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Introduction

The thinking of many – especially among politicians and science and technology policy makers – is that the building and construction sector is not innovative, and not worthy of a focus as an engine for taking New Zealand forward. I suggest this is wrong.

The sector and its product – the built environment – have a huge effect on the lives of every New Zealander. The building and construction sector puts in place work valued at around 10% of gross domestic product (GDP) every year, employs in excess of 100,000 people directly, has a jobs multiplier of 2.4, and has a huge – and expanding – export market for construction products and construction skills, especially around the Pacific Rim. An improvement in 'efficiency' of the building and construction sector – defined as a reduction in the cost of work put in place – will have a positive effect on every other economic sector, and consequently on the national economy[1].

The building and construction sector has provided basic shelter and workspaces for man for as long as we have had civilisation, and so although breakthroughs in new knowledge do not happen every day – in the sense that those mapping the genome make daily advances – the sector **is** innovative. Indeed, extensive academic study[2,3] provides evidence of this. The problem comes in capturing the benefits of that innovation, because the new idea or concept is often generated and applied in quite different ways from some other sectors.

Most traditional considerations of 'innovation' have a linear (or looped) development path with the ability at defined stages for someone to claim ownership of an idea and subsequently derive financial flows from it. In many instances of innovation in the building and construction sector, there is no ability for this 'capture' by an individual such that, if the idea is used somewhere else, the individual can benefit. Every construction project poses its own challenge, and thus every project has little incremental innovations made for it. These are often made day to day on the drawing board or on site, and are frequently not captured and re-used – even within the same company – except by their originator. They are visible to any competitor who wants to watch and copy, and it is difficult to put an economic value on them, so they tend to be ignored when policy-makers talk about innovation – even if they are the reason the project actually succeeds.

Seaden[4] has written at length about the economic barriers which relate to some of these issues, and an International Council for Research and Innovation in Building and Construction (CIB) Task Group[5] has provided views from Argentina, Australia, Brazil, Canada, Chile, Denmark, Finland, France, Germany, Japan, Portugal, The Netherlands, South Africa, USA and UK, on the systems by which new ideas are introduced to the building and construction sector, and the impediments to their introduction.

What drives innovation in the sector?

I have written in the past of a perceived agenda[6] for the building and construction sector that is mostly client driven throughout OECD countries, as building owners and users look for improved economic return. This agenda seeks:

- Faster delivery
- Zero defects
- Reduced operating, maintenance and energy costs
- Greater durability and flexibility
- Greater building user productivity and comfort
- Fewer building-caused illnesses and injuries to occupants
- Less waste and pollution
- Fewer illnesses and injuries incurred by workers in the construction industry.

To attain these outcomes demands innovation on the part of all involved in the industry.

There is also an inexorable force running through all the political circles of the world, that there must be greater attention paid to the natural environment and the human impact on it. This has led to the coining of the phrase 'sustainable development', which seems to mean different things to different people in different countries. But when it is backed up by laws, which is the way political circles operate to achieve their agendas, it creates some fertile ground for innovation. In the Netherlands now, there is a legal requirement that consideration be given to how sustainability is to be achieved in the built environment[7].

These customer-driven and legislation-driven innovation agendas are largely local and national in impact. But, for those with an eye to commercialization of innovation, there are some global-scale driving forces too. For example, energy demand in the world has been estimated by some to be likely to rise by over 50% of the 1999 level by 2020, with most of the new demand from developing countries. Fuel cells and direct capture/conversion of solar energy are still in their infancy, but will surely grow in importance, because conventional systems are incapable of meeting the demand. This is quite apart from the political pressures that would be exerted if CO_2-emitting sources were capable and were used to meet the demand. It is possible to capture intellectual property rights off innovations such as these technologies which require an extensive 'manufacturing' element.

Africa is likely to pose special problems. It has 630 million people now, but is projected to have 1.5 billion by 2030. Already there are regular news stories about famine and infrastructural problems. It seems inconceivable that it will be possible to provide housing, education and civil engineering infrastructure for these people by following traditional procurement/delivery chains, and there will have to be some highly innovative thinking.

Research sector response to these driving forces.

How is the research community responding to these driving forces? CIB[8], of which I am the Immediate Past President, has pursued three themes over the last seven years aiming at delivering new knowledge and innovation that will help the industry meet the emerging goals.

The theme of the CIB Congress in Gavle, Sweden in 1998 was Sustainable Construction. The theme has been developed in a number of ways, addressing an underlying 'Agenda 21 for Sustainable Construction' [9].

The theme of the CIB Congress held in 2001 here in Wellington was Performance-Based Building[10]. Among other issues, the themes that were pursued focused on the demands of customers, how the demands could be quantified, the effects of building control systems on the way innovation occurs, and some examples of innovations to deliver high-performance buildings. There is now a major EU-funded project looking at how buildings can be better provided to meet expressed performance levels[11] .

CIB has now started to prepare for a further theme, 'Re-engineering Construction', that will look at innovative means of operating in the construction sector, both from the procurement and provision viewpoints. This is heavily driven by concepts arising in the Construction Industry Institute[12] in the USA, and in the Egan report[13] in the UK. The Egan report called for measures to attain, for instance, annual reductions on comparable projects in capital costs by 10%, in construction time by 10%, etc, but has worldwide applicability.

Running in parallel to this are CIB Task Groups addressing Megacities, Tall Buildings[14], Health and Safety on Building sites, and a range of other topics. There are also other international initiatives under the direction of International Energy Agency, United Nations Environmental Programme, and the like

Against this international context, and drawing upon it, here in New Zealand we have seen:the recent proposal led from UNITEC of a Collaborative Centre for Property and Construction Innovation – which was unfortunately unsuccessful – and numerous efforts to focus the research being carried out at BRANZ, the Universities, CRIs, and other organizations to meet the industry's long term goals.

Another attempt is being made now to develop an overarching New Zealand building and construction industry research strategy, intended to have credibility in the eyes of the industry, the researchers and the potential funding agencies, under the umbrella of the Construction Liaison Group.

Buildings for tomorrow and the day after tomorrow

We all live in and use buildings, and we all know that buildings today are different from 50 years ago, let alone 500 years ago, even if they have the similarities of roofs, walls and floors. Though we can see many traditional styles and techniques still applied, in many more cases the materials and techniques used are quite different, and there is nothing surer than that they will be different again in another decade. High-technology products such as stainless steels and other alloys which were designed in the first place for quite different applications – aerospace, or food processing equipment – routinely find themselves used in buildings. Society's expectations of indoor environments in buildings are radically different from a century ago, when electrical appliances were almost non-existent and the energy efficiency requirements that many building codes contain today were not dreamt of. Some commentators have drawn disparaging comparisons between the innovativeness of the building and construction sector and those of the "sunrise" industries of information technology and biotechnology. In my view this is an unfair criticism, when we stop to think about how far we have come, and how far we still see ourselves going.

The future house

Imagine a future house where:

- materials are made-to-measure, and "programmable". These may consist of a multitude of phases, perhaps with hyperperforming fibres and complementary matrixes. They will be able to deliver precise structural and durability requirements. We already have fibre-reinforced plastics systems – imagine that concept of composite materials taken further, based on performance at the molecular level.
- the building has 'intelligence'. It is totally precabled and has built-in sensors for use with potential future equipment, rendering the house able to be developed to match the changing requirements of the occupiers themselves. This would imply a much increased importance of modularity, assembly protocols and connection systems.
- windows with controlled variable transparency to match the outside sunlight and the degree of brightness required indoors, controlled variable thermal performances based on the outside climatic conditions and the required indoor climate, and integrating heating or cooling elements in glazing.
- active acoustics to remedy the defects of the rooms and allow special effects; an electronic tool connected to the family computer adjusting the ambience room by room. To reduce the thickness of glazing without losing sound insulation, windows will be fitted with active double glazing integrating loud speakers.
- "made to measure" indoor environments, from building services controlling air quality, heating/cooling, water supplies, lighting, and acoustics. Air quality control could involve use of biological sensors, with pollutants eliminated by biotechnologies. A "living" wall painting could be created from lichen, purifying the air, regenerating oxygen and releasing spring-time scents.
- space heating and domestic hot water production separated, with centralised hot water production replaced by instantaneous heating of water at the point of use, for example using a microwave system.
- piping systems for treated rainwater, recycling of wastewater, and water-less toilet disposal systems, because water savings have become more important than heating in household budgets.

This fascinating collation of possibilities are just some of those that emerged from a French report in 1998[15]. Many of them are already a technical reality somewhere – if still relatively expensive – but when they are all put together they look astounding.

Across the Atlantic, there is the Canadian Centre for Housing Technology[16] and a North American consortium called Partnership for Advancing Housing (PATH)[17]. They aim to accelerate the creation and widespread use of advanced technologies to radically improve the quality, durability, environmental performance, energy efficiency, and affordability of housing. Both involve key Government agencies in partnerships with leaders from the home building, product manufacturing, insurance, financial and regulatory communities, and each disseminates information about demonstration projects using innovations.

Running demonstration projects is extremely important; and in particular running them for retrofit applications. While the list of innovative ideas addressed in the French study might be good for new buildings, what about products that will work on buildings which are to be refurbished? We have over a million residential units in New Zealand, and 70% of the residential construction that New Zealand will have in 2020 is already built. If we are to address issues of energy efficiency or water efficiency, we need systems that will be demonstrable to the owners of the buildings of today, and feasible by retrofitting.

But, while this high-tech picture for the built environment may be feasible for developed nations, what relevance does it have for the developing world? Such countries may be more in need of improved "green" materials? The high-tech materials proposed here may not even sit well in a developed economy's ideal of "reduce-reuse-recycle", such as the Dutch Building Law[7] portrays.

Innovation in non-residential buildings

Just as for residential construction, there are extensive networks looking at innovation in technology for non-residential buildings too. All of the innovative materials that are applicable in residential construction are applicable in non-residential applications. There are some initiatives, aligned to the construction re-engineering theme described earlier, which are more directly applicable in non-residential construction. Take for example FIATECH[18], which is a US consortium of owners, operators, contractors and suppliers, who together look for means to accelerate project processes for major capital works. It was conceived by the National Institute of Standards and Technology and the Construction Industry Institute in 1999, with a mission is to achieve significant cycle time and life cycle cost reductions and efficiencies in capital projects from concept to design, construction, operation, and even decommissioning and dismantling of capital facilities.

In our most recent issue of BUILD magazine[19] there was reference to the new head office for Mammoet in Rotterdam – a 10-storey building prefabricated in a shipyard, barged to site, installed onto prepared foundations, hooked up to services and ready to use.

Performance-based building codes and their impacts on innovation

Building codes are a key means of society protecting itself from poor products and failures, yet allowing new ideas to be brought into practice. Performance-based codes, such as we have in New Zealand, provide a far simpler avenue for incorporation of research findings and easier acceptance of innovative thinking than prescriptive codes.

It would also be honest to acknowledge that it is not straight-forward, and that while the theoretical possibility may well exist, in practice innovations may still not be easily introduced. In particular, verifying innovative solutions, in a small market, is often not cost-efficient. The Canadian study of innovation in housing[3] identified the regulatory system as a key barrier to the introduction of innovation.

An example has been provided by Gann and his co-workers[20], regarding energy efficiency in housing in the United Kingdom. They observed that the complexity of the system of regulation was very high. Thus, while the overall energy efficiency of the UK housing stock may be improving, and while the controls which are in place are probably flexible enough not to inhibit innovation (which presumably were the code-writers goals), '*most designers and builders appear to comply with prescriptive standards set out in the Approved Documents. Under these conditions there is no necessity or incentive to adopt new technologies, indeed doing so may only complicate the process*'.

There is a plethora of innovative concepts for enhanced energy efficiency, and a wide range of schemes for rating energy efficiency. Yet these researchers found that the easy path was to follow the 'deemed to satisfy' route, even if it was not necessarily the best long-term result for national energy demand or the building owner (who will probably not have the expertise of knowing the alternatives available). Obviously, code documents can have quite unintended effects on outcomes!

In summary, if codes are to create clear and efficient routes for acceptance of innovative systems and solutions, there are issues of code structure and code administration which must be very carefully designed and implemented.

Some final cautionary observations

There is a line between too little innovativeness, and too much. Over a decade ago, Groak[21] observed that there were problems emerging as designers pushed for more sophistication and moved away from 'robust technologies'. He defined 'robust' technologies as those which, over a number of years, appear to have proved themselves reliable good practice – well established in design offices, text books, manufacturers' literature, standards and amongst site personnel. He contrasted these to 'sensitive technologies', which are significantly responsive to errors of design, manufacture, assembly or use. He also pointed out that these descriptions represent the ends of a spectrum, and that some technologies which were traditionally regarded as 'robust', such as lead roofs on churches, or cavity walls in houses, have become 'sensitive'. The answer to this is, surely, not simply to innovate further, nor to stop innovating, but to first understand why the system is being 'sensitive'.

Bruce Kean, the then Managing Director of Boral Ltd, summarised the issue very well[22] over a decade ago: *'As performance is pushed further and further out, so the need for narrower and narrower performance limits becomes critical. … As designs are pushed to the limit, quality control and maintenance become critical elements in the construction and life of the structure.'*

Yet the inability of the majority of the industry to act in a 'learning mode', and develop its products and techniques by analysing performance in the past, has been commented upon very frequently. No innovation will occur without the occasional error; but repetition of an error is almost never excusable. No one sensibly argues against a need for innovation. But the innovation must meet the customer's needs. That means that the resulting built environment must function in a way that is cost-effective, safe and healthy for the users. I'm far from sure that we have achieved this, nor implemented the lessons that were contained in the thoughts of Groak and Kean, when I look at the number of building failures that are occurring on very new buildings.

Everyone in the design, realisation and operation chain has a part to play in this process of ensuring the effective use of innovation. The designer must interpret the requirements of the customer, who must in turn be prepared to have meaningful discussions with the designer about the limits of possibilities given budget and time constraints. The designer and contractor must have a good relationship which ensures that all of the assumptions made by the designer are clearly understood by the contractor as a context in which day-to-day operating decisions – and innovations – are made on the site. Sound drawings and specifications which define for the artisans on site the expectations of how the building will be created are also essential. This contract documentation is the subject of a working group within the New Zealand building and construction sector right now.

The building owner/user must also understand the assumptions that have been made about maintenance and operating regimes, and I suggest that the designer and/or builder has a responsibility to make sure that this happens, especially when innovative systems have been used. This appears to be a facet of industry performance which has been significantly lacking[23]. The discipline of facilities management will perhaps create some significant 'customer pull' in the near future. There are many guides to this issue[24]; but it seems from my discussions within the industry that it is unusual for a major building to be handed over to the customer and/or new user with a manual defining how the building is intended to be operated. Yet who would buy a new car if the salesman said that no such manual was available?

Conclusion

The building and construction sector is innovative, and does cast its net widely for ideas that will help it to deliver products more efficiently to meet customer needs. Code systems can be written to aid or inhibit innovation in the sector, and we still have lessons to learn in these areas to encourage appropriate innovation.

But in the final analysis, the real challenge to the industry, as it adopts innovation to meet emerging needs of its customers and society, is to ensure that the context in which the innovation works is not going to be compromised. The sector must learn better from experience on performance of new technologies. Everyone in the design, realisation and use chain has responsibilities in this respect if the maximum benefit provided by the built environment is to be attained.

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