Experience with the management of technological innovations within the Australian construction industry

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Abstract
The BRITE Project (Building Research Innovation Technology and Environment) was established by the Australian Cooperative Research Centre for Construction Innovation to encourage and report on innovative developments in the construction industry. Using both case studies and extensive industry surveys the BRITE Project has examined the creation, adoption and diffusion of innovations. A nexus is reported between technological innovations and the adoption of advanced management practices. Indeed the management of the innovation process is found to be critical to the successful implementation of technological innovations. The BRITE Project's combination of specific detailed case studies with a broad industry-wide survey allows the testing of the hypothesis that organizational and technological innovations are linked from two different perspectives. In both instances, a strong correlation is observed between high technological innovators and the proactive management of organizational knowledge with emphasis on continuing education and training. In contrast, the low innovators surveyed were characterized by a lack of business strategies to improve and monitor performance and by minimal investment in research and development. Technological innovations were found to be significantly more likely to occur in those firms with good profitability and with managers who seek out a broad range of sources for new ideas as well as actively working to capture project learning for ongoing reference. Such ongoing active management involvement fosters the appropriate atmosphere for new technological innovations to occur. The BRITE Project experience highlights the primacy of management skills for the encouragement of ongoing technological advancement within the often conservative construction and engineering sector.

Introduction

The BRITE Project was established by the Australian Cooperative Research Centre for Construction Innovation to foster the incidence and quality of innovation in the Australian Property and Construction Industry. The project seeks to redress industry skepticism about the benefits of innovation through demonstration and benchmarking activities. Case studies of successful innovations are recounted and this information is widely disseminated in the industry and the broader community. The case studies are intended to demonstrate best practice and contribute to the enhancement of industry capabilities. In addition, in alternate years, surveys are conducted on the nature, incidence and variety of technological and organizational innovations. The survey data measures the innovation activity in the industry over time, in order to benchmark performance and facilitate appropriate public policy development. The BRITE Innovation Survey Report 2004 is available at http://www.brite.crcci.info/publications/index.htm. The survey sample was drawn from 3,500 businesses in the commercial building and road/bridge construction sectors in the states of New South Wales, Victoria and Queensland. Areas covered included main contractors, trade contractors, consultants, suppliers and clients. One-third of this population was sampled and a response rate of almost 30% was achieved. This paper reports on some of the findings of the survey as they relate to the emerging discipline of Technology Management [30]. The principal finding is that a nexus exists between the successful implementation of technological innovations and the adoption of advanced managerial practices. Indeed, 90% of those organizations in the survey that were classified as organizational innovators were also technological innovators [5].

This finding is confirmed by a Statistics Canada report [33] which also found a correlation between technological and business innovation although its major finding was that "innovative behavior varies with the size of the firm" [34]. The importance of "a reliable stream of innovation" to ensure continued profitability and long term growth is widely recognized [1]. Such innovation is underpinned by economic success and made possible by appropriate technological management. A report by a distinguished observer states that continued prosperity in his homeland of the Netherlands is dependent on "promoting entrepreneurship, innovation and the effective and prompt importation of technological advance from abroad" [1]. An American author also asserts the primacy of technology management for successful implementation of innovations. He describes a paradigm shift from closed to open innovation where the new paradigm assumes "that firms can and should use external as well as internal ideas, and internal and external paths to market, as they look to advance their technology" [8]. The emerging discipline of Technology Management involves, among other things, the establishment of systems of innovation to actively manage change [30].

Organizations with long-term intentions and aspirations need to adopt business behaviors in accordance with sustainable growth objectives not ad hoc project based strategies [23]. The construction industry has traditionally fallen into the latter category but, as the BRITE survey shows, there is evidence of the process of transformation into a knowledge based sector. The main factors driving or hindering construction innovation have been identified from the construction literature [2] and these are verified and analyzed in the BRITE Survey (2004).

Rate of Adoption of Innovation

The BRITE Survey found a "new to industry rate" of technological innovation of 18% which can be compared to an economy-wide rate of 17% in a recent New Zealand study [37]. Research and Development (R&D) is a key indicator of technological innovation and one quarter of firms in the Australian Construction Industry report that they do invest in R&D. R&D Performance by the industry itself is however very much lower at less than 1%. The industry tends to rely on R&D performed by organizations outside its corporate boundaries: principally the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australian Universities and increasingly the Cooperative Research Centre for Construction Innovation (CRC-CI).

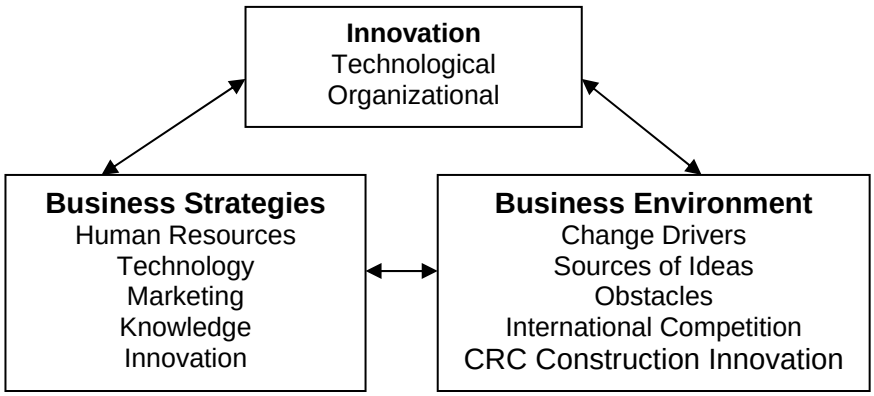

Fig. 1 Overview of Firm-Level Innovation Determinants

While many analysts focus almost exclusively on R&D and technological innovation, the BRITE Survey found organizational and managerial innovation to be of equal benefit to businesses. Furthermore such organizational innovations were closely linked to technological innovations. Business strategies are a key determinant of innovation outcomes. The survey results show a significant positive relationship between the number of business strategies

employed by construction firms and the number of advanced practices and organizational innovations adopted. The two key macro-drivers of innovation at firm level are shown in Fig.1 above. These are business strategies and business environment. The survey results also show a significant relationship between the use of formal evaluation programs to monitor innovation value and success, in both technological and organizational innovation. However, only 15% of the industry had such formal programs in place. Awareness of their usefulness was largely confined to high innovator groups.

Special Nature of the Construction Industry

As the BRITE case studies demonstrate, the project based nature of construction is at once a hindrance and an opportunity. In a sense each project is a prototype which seeks to solve an individual set of problems. This encourages innovation in the industry's participants but can lead to loss of lessons learned on past projects so that the wheel is constantly being reinvented. It has been argued that construction is a unique endeavor that cannot usefully be compared to other sectors such as manufacturing [43]. Other authors however, declare that the question of whether or not construction is unique is an unanswerable one, and it is therefore better avoided in favor of discussion of the "nature of knowledge diffusion and application processes" [4].

A significant distinction can be made between "innovation" and "invention" [36]. While the latter is a relatively rare event in the construction industry, the former is not. Innovation may take many forms and operate on many levels. Of particular interest in terms of Technology Management are those technical innovations that increase the feasibility of construction projects, thereby producing social and environmental benefits that would otherwise have been unachievable. The nature of constructed facilities is that they are "large, very complex and long lasting, and they are created and built by a temporary alliance of disparate organizations within an explicit social and political context" [36]. It is this complexity combined with physical scale that makes management issues crucial to successful implementation.

Construction has been described as a "loosely coupled system" characterized by continuously increasing complexity in projects [13]. As a result the direct transfer of management ideas from other sectors has frequently met with only limited success. Loose couplings favor short term productivity in individual projects but may not encourage innovation or the adoption of long term strategies and goals. In Singapore for example the motivational factors which encourage construction firms to adopt innovations have been studied and it was concluded that the benefits of the innovation must be substantial and all parties must be involved in the process for it to be successful [14]. Therefore the notion of construction firms as being strongly "risk averse" is significant, particularly as risk is an inherent part of the construction process.

The insular nature of many traditional construction firms is frequently discussed [20]. It is reported that many construction firms have been slow to adopt information technology advances because "the culture of the industry dictates that each function maintains total independence in all aspects including information retrieval and exchange" [20]. A paradigm shift is seen as necessary for the construction industry to fully embrace the advantages of innovation [31]. Some experts state that in their experience, this is because the education of industry leaders remains primarily technology and project based and is deficient in business and management skills. Change therefore requires leadership and "deliberate change is an act of human intervention" [31].

Despite this somewhat negative picture, the BRITE survey did find a significant rate of innovation adoption within the Australian construction industry which compared favorably with the rate in some other industries. The "new to industry" rate of technological innovation was 18%, and some 25 respondents reported "new to the world innovations". However the rate of innovation adoption across the industry was uneven with clients and consultants being

more likely to implement technological innovations than main or trade contractors. Those who did adopt innovations reported moderate improvements in profit as a result of the innovation.

Profitability and Innovation

Profitability is by no means the only measure of innovation success. Quality and safety aspects are also important. In addition, successful innovations may lead to an increase in market share and in security of market position. Both of these are benefits which do not necessarily increase immediate profitability but may do so in the long term. Nevertheless the high innovator group reported a significantly greater impact on profitability for their most successful innovation than either the mid range or the low innovator groups. Some 28% of high innovators reported a 'Great improvement in profitability' from their most successful innovation as shown in Fig. 2 below.

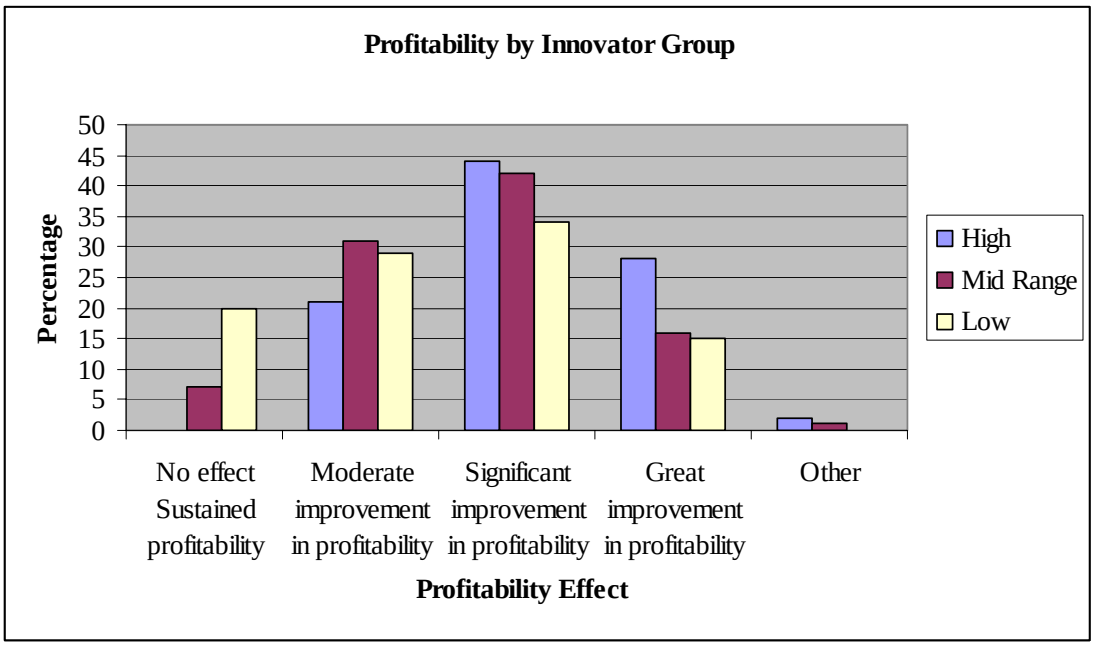

Fig. 2 Effect on Profitability of Most Successful Innovation by Innovator Group

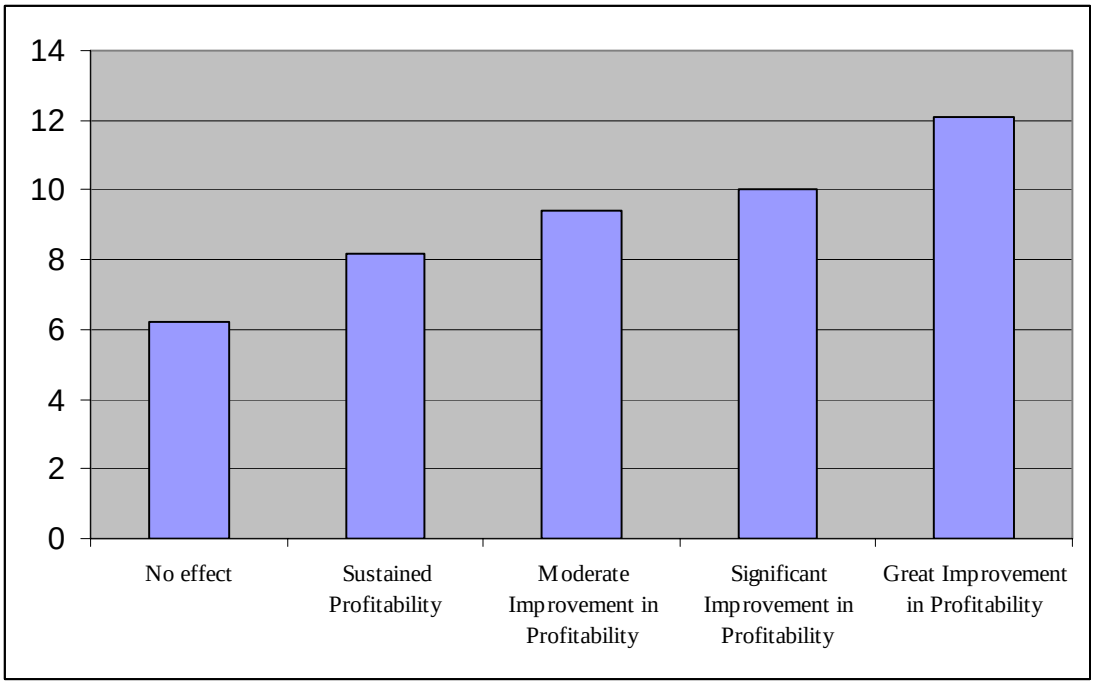

Fig. 3 Average number of Advanced Practices Adopted by Innovation Profitability Impact

The BRITE Survey found a correlation between profitability impact and the adoption of a greater number of advanced management practices. The advanced management practices surveyed included formal initiatives involving markets, human resources, financial systems, strategic plans, collaboration, relationship management, health, safety and environment initiatives but excluded routine changes. As Fig. 3 shows there was a direct relationship between the levels of novelty of the most significant innovation adopted and the use of the greatest number of advanced management practices. This indicates the interconnection between management and technological improvement. It does not establish cause and effect but we are able to say that in our study a relationship between the two exists.

A survey report on the US construction industry found that "differentiators" or those businesses which clearly conveyed their companies profile to customers were also the most profitable and the most effective business developers [17]. Profitability impact needs more attention if the frequency of technological innovation is to increase. It is likely that many good ideas fail to achieve acceptance because of fear of the risk involved in trying new things. It has been found that project based firms have difficulty implementing management strategies such as Continuous Improvement (CI) because their day to day management is not oriented towards improvement [19]. Only temporary alliances are formed and consequently participants are not willing to expend a lot of effort if they are unsure of reaping the rewards. In order to maximize the benefits of innovation, it must be given strategic direction. Consequently organizations need to take a holistic approach to innovation [9]. Suggested strategies include appointing directors of innovation and setting up innovation teams. These would help to bypass existing hierarchical structures which may be averse to innovation theory and practice. The specific problems of capturing practice based knowledge for innovation in service based industries have been well recorded [11]. Practice is not simply about tacit knowledge but rather its skilful combination with routines and procedures. Knowledge management to enhance technological innovation is needed to foster an atmosphere that is not "risk averse".

Characteristics of High Innovators

The BRITE team constructed an innovation index to differentiate between high and low innovators. High innovators were defined as those businesses that:

- Developed innovations with higher degrees of novelty;
- Developed innovations yielding higher levels of profitability;
- Adopted a higher number of advanced practices; and
- Invested in R&D.

These measures were considered to be the key innovation indicators. The team then looked for business features that were associated with these desirable behaviors. The survey results showed that high innovators were more likely to:

- Place significant value on employee, technology and knowledge strategies;
- Use a broad range of sources of innovation ideas;
- Have a formal evaluation program;
- Rely on research institutions for innovation ideas
- Recruit new graduates;
- Capture project learnings for ongoing reference;
- Reduce client costs;
- Have heard of the Australian CRC for Construction Innovation;
- Have successfully claimed the Australian Taxation Office's R&D tax concession;
- Regularly monitor international competition.

Sectoral differences were observed in the frequency and distribution of high innovators. Clients were significantly over-represented among high innovators, and, as this is not a finding reported elsewhere, it may relate to a particularly positive attitude to innovation among Australian construction industry clients, especially large public sector clients.

Table 1: Sectoral Performance by Key Innovation Indicators

Innovation Indicator	Clients	Consultants	Suppliers	Main Contractors	Trade Contractors
Number of Advanced Practices Adopted	Good	Reasonable	Poor	Reasonable	Poor
Degree of Technological Innovation Novelty – "New to the World"	Reasonable	Good	Good	Poor	Poor
Degree of Technological Innovation Novelty – "New to Industry	Good	Poor	Reasonable	Reasonable	Good
Innovation Profitability Level	Good	Reasonable	Poor	Poor	Good
R&D Investment	Very Good	Good	Good	Poor	Poor

In contrast, low innovators were characterized by lack of business strategies to improve and monitor performance and by lack of investment in R&D. This may be partially explained by constrained economic conditions but it seems that low innovators are less aware of possible strategies to foster innovation as well as less likely to take risks involved in developing and implementing a technological innovation. A recent study [38] identified the impediments to the implementation of IT in the Australian construction industry and these results correspond to some of the factors limiting innovation in some construction industry sectors as identified by the BRITE Survey.

Importance of Technological Innovations

The management of construction technology innovations has been widely recognized as important for the continued growth and profitability of construction enterprises. In Japan, the importance of cross industry research projects in the implementation of innovation in large Japanese construction firms has been reported [24]. The evaluation process for the adoption of a new technology was also studied and it was found that construction "…contractors historically have emphasized the ability to manage labor and subcontractors as the key element in competitive pricing [28]. However, key changes in the industry are forcing a shift in the basis of competition from managerial to technological issues". There is also a spin-off benefit in encouraging the awareness of technological innovations whether or not they are adopted. For example in the bridge building sector options to relate technology to competitive performance have been analyzed and it was found that encouraging construction managers to look at the possible advantages of technological innovations raises the probability of their finding technological improvements in their current systems [21]. The BRITE Survey results confirm the relationship between technological innovations and managerial processes in the Australian context.

It is reported that analysts have often assumed that the diffusion of a new technology is dependent on the attributes of that technology [29]. However, many other determinants are likely to be involved. Organizational and contextual factors are frequently significant. Four technological trajectories that predict the future success of innovative construction products have been identified [39]. These are: location of the work; means of production; materials used and incorporation of system design principles. In addition, a recent study found that the role of the end-user in technology adoption is often glossed over to the detriment of the innovation process and that both "technology push" and "market pull" factors influence the diffusion of innovations. [12].

Many construction firms find out about new ideas through a range of published material rather than through internal R&D [18]. Professional organizations have a significant role to play here though they may sometimes constrain innovation if they are too narrowly discipline based. "Technology watch" is a catchphrase with increasing currency in the construction industry. Borrowed from high tech industries such as computers, pharmaceuticals and aeronautics, it is seen as a key means of transferring research gains into practice [10]. There is a proposal for "relay stations" as intermediaries who will perform the function of technology watch as it is practiced in large organizations, for the benefit of small firms. The construction industry is, in large part, an industry of small firms so it is well placed to provide a ready market for such a scheme. Technology transfer is not however, a simple turnover process but an iterative one where the innovative technology is adapted to suit the needs of the new host [35]. Both "hard" and "soft" technologies will need to be transferred if the construction industry is to maintain its economic position and different mechanisms will be involved in each case. The Australian CRC for Construction Innovation aims to assist in this role through the BRITE Project and other information diffusion projects.

It has been found that construction managers in the USA rely heavily on trade magazines and informal relationships with colleagues to learn of technological innovations [41]. The BRITE Survey had similar findings for its low and medium innovator groups. Increasingly however the adoption of innovative technologies is becoming an interactive process which relies on the discipline of technology management. The importance of technology management was highlighted in the 2004 BRITE Project which published a series of case studies illustrating innovation through examples taken from local Australian industry. The case studies include: an energy efficient cooling system for an office building in a coastal tropics location; a precast concrete plank connection system for a major sports stadium; alliance contracts for a motorway development; a performance-based fire engineering solution for a gallery project; a fiber- reinforced polymer bridge decking system; and the use of ground penetrating radar to

detect defects in bridge beams. The case studies reflect the complexity of construction and the particular nature of the construction industry. Detailed examination of this diverse range of projects revealed that as well as active management the implementation process for a construction innovation requires the enthusiasm of an innovation champion and the willingness to accept the risk of uncertain outcomes. All the projects described required some degree of organizational change management in order to implement technological innovations. In most cases the technological innovation was closely linked to complementary organizational innovations. Case study information can be viewed at http://www.brite.crcci.info/case_studies/index.htm.

Knowledge Management for Technological Innovation

The successful adoption of a technological innovation involves a management process over time. This is apparent from the BRITE Survey and case studies and is confirmed by several authors writing in the field. It is apparent that within a knowledge driven economy both technologies and innovations are becoming more complex [7] and due to the amount of different knowledge required, networks must be formed to manage the divers competencies involved in successful implementation. The management of the "idea generation" process has received the considered attention of researchers [16] and it is established that while creativity is essentially an individual activity, a creative culture can be fostered by sympathetic management. Such a culture describes a strategic direction for the organization, practices environmental scanning leading to opportunity identification and then encourages idea generation. The process of technological innovation therefore is comprehensively managed without any loss of inspiration. The problem of the fragmented and short term nature of construction projects however remains, even when innovation is encouraged and learning is well managed.

The effect of theories such as Total Quality Management and Strategic Quality Management in construction has been examined and it is observed that adaptations have been necessary to produce good practice [31]. Systems such as Requirements Management have been proposed for construction in order to tackle complexity and impose a more disciplined way of working [15]. However, the prevailing "theory of construction" can be regarded as counterproductive, in that it leads to a systematic creation of added costs while at the same time discouraging both top down and bottom up innovation [25]. As a result, management theories introduced from other sectors have had disappointing results. Despite this, the BRITE Project has demonstrated that there is movement towards the development of industry appropriate management practices for the construction industry and that those businesses that fail to adapt to the new management environment are likely to have low rates of profitability and innovation and therefore to fail to achieve growth.

Primacy of Management Skill

A common theme that can be detected from both the BRITE Survey and the case studies, is that technological innovation is closely allied to organizational innovation. Those survey participants who reported high levels of innovation overall, also reported high adoption rates of advanced management practices. Similarly, low innovators reported the adoption of significantly fewer organizational innovative practices as shown in Fig. 4 below.

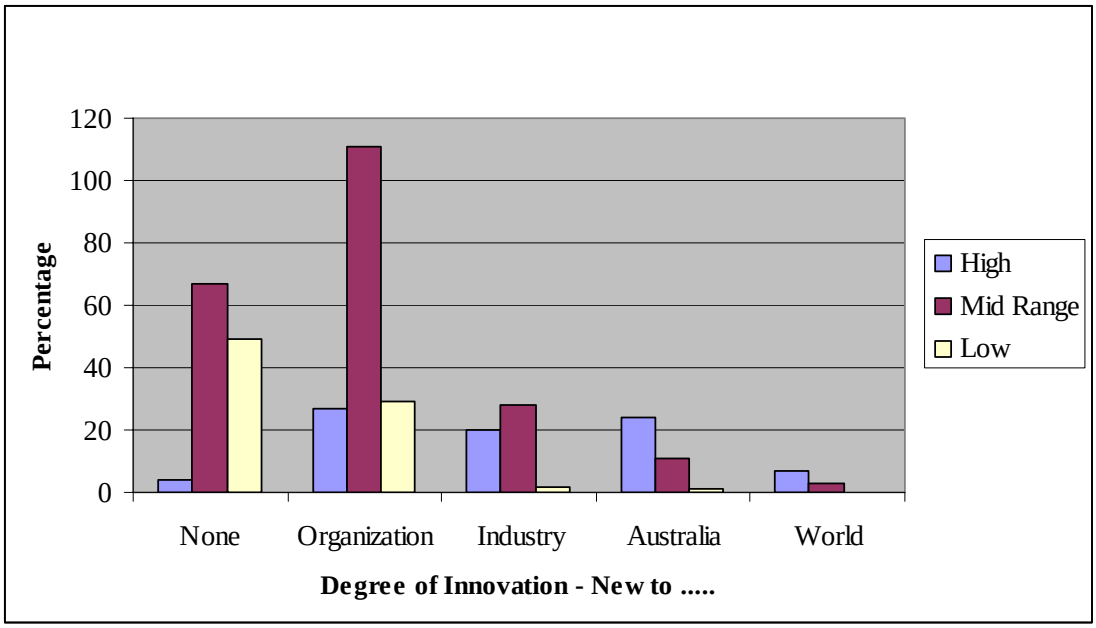

Fig. 4 Degree of Organizational Innovation by Innovator Group

Other authors have reported on this correlation between technology innovations and active management policies in various forms [22], [26], [27], [3] and [40]. The BRITE Survey and the BRITE case studies confirm the primacy of management practices to the implementation of technological innovations in the context of the Australian construction industry.

It has been reported that mass production theory was never very relevant to construction [42]. This may be true, but it is clear that adaptations of many kinds of management theory specifically tailored for a project-based and loosely coupled industry such as the construction industry can foster useful improvements in productivity and efficiency.

Conclusion

The BRITE Project's combination of a broad industry survey with specific illustrative case studies has been able to demonstrate a relationship between technological advancement and managerial practice in the context of the Australian construction industry. Those businesses which successfully introduce technological innovations exhibit a strong tendency to use advanced management practices and organizational innovations. The management atmosphere into which a new technology is introduced makes a great deal of difference to its chances of successful adoption and diffusion. Good technological ideas are not sufficient in themselves to produce widespread implementation. The implementation process must be actively managed. Creativity can flourish where risks and rewards are justly distributed. The BRITE Project demonstrates that active involvement of all construction participants in the generation of new ideas needs to be encouraged and rewarded.

Business strategies and business environment were seen to be the macro-drivers of construction innovation. Business strategies relating to human resources, marketing and knowledge management affect the frequency of innovation generation and its implementation. Business strategies are a key indicator of innovation success and they are entirely within the province of management to guide and direct. Ongoing and proactive management of these issues can create an atmosphere favorable to ongoing technology advancement. In the absence of such management many good ideas are likely to under achieve or fail. The message is that technology needs direction if it is to be useful and sustainable.

The BRITE Project continues to encourage innovation in the Australian construction industry by generating interest in the issues, giving recognition to successful implementations and monitoring the ongoing frequency of innovation and diffusion. While the conservative nature of much of the industry is acknowledged, experience shows that there is also a willingness to adapt and change when the benefits of such change are clearly explained. The advocacy of change management is the continuing task of industry based research groups such as the Cooperative Research Centre for Construction Innovation in Australia and its counterparts throughout the world.

The work of the BRITE Project is ongoing and the collection of case studies to illustrate successful innovations is continuing at the time of writing.

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