IMPROVING TECHNOLOGY TRANSFER IN THE AUSTRALIAN CONSTRUCTION INDUSTRY

Dr David Thorpe
University of Southern Queensland
thorped@usq.ed.au

Professor Neal Ryan
Queensland University of Technology
n.ryan@qut.edu.au

1.0 INTRODUCTION

The construction industry is a significant component of the Australian economy, which, in the five years to 2003, contributed an average of almost 6 per cent of Australia's gross domestic product, and, in 2003-03, was Australia's fourth largest industry (ABS 2005a, 562). However, there is evidence that the rate of innovation in the construction industry is less than in most other industries. For example, the Australian Bureau of Statistics conducted a survey of innovation in Australian industries for the period 2001 to 2003 and found that the construction industry, at 30.7 per cent, had one of the lowest proportions of business innovating. This is clearly not a low rate, but it is well behind that of other industries such as communication services, electricity, gas and water supply, in which over half the businesses undertook innovation (ABS 2005b, 7). At an international level, Winch (1998) supports this. Indeed, his research indicates that the industry is innovative, but that the rate of innovation has fallen behind other industries.

One of the features of this industry is that many of its member organisations are small and medium enterprises (SMEs). It has been reported that 94 per cent Australian construction businesses employ fewer than five people each (Hampson and Brandon 2004, 10). This is supported by the 1996-97 Australian Bureau of Statistics survey of the private sector construction industry, which stated that the average number of employees in the Australian construction industry was, at that time, 4.1 (ABS 1998, 5). This large proportion of smaller businesses means that the SME sector is of considerable importance to the construction industry.

Ofori (2002), researching the issues in small construction contractor development with emphasis on developing countries, also notes the importance of contractors in the overall development process of buildings and items of infrastructure. In arguing that small contractors should be given the opportunity by contractor development programs to both grow and mature, Ofori (2002) notes that they are important with respect to providing the framework for the upgrading of the industry as a whole.

Research has indicated that the SME sector tends to not perform well in adopting and implementing innovations (Koivu and Mantyla 2000; Acar et al. 2005). This is not always the case. Winch (1998, 269) stated that the industry "is a lively source of new ideas", while Harty (2005) describes the way in which design engineers developed innovative approaches to work around computer software requirements in an integrated 3D CAD system during the construction of the T5 terminal at Heathrow Airport. These papers suggest that innovation in the SME sector can and does occur, but perhaps occurs more slowly than in other industries.

The issues pertaining to the development of a more effective and efficient construction industry have been highlighted by Hampson and Brandon (2004), who reported that barriers to industry taking more responsibility for leading and investing in research and innovation included a) the cyclical nature of the industry, b) a shortage of client and industry leadership, c) the limited history of business deliverables from researchers, d) the self-interest of many participants, e) the inability of the industry to foresee the tide of competition (in global or green terms), f) a lack of trust between industry and researchers in sharing vital information, and, finally, g) a lack of long-term funding basis for a national R&D centre. Hampson and Brandon (2004, 10) have observed that commitment to collaborative research and innovation is required, with genuine mutual consultation with industry deemed essential for improved research and development.

This view is also supported in the international context by the European Constrinnonet project, which investigated construction innovation in the European Union (EU), with particular emphasis on the small and medium enterprise (SME) sector. The project found that no simple solution exists to address the problem of innovation in construction (European Commission 2004, iii). This report is discussed in more detail further below.

The construction industry is an important sector of the economy and is underpinned by a large number of SMEs. Innovation in this industry has been variable, with adoption of innovations being generally slow. Technology transfer in the construction industry is further discussed below, where the above points will be considered in relation to the innovation lifecycle, the research being undertaken by the CRC-CI, technology transfer in the construction industry both generally and more specifically within Australia, and the process of managing technology transfer in SMEs and the construction industry.

2.0 THE INNOVATION LIFE CYCLE

In describing the process of managing technology and knowledge, Trott (2005, 177) observes that one of the fundamental issues for firms is to transform technology into profit. Trott (2005, 184) has noted that, over long periods, firms build up a body of knowledge and skills through experience and learning-by-doing, which can then be transferred to competitive advantage.

Trott (2005) also holds that the fundamental feature that characterises successful firms is their ability to identify and exploit technological opportunities. Firms may develop distinctive competencies. These tend to form the tacit knowledge and embedded routines that are at the core of the organisation's abilities. The ability of organisations to develop firm-specific competencies that take time to evolve and are costly to imitate will, to a large degree, determine their survival, particularly if the firm can turn technical competencies into effective innovation and thereby generate effective organisational learning. Such firms will often develop a knowledge base that is more than the sum of the firm's individual parts. The learning organisation, therefore, is critical to the development of knowledge and is thus a key component of its innovativeness (Trott 2005).

With regard to the construction industry (with its many SMEs), one of the conclusions arising from Trott's discussion (2005) is that smaller firms are unlikely to have the vast knowledge resources of larger firms and will accordingly be disadvantaged with respect to these larger organisations. Another conclusion is that optimum development of these firms, and hence that of the industry itself, is likely to require the application of organisational learning principles.

Technology has a definite lifecycle. Bowden (2004), in discussing the ongoing development of the electronic integrated circuit, demonstrates how this development follows the classic “S” curve. This curve illustrates how performance of a particular development, as measured by some metric that is characteristic of it follows (when plotted on a linear scale) the shape of an “S” over time, ultimately reaching a limit determined by some physical constraint associated with the underlying technology. This curve is illustrated in Figure 1, which is based on Figure 2 in Bowden (2004, 5). It shows that the performance (or technological progress) of a new technology increases slowly at first, then, as it is becomes more widely adopted and improved, it increases more rapidly until it becomes a mature technology that has reached its physical limits, at which stage the rate of progress slows. As a consequence, the best marginal improvement is in the technology improvement stage.

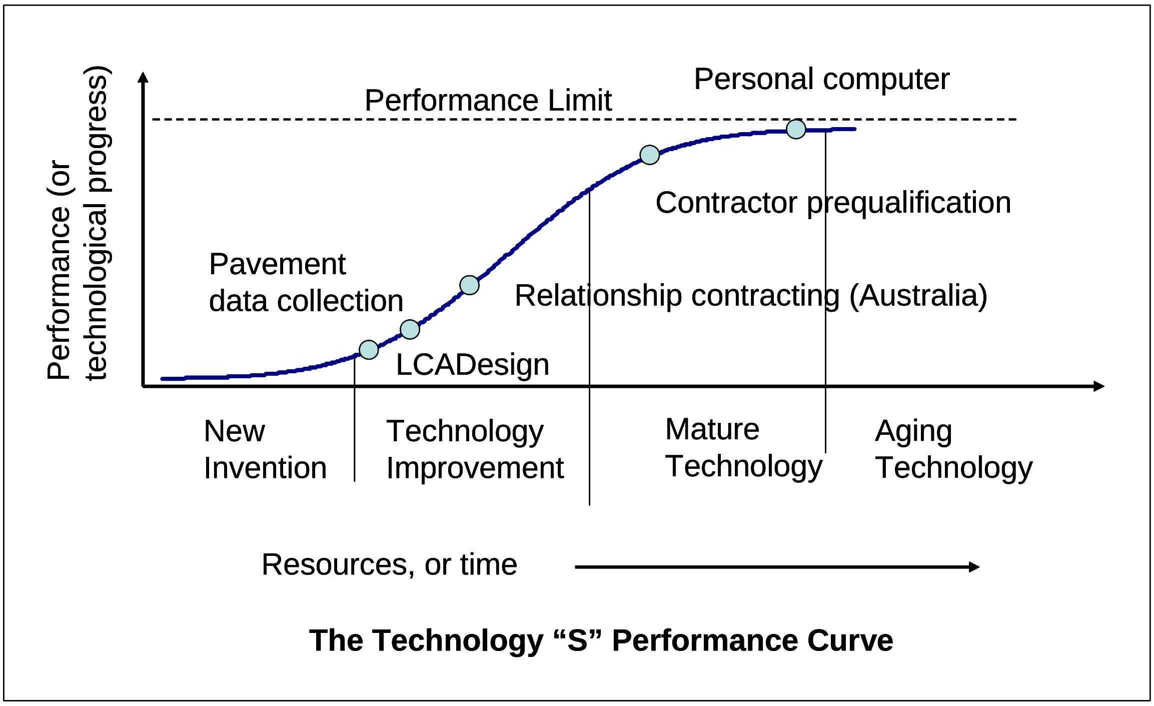

Figure 1: Technology “S” Performance Curve (based on Figure 2 in Bowden 2004, 5)

In order to illustrate the application of this curve to the construction industry, some innovations relevant to that industry are shown on this curve. The positions of these innovations on the curve are the authors’ estimates only and are thus not meant to be definitive.

Three of these innovations are general innovations adopted by the industry and two are quite new developments by the CRC-CI. The innovations are:

- relationship contracting, which is now becoming an accepted approach for procurement on larger, more complex projects and has therefore been placed in the earlier part of the “S” curve, which means that considerable additional performance is possible through its wider adoption;

- contractor prequalification, which has been in place for some time and is accordingly showing a diminishing ability to improve its rate of progress or performance;
- the personal computer, which is widely used in the industry (however, note that innovations with speed and size, web-based applications, and new uses for computers are likely to lead to increased performance from this technology); and
- the newer developments of the investment decision framework for infrastructure asset management data collection tool and the LCADesign tool for automated eco-efficiency assessment of commercial buildings, both of which have been developed by the CRC-CI.

The investment decision framework for infrastructure asset management (for example, Piyatrapoomi et al. 2004) optimises the collection of road structural data. It enables four times as much road maintenance data to be collected for the same amount of expenditure. This equates to approximately AUD4 million of savings for the government on state-wide data collection costs (CRC-CI 2005b, 10). This project received a High Commendation at the 2005 Queensland Engineering Excellence Awards conducted by Engineers Australia (CRC-CI 2005b, 62).

This technology has the potential to be developed for use in a range of asset classes. It is therefore likely to achieve high performance over time. Since it is still in the early stages of development, yet has already started delivering monetary benefits, it has been placed in the early stages of the “Technology Improvement” stage of the technology “S” curve. This placement recognises that it has delivered benefits *and* has considerable potential to deliver more in future.

LCADesign was developed through the Sustainable Built Assets research program of the CRC-CI and is best described as “an automated eco-efficiency design tool for commercial buildings that makes assessments directly from 3D CAD drawings” (CRC-CI 2004, 54). The prototype of this tool is being applied to seven commercial office designs (CRC-CI 2005b, 28). What is more, the University of New South Wales has requested prototypes of this tool for use in its Multi Disciplinary Design Studio postgraduate course (CRC-CI 2005b, 38). This tool has been placed at the edge of the “New Invention” stage in the technology “S” curve, for it is considered to be still at an early stage of development, yet has the potential to deliver considerable benefits to sustainable development both in Australia and globally.

The adoption of technology also follows a (different) S-shaped pattern. This curve is the cumulative frequency of the percentage of adopters of a technology over its lifespan. Rogers (1995, 261-266) describes this curve and divides adopters into five ideal types based on innovativeness, viz., innovators (2.5 per cent), early adopters (13.5 per cent) and the early majority (34 per cent), the late majority (34 per cent) and the laggards (16 per cent).

Each adopter has distinctive characteristics. These tend to relate to the risk involved in the adoption. Rogers (1995, 263-266) notes that:

- innovators are venturesome, prepared to accept setbacks, and play an important role in the diffusion process;
- early adopters are a more integrated part of the local social system, are respected by their peers and are often looked to by other adopters for advice;
- the early majority tend to deliberate more than the early adopters but adopt new ideas before the average member of the social system;
- the late majority tend to be sceptical at first and are not convinced to take up an innovation until most others in their system have done so; and

- laggards tend to use the past as a point of reference, often have limited resources and must be certain that a new idea will not fail before they can adopt it.

Figure 2, which is based on Figure 7-2 in Rogers (1995, 262), illustrates the five groups of innovation adopters.

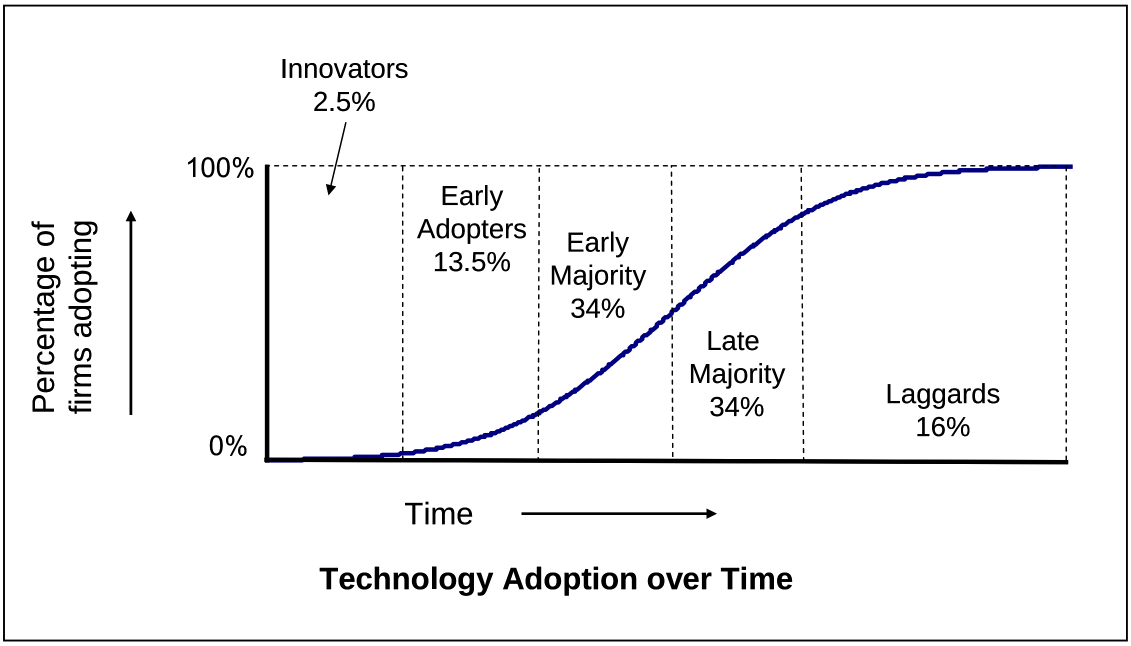

Figure 2: Technology Adoption over Time (based on Figure 7-2 in Rogers 1995, 262)

An inspection of Figure 1 shows that early adopters, who employ the technology at an early stage, will gain the most overall performance from the technology, should it be successful. The early majority, who adopt the technology at the technology improvement stage, where the performance curve is at its steepest, will gain more incremental benefit than the early adopters, but will gain less overall performance from a successful technology in the long run than the early adopters. Laggards, who adopt the technology late and are, as a consequence, in the region where the slope of the performance curve in Figure 1 is relatively flat (and thus where little overall performance can be gained) will achieve the least benefit.

The innovation process is characterised by a number of key points. First, firms tend to build up knowledge and skills over a long time. Second, the more successful firms have the ability to recognise and exploit technological opportunities. Third, the marginal advantage (performance or technological progress) of these opportunities is at its least in the early and late stages of the innovation lifecycle. Fourth, early adopters have the opportunity to enter the market early and gain maximum total advantage from the innovation, while late adopters gain little total or marginal advantage. Finally, early adopters tend to be risk takers, while late adopters tend to be more risk adverse.

Understanding the technology lifecycle and the associated performance and adoption curves, and the way in which they interact, is important with respect to understanding the process of technology transfer from researcher to end-user, which represents a complex and quite interactive process. Such understanding will assist the critical judgment required by industry to select the right point in the innovation lifecycle at which to adopt (and possibly enhance) an innovation. This is particularly important for SMEs, many of which, on account of their small size, are unlikely to possess the resources required to take significant risks should the prospect of a return on their investment in new or improved technology be low.

3.0 RESEARCH IN THE CRC FOR CONSTRUCTION INNOVATION

The objectives of the CRC-CI are to enhance the contribution of long-term scientific and technological research and innovation to Australia's economic and social development, to enhance collaboration between researchers and, what is especially important, to create and exploit (in a commercial sense) tools, technologies and management systems in order to deliver innovative and sustainable constructed assets that will be of financial, environmental and social benefit to the construction industry and the broader community (CRC-CI 2005a).

In achieving its objectives, the CRC-CI undertakes research projects under the three related programs of Business and Industry Development, Sustainable Built Assets, and the Delivery and Management of Built Assets. These programs are supported by an information communications and technology (ICT) platform. Each of these programs delivers its outcomes through a number of research projects and other publications of interest to the industry. This direct dissemination is supplemented by an educational strategy that seeks to transferring its technology to industry by means of education and training, especially through links to vocational education and training, technical and further education and higher education (CRC-CI 2005a).

Some of the specific initiatives of the CRC-CI are the Building Research, Innovation, Technology and Environment (BRITE) innovation surveys of perceptions of innovation determinants (CRC-CI 2005b), the publication of special reports to industry, and its relationship with the Australian Construction Industry Forum (ACIF) (CRC 2005b). In an early annual report, the CRC-CI also noted that the leading industries represented in the CRC-CI have a "substantial pull impact on smaller players" (CRC-CI 2002, 20). If this pull can be harnessed, it will greatly assist the technology transfer process.

Like other CRCs, the CRC-CI employs a large number of knowledge workers. Through their intellectual capital and their research and development activities, CRCs possess and develop considerable tacit and explicit knowledge. Sullivan (2000, 162-163) expresses this as the knowledge and know-how possessed by human capital and the organisation's intellectual assets (commercialisable intellectual assets and supporting intellectual assets, viz., organisational structure, managerial methods, operational methods and procedures). The commercialisable assets (or intellectual property) form the technology that is transferred by the CRC, whereas the tacit knowledge possessed by its people may assist this process.

CRCs deliver the outcomes of their research through the Commercialisation and Utilisation Plan Guidelines for the CRC Programme (Department of Education Science and Training 2004), which sets out the way in which national benefits can be demonstrated and describes the development of the commercialisation and utilisation plan (including intellectual property) for the CRC.

Sheen (2005, 3), who undertook an extensive study that "rests on the proposition that research and development (R&D) has a critical role to play in making important contributions in the new economy where high prices for knowledge can be realized", surveyed sixty-two CRCs in an extensive study of managing intellectual property and licensing. He observed that CRCs need to understand the nature and process of managing intellectual property in a collaborative context, and also added to Sullivan's model of intellectual asset management the components of relationship, project management, agreements and licensing (Sheen 2005). The implications of this research for the technology transfer process in the construction industry is the importance of developing relationships throughout the supply chain, in addition to the need to project manage the technology-transfer process.

Garrett-Jones and Turpin (2002) noted that the most universal measure used by CRCs for promoting the utilisation and application of research outputs was engaging potential end-users and requiring them to pay for the CRC's expertise (this was often a good source of income). In the construction industry, this is likely to result in more effective transfers of technology to industry participants.

Thus, in common with all CRCs, it is important that the CRC-CI effectively transfers the technologies it develops to the industry it serves. While the core members of the CRC-CI are likely to have the resources that will enable them to be early adopters of new technology, it is also important to remember that the benefits of technological developments should be realised throughout the supply chain, and particularly by the SMEs, the combined performance of which clearly has a significant impact on the performance of the industry as a whole.

The successful achievement of technology transfer in a way that delivers maximum benefit to Australia thus requires a careful balance between a range of factors such as research, development, project management, industry relationships, education, training, industry assistance and effective commercialisation practices. The next two sections, the first of which reports on studies in technology transfer at a more global level, and the second of which considers more specific Australian issues, discuss technology transfer in the construction industry in more detail.

4.0 TECHNOLOGY TRANSFER IN THE CONSTRUCTION INDUSTRY

One of the important characteristics of the construction industry (like many other industries) is that the group of firms referred to as SMEs are far from uniform in their capabilities. For example, Acar et al. (2005) investigated the take-up of information communication and technology (ICT) in SMEs in Turkey and found that organisation size was an important factor with respect to the adoption of this type of technology, one of the reasons being that smaller contractors lacked the staff to use ICT effectively and were unaware of its potential benefits. The researchers also concluded that what organisations traditionally referred to as SMEs were, in fact, clusters of firms with varying characteristics rather than a set of organisations that could be treated as homogeneous.

Researchers have identified a range of other barriers to technology transfer in the construction industry. One of these barriers is organisational culture. The research of Acar et al. (2005) found that not only was the implementation of ICT a complex process requiring special skills that may not be possessed by SMEs or their staff, but also that the cultural context, such as the attachment of professionals to established practices, was important with regard to technology diffusion. They also found that ignorance of the benefit of ICT systems was a factor that impeded their take-up among SMEs.

Supply chain issues can also be important. Bresnen and Marshall (2000), who explored the presumed link between partnering and cultural change within the construction industry, observed that evidence from other sectors showed that collaborative forms of contracting can depart from the ideal. Indeed, they found that collaborative contracting was often used in order to drive down costs, or else pass on costs and risk further down the supply chain. Clearly, contractors towards the bottom of the supply chain (the SMEs) would be affected most by such practices. It has also been suggested that the transactional nature of the construction industry might enable larger contractors to take advantage of their superior networks and strategic knowledge with a view to reducing operational costs at the expense of the small firm, thus leading to mistrust and a general unwillingness to adopt new technologies and processes (Miller et al. 2002).

Another issue with respect to technology transfer is the nature of the industry itself. As a case study for their research, O'Farrell and Miller (2002) assessed the viability of pozzolanic materials as substitutes for cement in concrete (the production of cement not being an environmentally friendly process) in South Wales. Although the SME firms that were part of the research could see the benefit of this approach, it appeared that price (driven by the competitive tendering process) was the main concern in the industry, rather than the development of new products in the traditional sense. This research seems to suggest that a way needs to be found to encourage (perhaps financially) the adoption of products and processes that are environmentally friendly but not necessarily profitable to the contractor.

The report of the European Constrinnonet project, which was undertaken by a consortium of leading European universities, such as VTT and the University of Salford, found that no simple solution exists to address the problem of innovation in the construction industry (European Commission 2004).

The basis for the Constrinnonet project was an OECD finding that construction was among the more traditional sectors of the economy, with a relatively low R&D performance, and yet accounted for about 7 per cent of the working population and contributed over 6 per cent to national GDP. It was found that the industry was populated predominately by SMEs. The sector also struggled with a complex, fragmented structure, in addition to a poor reputation. At the same time, its level of investment in R&D was generally less than 0.5 per cent of company turnover, although there appeared to be no lack of public services generally available for the provision of economic support for the purpose of research training and development (European Commission 2004, 1- 2).

The objectives of the Constrinnonet project were as follows:

- to study the mechanisms behind successful innovation and to develop strategies to help transfer these into practice; and
- to examine the way in which various service providers in the market can assist in spreading these mechanisms to construction SMEs (European Commission 2004, 2).

The report consisted of two phases – a six-month definition stage and a 2.5-year implementation stage aimed to a) enhance know-how of the mechanisms behind successful innovation, b) develop and test actions for improved innovation support, and c) exchange this information with stakeholders trans-nationally (European Commission 2004, 3).

In addition to its conclusion that no simple solution exist to address the problems of innovation in construction, the project found that business support was the most relevant mechanism through which to promote innovation in construction sector SMEs and that European governments and their agents had generally failed to engage with the vast majority of construction SMEs in crucial areas. At the regional level, there was an absence of focus on innovation support mechanisms or business development services (European Commission 2004, 20).

Recommendations were made at an EU level, at national/regional level, and for service providers and SMEs (in addition to larger companies). Policy issues included initiating specific innovation efforts for construction in the EU, developing statistics about construction, innovation in business support, and regional initiatives (European Commission 2004). Among the recommendations for service providers was the need to promote innovation, identify regional resources and avoid "one-size-fits-all" solutions (European Commission 2004). It was also found that more could be done by the industry itself in order to bridge the gap. While the construction sector should utilise some common objectives and strategies, each SME, it was argued, needed to identify a clear and concise benefit it could achieve from involvement in common activities (these were not defined in the report) (European Commission 2004, 20-21).

The Australian construction industry is not dissimilar to that studied in the report discussed above, especially since Australia's construction industry also contributes approximately 6 per cent to GDP (ABS 2005a, 562), has a large number of SME firms, has a fragmented structure (Hampson and Brandon 2004), and is also variable in the characteristics of its member firms, especially from an innovation adoption perspective. In view of this, the findings of the Constrinnonet report are well worth considering when discussing the way in which to best promote innovation in the Australian construction industry.

The above studies have shown that there are a number of factors in technology transfer to the construction SME sector. These include organisational size and culture, supply chain issues, the price-driven nature of the construction process, and the importance of developing appropriate policies at both government and firm level. An important finding from a number of the studies was that there is no easily defined "SME". Perhaps this can be summed up by the statement that policy makers should "avoid one-size-fits-all solutions to the problem of innovation in construction" (European Commission 2004, 21).

5.0 TECHNOLOGY TRANSFER IN THE AUSTRALIAN CONSTRUCTION INDUSTRY

One of the projects supported by the CRC-CI was Blayse and Manley's study (2004) into influences on construction innovation. They identified six main factors, these being a) clients and manufacturers, b) the structure of production, c) relationships between individuals and firms within the industry and between the industry and external parties, d) procurement systems, e) regulations/standards and f) the nature and quality of organisational resources. Innovation in this sense tended to be the actual use of a nontrivial change and improvement in a process, product or system novel to the institution developing the change (within the broader product system). The authors noted that the identified influences can be managed strategically in order to maximise innovation outcomes.

A survey of innovation in the Australian construction industry by Manley et al. (2005), within the BRITE program, found that the "new-to-industry" rate of technological innovation was 18 per cent, and that 6 per cent of respondents (including a number of consultants) reported "new-to-the-world" innovations. Business strategies were key determinants of innovation (however, research and development strategies had a relatively low rank among business strategies), while the main driver for innovation was the desire for improvements in efficiency or productivity and customer needs. Indeed, 93 per cent of the industry reported a positive impact on profitability arising from their most successful innovations over the previous three years (Manley et al. 2005, 11-12).

The Australian Bureau of Statistics survey of innovation in Australian businesses (which included construction) (ABS 2005b) divided innovation (i.e., any new or significant improvement) into the three areas of a) goods or services, b) operational processes and c) organisational or managerial processes. The survey found a rise in the percentages of firms innovating as organisations increased in size (ABS 2005b, 5). The main barriers identified in innovating firms were cost and market related. These were less important for non-innovating firms (ABS 2005b, 20). On the other hand, the main drivers of innovation were profit and market demands. Legal-related drivers were also significant (ABS 2005b, 28).

These findings were reflected in the construction industry, with the general exception that market-related factors were less important to individual firms than to industry as a whole. Like a number of other industries, institutions (such as universities) were not significant sources of innovation for the construction industry. Contribution to expenditure on innovation by the construction industry in 2003-03 was about 1.2 per cent of total business expenditure (although this figure needs to be treated with care owing to its variability) (ABS 2005b, 69).

Love et al. (2001) researched the barriers to implementing e-commerce in construction SMEs in Victoria, Australia. They noted that many small- and medium-sized firms find it difficult to compete in today's competitive markets. Using an unstructured interview process, they found that the rate of e-commerce implementation was related to turnover and number of employees. They stated that a contractor with a higher turnover would be expected to bid for more projects or for larger projects and thus be expected to invest in IT in order to support the tender documentation and contract administration. On the other hand, a contractor with more employees may need to invest in an IT-based communication and co-ordination network. From their interviews, the researchers were also able to categorise identified barriers into organisational, financial, technical and behavioural. They identified risk, uncertainty, change and knowledge as the underlying factors that businesses considered as being constraints with regard to the introduction of the technologies needed to support an e-commerce infrastructure.

The above studies and surveys tend to confirm the studies discussed in the previous section, i.e., that factors like organisational culture, supply chain considerations and the nature of the industry itself play important roles in the technology transfer process. Such studies have also shown the importance of key drivers of innovation in the industry such as the desire for improvement, profit and addressing customer needs, and have furthermore shown that cost represents a significant barrier to innovation. Again, size of organisation was significant.

6.0 MANAGING TECHNOLOGY TRANSFER IN SMEs AND THE CONSTRUCTION INDUSTRY

Previous discussions have focused mainly on the issues related to technology transfer in the construction industry. This section develops this discussion further by exploring the mechanism of technology diffusion and adoption.

Knol and Stroeken (2001) developed a model for the diffusion and adoption of information technology (IT) in SME organisations through an IT-scenario model. In their model, diffusion tends to occur at a higher aggregation level than adoption and has a strong communication element, while adoption (which is associated with the implementation process) takes place at the level of the individual adopting unit, which can be as far down the organisational chain as an individual. The scenario model contains three main components, viz., the environment, six phases (in time) and three aspect areas (strategy, organisation, technology). The model was piloted in interviews with SMEs operating in the furnishing sector.

The researchers concluded that, all things considered, this model seemed to provide insight into the strategic application of IT in companies and supply chains for each phase. Furthermore, it could depict these concretely. With respect to application, dissemination of information would take place before organisational decision-making about an innovation and its implementation. While this study was in a non-construction industry sector, it shows the need for an innovating SME to take into account environmental factors, communication processes, technology and organisational factors.

Another study on innovation diffusion in SMEs was undertaken by Thomas (2000). His focus was on inter-firm diffusion (the spread of a new technique from one SME to another). Thomas discussed the two categories of "disembodied" diffusion (the transmission of knowledge and technical expertise) and "embodied" diffusion (application of the new technology) (Thomas 2000, 3). He noted that there are differences in the speed at which technology is diffused and the length of the diffusion process. He also observed that, as the speed of diffusion is related to SME awareness of the advantages of adopting a new technology, both the communication process and the ability of SMEs to assess the merits of the technological advance were important.

Thomas (2000) developed a mathematical model of inter-firm technology diffusion based on these principles and that of technology transfer networks. He concluded that the successful diffusion of a new technology involves considerably more than mere technical competence, with many complementary factors (including sociological forces) being important. Moreover, Thomas (2000) found that an SME may be retarded in its acquisition of technology by other SMEs who are slow to adopt (for example, laggards). Thus, in his view, rapid diffusion of a technology will be facilitated by a willingness of SMEs to make adjustments.

While the above research has focused largely on the technology diffusion process in SMEs in a general sense, other researchers have considered the specific issues affecting the adoption of technology in the construction industry. One of these was Bjork (2002), who developed a typology of research questions and methods for electronic document management (EDM) in the construction industry. His analysis of the many case studies in this particular technology area put forward the notion that, while there was rapid take-up of this technology (particularly in larger projects), the organisational issues surrounding its use (i.e., who is in control), in addition to the psychology involved in getting all project participants to accept the use of new technology, were much more significant than technical problems.

In addition, Winch (1998) has demonstrated that construction was a complex systems industry. He proposed a model for the management of innovation processes at the firm level facilitated by two-moment model, in which there is a top-down moment (or dynamic) of adoption and implementation, and a bottom-up moment of problem-solving and learning. This concept of the learning organisation was discussed in connection with the innovation adoption cycle (Trott 2005) and is likely to be a significant component of the technology transfer process from researchers to the construction industry.

Another approach to understanding innovation was proposed by Harty (2005). He used the two intersecting ideas that successful innovation requires consideration of the social and organisational contexts in which it is located, and that innovations can be divided into bounded and unbounded modes. In his approach, bounded innovations are those that can be contained within an implementer's control, whereas unbounded innovations are those that spill beyond this into potentially more contested domains (Harty 2005, 515).

Harty (2005) applied sociology of technology concepts with a view to assessing the negotiations and alignments that constitute the implementation of unbounded innovations. He illustrated this discussion with the example (briefly discussed in the introduction to this chapter) of the way in which design engineers developed innovative approaches in order to work around restrictions in an integrated 3D CAD system (an unbounded system which, because of its specifications, had implications for team members possessing different software that did not integrate with the CAD system, or who did not have the requisite training) in construction of the T5 terminal at Heathrow Airport. Harty (2005) also discussed the usefulness of an inclusive multi-centred system-building approach in order to recognise better the complexity of the construction industry and its processes.

The significance of the research undertaken by these researchers is that successful innovation requires an understanding of social systems and management processes, in addition to the technological benefits derived from using the innovation. Furthermore, it is important to foster the promotion of a learning organisation in the technology transfer process. This can be combined with a better understanding of the technology diffusion process (and particularly the role of effective communication in this process), especially with regard to the way in which technology developed by researchers can be transferred effectively to the construction industry and, in particular, its SME sector.

7.0 CONCLUSIONS

The transfer of technology from research organisations like the CRC-CI into the construction industry, and specifically its SME sector, is quite complex. It involves a complex network of researchers, sponsors of research, clients, consultants, contractors, trade and industry associations, and other parties. While there have been successes in terms of achieving this transfer (the construction industry has generally been quite innovative), there is a need to improve the rate at which innovation occurs in the industry.

Overlaying the technology transfer process are a) the benefits and risks that organisations take on board when they adopt innovations, b) the innovation lifecycle, and c) the need for fair recompense for researchers and their financial supporters. The role of the learning organisation and other concepts discussed above, such as the importance of social, organisational and cultural factors, in addition to the technological and financial factors in the technology diffusion and adoption process, are also important. Government policy decisions and industry-wide factors are also likely to impact on the technology transfer process.

Organisations like the CRC-CI have successfully adopted a range of strategies for this process, including industry presentations, involvement of industry in the innovation development process, and making close links with industry associations. However, if maximum benefit is to be achieved, there needs to be further research into technology transfer processes in the construction industry.

In order to better evaluate the transfer of technology from researchers to the construction industry, research is currently being undertaken with a view to a) identifying and evaluating drivers, barriers and facilitators in technology transfer, and b) recommending suggested improvements to the technology transfer process. This research is expected to focus on the SME sector of the industry.

An important aspect of the SME industry sector is that it is not one homogeneous body. Rather, it represents a cluster of a range of organisations of different sizes and functions. As a consequence, the optimum technology transfer process may well be different for different clusters of SMEs. Therefore, as a first step, the research is being targeted at a limited number of groups within the SME sector that are related with respect to size and function.

The main components of this project are to:

- assess the benefits (and the perceptions of the value of those benefits) that SMEs could expect from more quickly evaluating and adopting the results of CRC-CI research;
- evaluate the drivers and barriers to technology transfer from the CRC-CI to individual SMEs;
- review the strengths and weaknesses of the existing technology transfer process from the point of view of the SME sector of the construction industry; and
- recommend improved ways of facilitating this process.

This research is based on the innovation lifecycle and technology adoption cycles and aims to evaluate a number of factors that are considered important to transferring technology to the SME construction sector. These include industry attitudes, levels of support available, aspirations of CRC-CI partners, government policy, type of research project and outputs, intellectual property considerations, the role of the learning organisation, and the management of the technology transfer process by the CRC-CI.

Wherever possible, this research uses a case-study approach in order to investigate the diffusion of new technologies developed by the CRC-CI to industry. It also employs available data supplemented by interviews and questionnaires undertaken with a range of industry participants, including CRC-CI core participants, consultants, industry associations and relevant SMEs. CRC-CI case studies may be supplemented by research undertaken in other engineering-related CRCs and research organisations. It is expected that this research should not only provide a better understanding of the technology transfer process from the CRC-CI to the construction industry and, in particular, in smaller organisations, but also should also provide insights into the way in which this process could be improved.

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