supply chain. Ultimately, the collaborative research between industry and the IRC program will lead to better project performance which improves the global competiveness and resilience of the Canadian construction industry with flow-on benefits to the broader economy.



Fuzzy Expert System



(Above): Example of fuzzy expert system; (Above right): Fuzzy membership functions representing construction crew size

Authors - Aminah Robinson Fayek, Jeff H. Rankin, Saiedeh Razavi and Russell J. Thomas

[2] Fuzzy hybrid modelling fuses conventional mathematical modelling techniques with fuzzy logic techniques to draw definite conclusions from ambiguous information and build improved models.

FRANCE
Supporting the Growth of SMEs

Oséo offers consultancy services and financial support to SMEs by sharing risk in the most decisive phases of their life cycle.

Context

During the 1960s, the French research system was characterised by having a limited number of large companies which monopolised public support for research, limiting access of SMEs to these benefits. In common with many other countries, the French construction industry is however characterised by a high number of very small firms (less than ten employees), accounting for 92% of all firms in 2007. Over the last three decades, changes in national policy have addressed this issue by providing support to innovative SMEs including the more traditional sectors such as construction, which were previously excluded.

Case

Oséo (previously National Agency for the Valorisation of Research, ANVAR) was created in the early 1980's to promote innovation and help innovative SMEs. In 2008, 56% of the companies supported by Oséo had fewer than 20 employees and 29% were less than three years from start-up, revealing that innovation is frequently the source of new business opportunities.

Oséo has three key activities:

- supporting innovation and technology transfer (*Oséo Innovation*)
- financing investments and operation cycle, in partnership with banks and finance institutions (*Oséo Financement*)
- guaranteeing bank financing and equity investments (*Oséo Guarantee*).

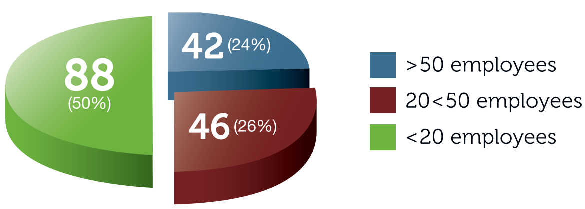
Although the financial support brought by Oséo *Innovation* does not include basic research, it covers expenditures dedicated to research, development and innovation (RDI) such as acquisition of technology; industrial design; trial production; feasibility studies; market tests and launch.

While the financial products and services developed with support from Oséo are not specific to the construction industry, in 2009 innovation aid contributed to the development of 176 projects:

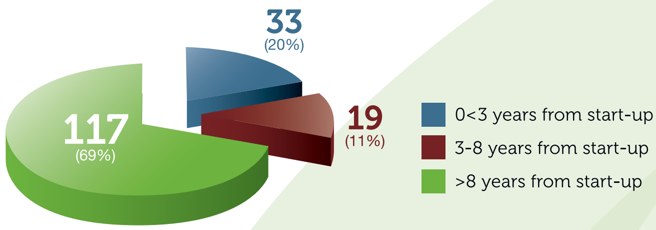
- 131 innovative projects in the building sector (EUR10.9 million; USD14 million); 23 projects in civil engineering (EUR2.4 million; USD3 million); and 22 projects proposed by material suppliers (EUR1.4 million; USD1.7 million)
- 33 projects (20%) were developed by construction SMEs that were less than 3 years from start-up. Together they received EUR2.7 million (USD3.5 million)
- construction firms with less than 20 employees received EUR6.2 million (USD8 million) for 88 projects (50%).

By leveraging the Oséo's innovation aid, EUR1.9 billion (USD2.5 billion) of public and private financing was mobilised in 2011 at a national level to all sectors, for the benefit of 3,100 innovative projects.

The Oséo model has demonstrated its effectiveness by generating excellent returns on the investment of public resources thus contributing to economic welfare. In 2010, the net profit before tax was EUR82.7 million (USD105 million).



Innovation aid by size of firms (Construction Industry 2009)[3]



Innovation aid by years from start-up (Construction Industry 2009)[3]

Author – Frédéric Bougrain

[3] Oséo (2010) L'innovation dans les PME en 2009 – Bâtiment-Travaux Publics, Synthèse Sectorielle, Oséo, France

GERMANY
Houses as Power Plants

The German Government is encouraging its people to build homes that compensate for their everyday energy use by incorporating renewable energy generation at the local level.

Context

Germany is committed to becoming a world leader in energy efficiency and has legislated energy-conscious construction since the 1970s. New buildings must fulfil strict energy efficiency standards and cover part of their energy demand through the incorporation of renewable energy resources. It is expected that the percentage of renewable energy resources mandated will sharply increase over time.

Case

The German Government is encouraging the construction of buildings that produce more energy than they consume through the *plus energy* housing project. The project is being carried out in three ways:

- Directly funding owners - in 2011 EUR1.2 million (USD1.5 million) were given to owners to subsidise housing construction incorporating renewable energy systems.
- Funding prefabricated housing companies to develop and test *plus energy* homes. The model homes and individual prototypes are produced using innovative materials, systems, and technology (such as docking stations for electric cars). These are displayed across Germany and evaluated by a Fraunhofer Institute for Building Physics Program.
- Directly constructing demonstration houses through universities and government bodies. The Technical University at Darmstadt developed the 2007 and 2009 winners of the Solar Decathlon competition held in Washington DC, USA. The 2007 winner was displayed in six German cities between 2009-2011 before finding a permanent home in Dortmund.

Family living in the Efficiency Plus House with Electromobility (Effizienzhaus Plus). Courtesy of BMVBS

Author - Alexandra Staub

The Federal Ministry of Transport, Building and Urban Development (BMVBS) also sponsored a competition for university institutes in conjunction with commercial architects to create *plus energy* houses. The winning design, *Efficiency Plus House with Electromobility*, created surplus energy to power two electric cars and an electric scooter. The project captured the attention of the German public when a family moved in for 15 months. They communicated their experiences of living in the house through a blog, while their energy consumption information was made available through a series of monitors and displays on the street-side of the house.

The plus energy housing information campaign is an effective investment in consumer awareness of their responsibility for climate protection and is expected to lead to a demand for companies to produce energy efficient products. This awareness may influence business to adopt energy and resource efficiency innovations (EREIs), which has been noted to be linked to: higher revenue; higher cost efficiency; and better product quality due to improved process quality.

Through some of these campaigns, the German Government is promoting its national economic interests as a producer of advanced building systems as well as supporting its automotive industry into a post-oil era. This focus on energy and technology is consistent with the German Government's focus on creating a national identity as a high-end, high-tech powerhouse.

Solar Decathlon 2007 winner. Courtesy of Leon Schmidt, TU Darmstadt.

HONG KONG (CHINA)
Enhancing Energy Efficiency in Commercial Buildings

Collaboration between industry and researchers in optimising heating, ventilation, air-conditioning and refrigeration has resulted in significant energy savings for commercial buildings in Hong Kong.

Context

Heating, ventilation, air-conditioning and refrigeration (HVAC&R) systems are responsible for 30 to 50 per cent of the energy consumed by commercial buildings in Hong Kong. Energy consumed by this sector has continued to increase over the past three decades. Commercial building energy use increased from 45 to 60 per cent of total electricity use from 1990-2000 and from 40 to 56 per cent of total annual electricity generated from 1981-1995.

Case

With funding from Sun Hung Kai Properties (SHKP), the Faculty of Construction and Land Use (currently Faculty of Construction and Environment) in the Hong Kong Polytechnic University (PolyU) put their lab-based expertise in simulating building HVAC&R systems into practice. Using research-based control systems and theories, the team proposed to save energy while maintaining internal comfort by using system diagnosis and optimisation throughout the building's life cycle.

This was achieved through simulations to optimise the design of the plant system configuration and system controls. Over a five year period starting in 2005, PolyU collaborated with: the client (SHKP); the mechanical and electrical consultant; the contactor; and others in the design, construct and operations and maintenance of the system for the International Commerce Centre (ICC). The final solution incorporated on-line software that interfaced with the building's automation system and monitoring systems.

The resulting redesign has saved about HKD6 million (USD770,000) per annum by reducing 7 million kWh of energy (approx. 18% of the air conditioning chiller plant energy consumption). The ICC building was upgraded to Platinum under the Hong Kong Building Environmental Assessment Method (HK BEAM) certification due to reduced energy consumption and peak demand, and the use of advanced control technologies.

(Above): Hong Kong skyline with ICC building. Copyright Baycrest; (Top): Access to International Commerce Centre.

The ICC building project has reinforced SHKP's reputation for sustainable environmental development policies and social responsibility. The project demonstrates the rapid application of technical advancements when private industry and academia collaborate, confirming Hong Kong's status as a leading international metropolis.

Authors - Geoffrey Q. Shen, Shengwei Wang and Jingke Hong

INDIA
Innovative Building Materials and Affordable Housing

This government-led program helped transfer knowledge across India's rural and semi-rural areas for local production and use of innovative building materials for low cost housing.

Context

Almost 30 per cent of India's population was estimated to be under the poverty line in 2010. This means almost 360 million people cannot afford to build homes from conventional building materials.

The productivity of Indian construction workers is low due to: the predominance of manual labour; low levels of education; lack of trade-based training; and the transitory nature of the workforce. Additionally, government employment programs in other sectors have created a shortage of workers resulting in an increase in costs of construction labour.

Case

In 1990 the Indian Government launched a five year Action Plan for Innovative Building Materials and Housing to promote knowledge transfer across all sectors of society. Responsibility for the plan was given to the Central Building Research Institute (CBRI) and several national agencies. Two main tools were used to enable local poor people to acquire the skills and knowledge to set up a production unit for low cost residential construction materials and then use them to build residential dwellings in their local area:

- trainers were trained throughout the country to assist the locals, especially women and unskilled youth, develop skills and knowledge in production and construction
- decentralised production facilities and housing construction demonstrations were set up to show how to produce and use the materials.

Street in rural India

The aim was to have mass participation by setting up 100 demonstration units and six integrated training programs annually. This was accompanied by awareness campaigns through mass media, get-togethers and exhibitions. Potential sites for production units or houses were mostly selected based on the ability of the beneficiaries to finance it or collaborate with organisations and agencies.

Over the five year program, a total of 34,000 demonstration units ranging from a small production unit or hut to a cluster of as many as 2,000 dwellings were set up in rural or semi-rural areas across 18 states of India. The savings achieved in the demonstration units was INR80 million (USD1.5 million), and less use of scarce building material such as cement and steel.

By incorporating a training program and decentralising production 30,000 locals were trained and over 6.3 million person-days of employment generated. In addition, the projects gave first-hand experience of building low cost housing to thousands of masons, builders, contractors, engineers and architects. The program benefits go beyond the tangible, helping to change the attitude towards the poor, both nationally and internationally.

Rural home in India

Author - Arun Kashikar

NORWAY
Cutting Edge Wood Construction

Innovations in wood-based products have helped Norway adapt its traditional construction material to create a modern, sustainable, robust and aesthetically beautiful built environment.

Context

With extensive forested areas, wood has been the dominant building material in Norwegian construction since ancient times. However, during the twentieth century concrete and steel became gradually more dominant. Since the 1990s there has been a concerted effort across private and public sectors to re-introduce this traditional material with new technology to address the issue of fire resistance and improve overall performance. As a natural, beautiful and renewable resource that reduces CO_2 emissions, wood is ideally suited to meet the built environment demands of Norway's expanding population in a sustainable way.

Case

Norway boasts a showcase of remarkable wooden structures including Vikingskipet (1994), Oslo Airport (1994-1998), Svartlamoen (2005), Kjøllsæter Bridge (2006), and Vennesla Library (2011). These showcase buildings are the tangible result of the combined effort of industry, government, research, and academia to innovate with this traditional material to create new designs and constructed facilities.

Since the 1990s, advances in wood technology, such as fire retardants and glulam (glued laminated timber), have made it possible to increase the span, strength and cross-sectional dimensions of beams. This addressed the challenges of fire, application in multi-storey buildings and load capacity.

Research and education by architects and engineers into the use of wood products has been instrumental in technology developments. The Norwegian University of Science and Technology (NTNU) in Trondheim is collaborating with industry partners and the Foundation for Scientific and Industrial Research (SINTEF) through the *Wood Programme (Treprogrammet)* to increase research into: the qualities of wood; improving strength and durability; and documenting effects on natural environment and indoor climate.

The Norwegian Government has also given its support at a local level to: *Program for Wood* which explores the whole production chain; *Norwegian Wooden Cities* is a policy promoting timber use for public buildings; the *Norwegian Wood Program* as an international showcase; *Nordic Wooden Towns,* which promotes timber use in urban development; and the EU Culture 2000 initiative *Wooden Towns* in Europe. These kinds of initiatives are paving the way for international use of wood in larger scale buildings such as the ten-story residential *Forté* building in Melbourne, Australia.

Above: Oslo Airport clearing runway. Courtesy of Espen Solli / Oslo Lufthavn AS. Top: Vennesla Library interior. Courtesy of Anne Kjersti.

Over the last few decades, technological development, education of professionals, and the practical application of wood products have elevated it as a sustainable 21st century construction material. Collaborative efforts of industry, government and academia are helping address the challenges of using wood as a modern sustainable building material.

Authors - Marit Støre Valen, Knut Samset,
Ole Jonny Klakegg, Torill Meistad and Anita Moum

SWEDEN
Swedish Building Innovation Program (Bygginnovationen)

This Swedish innovation program fosters closer collaboration between academia and the construction industry, with particular benefits for SMEs.

Context

Although there is a long history of Swedish Government support of construction research, there has been no earlier program with a focus on innovation and bringing in a broad range of firms able to commercialise university research.

One current objective of Swedish research and innovation policy is for Sweden to become a prominent research nation where high quality research and innovation contributes to the development of society and international competitiveness of the industry. SMEs will need further support in order for Sweden to become a successful industrial and service nation.

Case

Bygginnovationen (2011-2014) is an innovation program based on an agreement between the Governmental Agency for Innovation Systems (VINNOVA) and a consortium of 19 built environment businesses. Collaboration between VINNOVA and industry is instrumental in achieving the program's overall purpose of creating a strong and durable innovation environment in Swedish construction. This is being achieved through close collaboration between academia and industry, and promoting commercialisation of knowledge, solutions and research results.

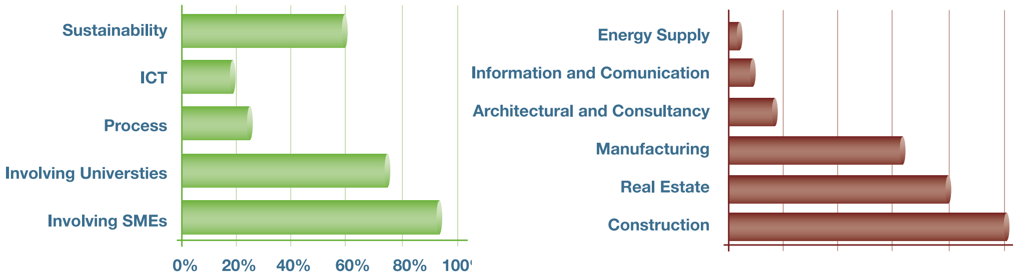
With a total budget of SEK42 million (USD6 million), this program is co-financed by VINNOVA and the Swedish industry, primarily through in-kind work by employees. The continuous, rapid and confidential assessment of grant applications by a business advisory committee (comprising experienced industry specialists) makes the process efficient and non-bureaucratic. Thirty of the thirty-three grants awarded in 2011-2012 involved SMEs.

Bygginnovationen development project: "Training simulator for virtual concrete spraying" (Copyright Edvirt AB)

Rather than focusing on financial gain from projects, the program is intended to become a mechanism for the Swedish construction industry to: generate employment and turnover through green growth; bridge the gap between academia and industry; and be a strong international competitor.

The program is an integral link in developing innovation within the Swedish construction industry. Initial expert assessments concluded that the construction; real estate; manufacturing; architectural and consultancy services; information and communication; and energy supply industries will increase their productivity because of projects carried out under this program.

Program activities are expected to produce short-term results including new solutions, prototypes and software. Expected medium-term results include: new products, processes and services developed by the firms; reducing costs; raising productivity; and contributing to increased sustainability.



Grants awarded 2011-2012 by Bygginnovationen by field and participants (left); and Grants with predicted impact in productivity by sector industry (far left).

Authors - Jan Bröchner and Anna Kadefors

UNITED STATES OF AMERICA
Counting the Costs of Inadequate Interoperability

By measuring the impact of inadequate ICT interoperability across the supply chain it is evident that there are significant opportunities to reduce costs by improving efficiencies in the USA construction.

Context

An alarming trend in the USA construction industry is its relatively stagnant labour productivity improvement compared to other non-farm industries. Widespread deployment and use of interoperable technology applications across the supply chain have the potential to lead to improvements in the efficiency and productivity of construction-related activities but, because these losses had not previously been quantified by an unbiased study, the industry lacked real motivation to change.

Case

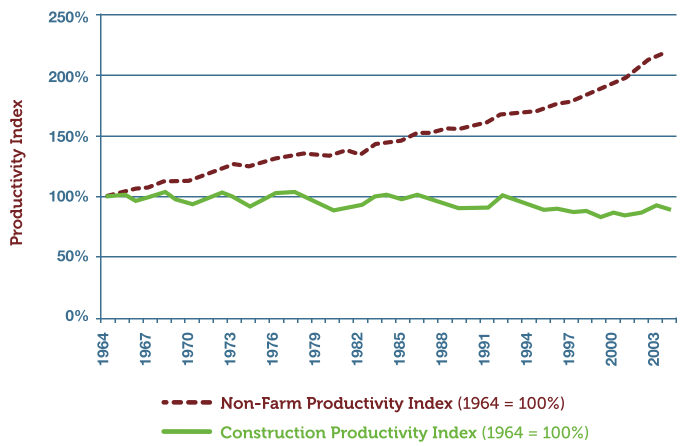
When organisational systems do not function well together, efficiency losses are incurred due to avoidance activities, mitigation costs and delay costs. To address this issue, the National Institute of Standards and Technology (NIST) carried out a study to consider the effects of inadequate interoperability on internal business functions. This research compared the annual cost burdens of four stakeholder groups across the life cycle of capital facility management: architects and engineers; general contractors; specialty fabricators and suppliers; and owners and operators, against measures of economic performance.

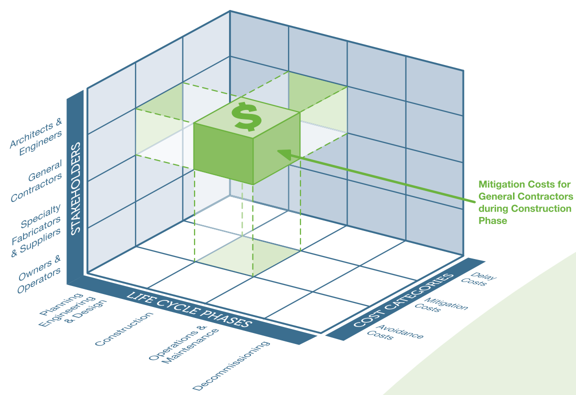
Business process management functions affect efficiency between different units within the firm and information exchange between project participants external to the firm. Reducing the cost burden of these processes offers potential for mutual gains. This study identified three main areas of concern across all stakeholder groups: project management; document management; and information request processing.

The study estimated an annual cost burden of USD15.8 billion due to inadequate interoperability in the capital facilities segment of the USA construction industry. Because the cost burden compounds as the project life cycle progresses, even though all stakeholders are affected by these losses, owners and operators have the highest cost (USD10.6 billion, with USD2.6 billion due to inefficient business process management alone) and architects and engineers the lowest (USD1.2 billion, with USD400 million from inefficient business process management).

Authors – E. Sarah Slaughter, Douglas Thomas and Robert E. Chapman

By identifying specific inefficiencies and finding opportunities for collaboration both within individual firms and across firms and stakeholder groups in the capital facilities industry, this research provides the tools to generate change resulting in gains for all stakeholders.





(Above): 3D representation of approach for estimating costs of inadequate interoperability; (Top): Labour productivity index for the USA construction industry and all non-farm industries.

FUTURE DIRECTIONS

Several country authors have considered future directions and development needs of the construction industry in their country. Some common themes have emerged:

- Germany and USA - **translate research** from more technologically advanced sectors to the construction industry
- Canada and USA - expedite practical implementation of research outcomes **through pilot trials, field tests and demonstrations**
- Australia, Brazil, Canada, Denmark and Germany – improve **research collaboration and dissemination** of findings between industry and researchers
- Brazil, Canada, Denmark, Finland and USA - **develop partnerships** to access the necessary expertise, resources, and experience between the construction industry and sectors servicing the industry
- Australia, Norway, Sweden and USA - improve productivity and reduce costs using **advanced information and communication technologies**.

In **Australia**, the CRC for Construction Innovation's national industry R&D priority initiative, *Construction 2020*[4], recognised that the industry would need to make financial investments in R&D as well as take a leading role collaborating with government and research institutions. *Construction 2030*[5] identified climate change, skills, economy, attitudes, policies/ governance, energy and technology as key uncertainties relevant to the industry's future.

The **USA** future roadmap identifies new capabilities to improve effectiveness, efficiency and productivity in the creation and renewal of the built environment to provide services critical to communities. Several areas identified include: cross-fertilising innovations from other fields to improve performance while reducing resource and environmental impacts, and maintenance costs; shift investment focus to provision of services and interdependence of systems, rather than the physical means to provide them; develop partnerships across the value chain to access expertise, resources, and experience relevant to the industry; undertake field tests and demonstration projects to expedite research results being applied in the field; and focus on interoperability, effective interfacing to improve efficiency, prefabrication, and performance measurement.

The industry in **Canada** is facing diverse challenges such as sustainability, energy efficiency, health and safety, and global competition. To meet these challenges, investment and collaboration is required to support R&D and its subsequent implementation and dissemination. The Canadian focus is on: piloting innovation on public projects; efficiently capturing and sharing information about impacts and lessons learned; developing an evaluation system to measure R&D impact; better dissemination of research findings (especially to SMEs); improved communication between government

[4] Hampson, K. D. & Brandon, P. 2004. Construction 2020: A vision for Australia's property and construction industry. Brisbane: CRC for Construction Innovation.

[5] Bok, B., Hayward, P., Voros, J. & Roos, G. 2012. Construction 2030. Brisbane: Sustainable Built Environment National Research Centre.

agencies, university researchers, funding agencies, and other stakeholders; addressing the lack of impetus to implement significant long-term change; and developing a multi-disciplinary approach characterised by collaboration, communications and relationships with non-traditional sectors such as financial and legal.

A 2012 white paper[6] prepared in **Norway** suggests that the built environment should aim to be well designed to encompass: aesthetic considerations; universal accessibility; a healthy indoor environment; the challenges of climate change; and a significant reduction in energy-use. To assist with the construction process, legislation should be simplified to be more user-friendly and information and communication technologies should be used to improve productivity and cost efficiencies.

In **Sweden**, the national innovation program, Bygginnovationen, focuses on developing a strong and lasting innovation environment through collaboration between the construction industry, research institutes and other organisations. Areas prioritised and supported include: sustainable growth; ICT; and efficient supply chain processes.

In **Germany**, both federal and state governments have taken an active leadership role in R&D. Programs have focused on the social implications of building programs, promoting energy efficiency and renewable energy systems, preparing for the challenges of climate change and increasing public awareness. The 21st century focus is on: high-tech products; prefabricated building elements; accommodating environmental demands; and merging the construction industry with a strong technology and engineering sector. Future research focus might continue to optimise collaboration and technology transfer with technology firms, which has been exemplified by the integration of electrical vehicles in the plus energy program.

The **Finnish Roadmap** focuses on improved maintenance of existing assets, infrastructure and the development of a robust construction industry. The 2020 vision is to exploit a user perspective as a key driver for development. Key recommendations include: the real estate and construction industry as the driver for energy and climate policy; developing cross-departmental cooperation for administrative and legislative reform; and conducting larger and more efficient projects.

Brazil is undergoing great development reflecting the urgent need to modernise the construction industry to increase efficiency, reduce costs and develop the capability for large scale production. To facilitate this, the National Association of the Built Environment is prioritising research areas. The five areas identified are: building management systems, components and processes; quality materials and construction; water, energy and comfort; design, use and operation; and urban infrastructure, real estate and housing management.

To be able to implement R&D over the next decade, specific challenges for Brazilian construction include: collaboration, conception, communication and dissemination of research efforts and innovation between industry and researchers; better financing and training to support R&D efforts; and greater integration between industry participants to overcome the fragmented nature of the supply chain.

[6] Norwegian Ministry of Local Government and Regional Development. 2012. Good buildings for a better society. Oslo: Government of Norway.

INSTITUTIONS INVOLVED

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

Curtin University, based in Perth, Australia, has established a strong track record of working with industry, government and community groups to understand their needs and, through innovative research and development, to provide long-term benefits through research and study programs.

Queensland University of Technology (QUT) is a successful Australian university with an applied emphasis in courses and research. The focus is on innovative world-class teaching and courses; delivering cutting-edge, high impact research; and sustaining productive partnerships to confront global challenges.

The **Department of Civil and Environmental Engineering of the University of Alberta**, Canada, has world-renowned researchers and scientists working on ground-breaking research. The Department hosts the Natural Science and Engineering Research Council of Canada (NSERC) and the Senior Industrial Research Chair in Strategic Construction Modeling and Delivery, among other programs.

Sao Paulo University (USP) is the largest higher education and research institution in Brazil and also has outstanding projection around the world, especially in Latin America. Within the USP, the School of Engineering (Escola Politécnica) plays a distinguished role in Brazilian engineering.

The University to New Brunswick (UNB) is among the oldest public universities in North America and the oldest English-language university in Canada. UNB contributes to the New Brunswick economy with patents and revenue from technology and knowledge transfer.

McMaster University Engineering is one of the most research-intensive faculties of engineering in Canada. The Chair in Heavy Construction provides leadership in advancing innovation in the heavy-construction sector, attracting and developing talent, and contributing to the advancement of a modern, durable and sustainable infrastructure in Ontario.

The **Danish National Building Research Institute (SBi)** is affiliated with Aalborg University. SBi develops research-based knowledge to improve buildings and the built environment and strives to identify subjects that are important to professionals and decision-makers involved in the built environment sector.

The **School of Engineering at Aalto University** in Finland builds on the combine 300-year-history of three highly regarded universities to create new information and solutions for sustainable development focusing its teaching and research on areas like global warming, energy conservation and clean energy, and the sustainable use of natural resources.

VTT Technical Research Centre of Finland is the biggest multi-technological applied research organisation in Northern Europe. VTT provides high-end technology solutions and innovation services in forecasting future technological and market development trends.

The **Scientific and Technical Centre for Building's (Centre Scientifique et Technique du Bâtiment - CSTB)** CSTB's primary mission is dedicated to developing scientific and technical knowledge relevant to sustainable construction in France. It provides support for public policies and contributes to innovation, future prospects, and sustainable development tools.

The **College of Arts and Architecture at Penn State University** in the USA has a strong tradition in drawing, model-making, community outreach/service learning, and hands-on construction used to prepare students to explore innovative models of architectural practice as well as to engage non-traditional means of building delivery.

Tata Housing is one of the key players in the Indian real estate industry to provide an enhanced lifestyle coupled with sustainable environment. Tata Housing has also been one of the biggest proponents of green initiatives in the Indian real estate space.

The **Faculty of Engineering at the University of Auckland** in New Zealand carries out large scale research activities and collaborations with other institutions and members of the industry. In the academic space, the faculty's programs and courses aim to give students tools to join the next generation of innovators, problem-solvers and entrepreneurs.

The **Hong Kong Polytechnic University (PolyU)** is the largest government-funded tertiary institution in Hong Kong (China), with over 28,000 students. PolyU has ranked among the top best Higher Education Evaluation & Accreditation Council of Taiwan list and in Thomson Reuters' top research performance list in Civil Engineering, Construction and Building Technology.

The **Department of Technology Management and Economics at Chalmers University** in Sweden focuses on the interaction between technology and society in an economic and social context. With a strong connection to the industry, the department interacts both nationally and internationally with society, researchers and other universities.

The **Department of Construction Management & Engineering at the University of Twente** in the Netherlands aims to develop interdisciplinary research focusing on the integration of technology and management for the purpose of producing innovative solutions.

The Department of the Built Environment at Eindhoven University of Technology in the Netherlands is primarily oriented towards the technology of building and technological solutions that contribute to the cultural dimension of the built environment.

Research groups at **HAN University of Applied Sciences** in Arnhem and Nijmegen in the Netherlands are dedicated to stimulating the exchange of relevant information and knowledge between professional trainers and trainees (teachers and students), and professionals in the field.

The **Department of Civil and Transport Engineering (BAT)** belongs to the Faculty of Engineering Science and Technology at the **Norwegian University of Science and Technology (NTNU).** While BAT primarily conducts basic research, the department also engages in commissioned research initiatives in cooperation with well known partners in industry and the public sector in the areas of construction, geomatics, geotechnical engineering, and road and transport.

The **Built Environment Coalition (BEC)** is a non-profit research and education consortium based in the USA. It advances practical knowledge to improve the sustainability and disaster-resiliency of the built environment.

The **National Institute of Standards and Technology (NIST)** is a federal agency with the mission to promote the USA's innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhances economic security and improves our quality of life.

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REFERENCES

This publication includes a summary of case studies being developed by authors as noted. Complete references will be included in the future Taylor and Francis publication in 2014. Prior to this publication, individual country reports' authors may provide references on request.

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