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Exploring the drivers of firm-level innovation in the construction industry

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A survey of 335 businesses in the Australian road industry has been carried out to ascertain those factors that make firms innovate. 'Innovative' is measured by adoption rates of advanced technologies and practices, and the range of innovation drivers reviewed encompasses business strategy and environment. The findings indicate that business strategies are more important than business conditions, and that the following three strategies are significant in differentiating between firms with high and low adoption rates: (1) hiring new graduates; (2) introducing new technologies; and (3) enhancing technical capabilities. The findings also highlight the importance of undertaking R&D and encouraging employee ideas for improvement. The public policy implications are that the quality of university graduates should be protected and advanced, as should technical skills within public sector client agencies.

Keywords: Innovation, technology adoption, business practices, business conditions

Introduction

Since the emergence of innovation studies as an academic discipline in the 1970s (Nelson, 2003), the precise role played by innovation in the growth of firms, industries and nations has been the subject of vigorous debate (Freeman, 1991; Wolfe, 1994; Cohen *et al.*, 2002). This debate has highlighted the complexities of the innovation process, and led to many diverging opinions. Indeed, debate is to some extent fuelled by the fact that neoclassical economics dominates policy making in the Organisation for Economic Cooperation and Development (OECD) countries, yet, as a discipline it says little about innovation processes (Nelson and Winter, 1982; Marceau, 2000). This opens the way for varied input and has led to the development of innovation studies as a richly multidisciplinary field. In such an environment consensus is hard to find, but over the past decade it has become clear that innovation is widely considered to be the major force behind growth at all levels of economic endeavour (summarised in OECD, 2000).

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This study focuses on innovation by organisations within the Australian construction industry. The construction industry globally is being challenged to improve outcomes for clients and industry participants. For over a decade, government inquiries in the UK and Australia have sought to document a process for improvement (Gyles, 1992; Latham, 1994; CIDA, 1995; Egan, 1998; NatBACC, 1999; PWC, 2002; Fairclough, 2002; Cole, 2002; and DISR, 2004).

The problems covered in these reports, and reflected in academic discourse globally (Marceau *et al.*, 1999; Gann, 2003), include the fragmented and project-based structure of the industry, lowest-cost tender selection, prescriptive specifications and adversarial relationships. These problems have resulted in construction projects marred by cost and time overruns and consequently, dissatisfied clients. This situation is seen to reflect low levels of innovation, with a recent report finding that the Australian industry is slow to innovate, compared to other countries and other Australian industries (PWC, 2002).

Inquiries into the industry have unanimously found that innovation is the key to improvement, and this is reflected in the academic literature (Gann, 2003).

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Innovation is defined by the OECD/Eurostat (2005, p. 46) as:

> the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relations.

Innovation may be new to the world, or just new to the industry or business concerned (OECD/Eurostat, 2005, p. 17). This definition thus includes the adoption of existing advances developed outside a particular business. Globally, surveys of innovation employ definitions that do not involve a requirement that the new or improved products and processes lead to improved business or societal outcomes. In this sense, innovation is simply about non-trivial change.

This paper focuses on the adoption of advanced technologies and practices. In its latest national all-industries innovation survey, the Australian Bureau of Statistics (ABS) asks respondents to rank the novelty of their innovations, as new to the organisation, industry, country or world (ABS, 2003, p. 6). This paper focuses on the least novel form of innovation—advances that are new to the organisation only. Such innovation should not be considered less valuable than more novel innovation in terms of its impacts. The OECD notes the benefits of innovation diffusion, commenting that the main impact of innovation on an economy arises from the adoption of initial innovations by other firms (OECD/Eurostat, 2005, p. 18). Indeed, the innovation diffusion literature is based on the argument that high rates of innovation diffusion within an industry or country promote economic growth (Rogers, 2003). Even at firm level, recent research underlines the significant value of adoption activity (Thorburn and Langdale, 2003).

The literature on the diffusion of innovation is robust, with prominent contributors such as Rogers (2003) having a major influence on business practices. Yet the focus of existing work is typically on innovativeness as measured by propensity to adopt over time, and the processes underpinning the adoption decision and successful implementation. This paper fills a gap in the literature by measuring the level of a firm's innovativeness by the number of advanced technologies and practices adopted at a particular point in time, and examining the factors associated with high level adoption rates.

As adoption activity is a form of innovation, high adoption rates reflect high levels of innovativeness. The research question underpinning this study is 'What makes road industry participants innovative?' 'Innovative' is measured by adoption rates of advanced technologies and practices and the range of innovation drivers reviewed encompasses business strategy and environment. The answer to the research question will assist businesses and governments to focus their efforts on the areas that are most likely to promote diffusion of advanced technologies and practices.

Background

A large-scale mail survey was employed to investigate the research question. This innovation survey contained 12 questions which investigated innovation outcomes and determinants. The simple conceptual model underpinning the survey is shown in Figure 1.

This model focuses on the key roles played by the business environment and business strategies in driving or impeding innovation outcomes (Porter, 1990; Tzokas and Saren, 1997; Manley, 2003a; Seaden *et al.*, 2003; Ritter and Gemunden, 2004; Reichstein *et al.*, 2005). These two macro-drivers can be thought of as the external and internal influences, respectively, on an organisation's innovation performance.

The relationships between the macro-drivers and innovation outcomes are shown in all cases as two-way flows, indicating the impact of environment and strategies on innovation, and the influence of innovation, in turn, on these factors. Although the latter dynamics are important, this study focused solely on the drivers of innovation. Similarly, it was beyond the scope of the present study to examine relationships between innovation drivers.

In the questionnaire, 'new-to-firm' innovation levels were measured by a list of prescribed advanced technologies and practices. As none of the advances had been invented by any of the firms in the population, their use was the result of adoption behaviour, resulting in 'new-to-firm' innovation. This approach to innovation measurement avoids the difficulties associated with inconsistent interpretation of generic innovation descriptions by survey respondents (Seaden *et al.*, 2001, p. 9; ABS, personal communications).

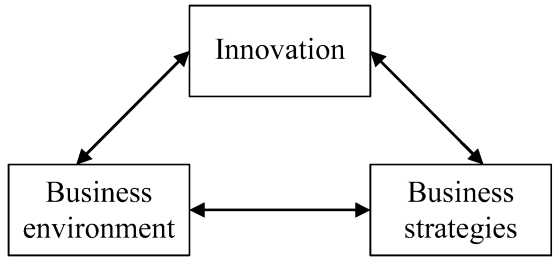

Figure 1 Simple model of the firm-level innovation process. *Source*: Based on Seaden *et al.* (2003, p. 605); Manley (2003a, p. 13).

Innovation surveys by OECD countries such as Australia, New Zealand and Canada are world's best practice (Pattinson, 2002, p. 4). Hence the approach of this study, in listing advanced technologies and practices in the questionnaire to measure innovation, can be considered a best practice approach, following the Canadian example as it does.

The business strategy section of the questionnaire covered human resource strategies, technology strategies and marketing strategies, as these are highlighted in the literature as key innovation drivers. See for example Black and Lynch (2004) and Searle and Ball (2003) on the role played by employees in promoting innovation; for the value of technology strategies see Christensen (2002), Smith and Rogers (2004) and Wonglimpiyarat (2004); and for the role of marketing strategies in driving innovation see Kumar (2004) and Vorhies and Morgan (2005).

The business conditions section of the questionnaire focused on the competitive features of the firm's environment. Porter's (1990) seminal work highlights the role competitive pressure plays in driving innovation. Indeed, recent OECD research underscores the continuing importance of innovation as an effective response to competitive pressures, particularly value-adding innovation (as opposed to cost cutting), in the context of 'knowledge economies' (OECD, 2000). The current research was based on the understanding that stronger competitive forces lead to higher levels of innovation, which, on balance, appears to be the case despite the role that market power can play in providing the resources for innovation (eg. Porter, 1990; Nickell, 1996; Blundell *et al.*, 1999).

Methods

The survey covered the state of Queensland in Australia. The study population was defined as 'participants in the Queensland road sector' and split into four sub-groups:

- clients—Queensland Department of Main Roads (QDMR) district offices and local governments;
- contractors—private and public sector;
- consultants—architects and engineers; and
- input suppliers—product manufacturers and other suppliers.

Altogether, the study population comprised 335 organisations. The population list was derived from industry and professional association membership lists, together with QDMR contractor and consultant pre-qualification lists. The population comprised all the organisations for whom the Queensland road industry is of major importance. The questionnaires were sent by standard mail. The contact person on the lists was the business owner or a senior manager. The questionnaire was sent to one contact within each organisation.

The four core groups can be further disaggregated to 11 sub-populations as shown in Table 1.

Table 1 Respondents to the survey by group

Sector	Number of surveys distributed	Number of respondents	Response rate	Representation in population	Representation in sample
Clients					
Local governments	125	77	62%	37%	37%
QDMR District Offices	14	12	86%	4%	6%
Contractors					
Private contractors	68	37	55%	20%	18%
RoadTek (public contractors)	15	15	100%	5%	8%
Consultants	59	39	66%	18%	19%
Input suppliers					
Product manufacturers					
Cement	6	6	100%	2%	3%
Asphalt	6	5	83%	2%	2%
Binder	3	3	100%	1%	1%
Other suppliers					
Extractive industry	18	9	50%	5%	4%
Hire firms	14	4	29%	4%	2%
Equip. distributors	7	1	14%	2%	0%
Total	**335**	**208**	**62%**	**100%**	**100%**

The overall response rate to the survey was 62%, which can be considered high for a voluntary mail survey (Saunders *et al.*, 2000, p. 159).

This paper reports on the innovativeness of the sample as measured by adoption rates, and correlates these results with a range of potential innovation drivers within business strategies and conditions as identified in the literature (see previous) and summarised by Statistics Canada (Anderson and Schaan, 2001).

The respondents were ranked according to how many of the 46 advanced technologies and practices listed in the survey they employed. In constructing this ranking it was assumed that each advanced technology and practice had equal value. This is reasonable given that the research investigates the respondent's openness to change, in view of the value of innovation diffusion to economic growth (Rogers, 2003).

Respondents indicated which of the advanced technologies (listed in Table 2) they employed.

Respondents also indicated which of the advanced practices (listed in Table 3) they employed.

These two lists are the result of industry workshops conducted in Brisbane, Australia in 2002. They represent a refinement of lists contained in the Statistics Canada survey in 1999, which themselves were based on industry workshops in that country (Anderson and Schaan, 2001, p. 14). The Brisbane workshops developed the two lists to apply equally to the contractor, consultant and client sectors. Shorter tailored lists were developed for suppliers and their percentage usage rates were based on the lower number of advances that potentially applied to them.

Although some of the technologies and practices listed may appear to represent business-as-usual rather than best practice, it should be kept in mind that best practice changes quickly and that this study was in the field in 2002, in Australia. Regardless of the level of novelty contained in the list, the results reveal the relative openness to change of the 208 respondents.

The researchers separated respondents into two groups—high and low adopters. Difference testing was then conducted to identify the strategies and conditions that were significant determinants of whether an industry participant was a high or low adopter at the 95% confidence level.

Sensitivity analysis was conducted around the percentile cut-off that differentiated high and low innovators. This work classified respondents based on how many advances (technologies or practices) they

Table 2 Advanced technologies listed in the survey

Design
Computer-aided design
Computerised visualisation techniques
Simulation technologies
Systems dependent on CAD files
3-D CAD files
Materials
Fibre composites
Foam bitumen
Geotextile fabrics
High performance concrete
Noise inhibiting road surface materials
Stone mastic asphalt
Plant and equipment
Digital videos of road surface condition
Electronic distance measuring device (EDMD)
Global Positioning System (GPS)
GPS-guided equipment
Laser-guided equipment
Paving/rehabilitation train
Pug mill cement/lime stabilisation processes
Systems
Bio-remediation clean-up
Health monitoring of road pavements/structures
Recycling asphalt/concrete
Remote sensing and monitoring systems

Table 3 Advanced practices listed in the survey

Computerised practices
Computer networks (LAN or WAN)
Computerised estimating software
Computerised inventory control
Computerised modelling
Computerised pavement/bridge investment analysis (eg. HDM4)
Computerised project management
Digital photography
E-mail
Intelligent transport systems
Office-to-site video links or video conferencing
Online remote-construction management
Website
Contracts
Alliance contracts
Cost-reimbursable-performance-incentive contracts
Design and construct contracts
Design/Build/Fund/Operate (DBFO) contracts or public–private partnerships (PPPs)
Managing contractor
Partnering on road projects
Organisational practices
Documentation of technological/organisational improvements developed by your organisation
Long-term collaborative arrangements with other businesses
Quality certification (e.g. ISO 9000)
Staff training budget
Written evaluation of new ideas in order to develop options for your organisation
Written strategic plan

Table 4 Business strategies listed in the survey

	Not applicable to QDMR district or local government respondents
Human resource strategies	
Actively encouraging your employees to seek out improvements, through a 'no blame' organisational culture	
Ensuring employees are aware of business/community issues	
Hiring experienced employees	
Hiring new graduates	
Participating in apprenticeship programmes	
Providing or supporting local training programmes for your employees	
Use of multi-skilled teams	
Technical strategies	
Enhancing your organisation's technical capabilities	
Introducing new technologies	
Investing in research and development	
Participating in the development of industry standards and practices	
Protecting your organisation's intellectual property	
Marketing strategies	
Delivering products/services which reduce your client's costs	
Seeking business outside your present region	
Increasing your market share	
Building relationships with existing clients	
Attracting new clients	
Providing a broader range of services to your clients	

had adopted at the time of the survey, as a percentage of the total number listed. Results were also tested to assess the role of clients, as clients were not asked to respond to the marketing strategy statements or the business condition statements. Both of these sets of statements assumed competitive conditions that did not apply to the clients surveyed, who were all in the public sector.

The original cut-off tested to separate high and low adopters was where respondents had adopted 75% or more of the advances listed in the two charts above. The 75% point was chosen based on observed clumping of the descriptive rankings. At this cut-off, there were 30 high adopters (178 low adopters) with clients included; without them there were 22 high adopters (156 low adopters).

Sensitivity analysis was then conducted to ensure that this cut-off was robust. It was found that applying the 'high adopter' cut-off at 85%+, 75%+ and 65%+ of advances yielded a common set of three differentiating business strategies, with or without clients included in the analysis.

Table 4 shows the 18 business strategies that respondents rated on a five-point scale according to the importance of the strategies to the success of their business.

Respondents were also asked to rate how strongly they agreed (on a five-point scale) with a set of statements about their business conditions (see Table 5).

Positive rankings, that is, 'high'/'very high' for importance of strategies to their business success, and 'agree'/'strongly agree' for relevance of business environment statements to their business, were thought to promote innovation, based on findings in the literature (Seaden *et al.*, 2003). A Kruskal–Wallis test (a non-parametric version of one-way ANOVA) was

Table 5 Business conditions listed in the survey

	Not applicable to QDMR district or local government respondents
Materials and supplies quickly become obsolete	
My clients can easily find a substitute for my services	
My clients' needs are easy to predict	
My competitors' actions are easy to predict	
My organisation has many suppliers to choose from	
Our organisation receives high quality technical support provided by other organisations	
Our relationships with other organisations in the road industry are assisted by a culture of trust	
Regulations impacting on our organisation encourage improvements in products/services	
Technologies in the office are changing rapidly	
Technologies on the construction/building site are changing rapidly	
The arrival of new competitors is a constant threat	

carried out to assess this and determine which of the statements were most important to innovativeness (high adoption rates). This test was employed because it is best suited to identifying differences between groups of respondents when it is assumed that the data will not be distributed normally, as in this case (indeed an ANOVA test was also conducted, yielding the same findings).

The next section presents the results to the research question: What makes road industry participants innovative? Did high and low adopters respond significantly differently to the strategies and conditions presented in the survey?

Results and discussion

Business strategies

High adopters were more likely than low adopters to rank the importance of every business strategy as 'high' or 'very high'. Further, the Kruskal–Wallis test indicated, with 95% confidence, that high and low adopters responded significantly differently to three of the strategies listed above, with high adopters valuing the strategies more highly. Difference was analysed with reference to respondents who rated the importance of strategies 'high' or 'very high', versus other responses along a five-point scale.

The three differentiating strategies are shown in Table 6. One is a human resource strategy and the other two are technical strategies. None of the marketing strategies were significant, even when clients were excluded from the analysis.

Hiring new graduates

The importance of human resource strategies to innovativeness is reflected in the literature (Barlow, 2000; Love *et al*., 2002). It is interesting that among the human resource strategies listed in the survey, the role of new graduates in supporting adoption activity should stand out above the roles of experienced employees, apprentices, training programmes, organisational culture and multi-skilling. This suggests that despite criticisms in the literature about the shortcomings of engineering education (Hecker, 1997), the university education system, in Australia at least, is currently meeting the needs of innovative construction firms.

Table 6 Significant business strategies: high versus low adopters (common to all sensitivity scenarios)

Business strategy	Significance*
Hiring new graduates	0.000
Introducing new technologies	0.000
Enhancing your organisation's technical capabilities	0.007

Note: *Significance values relate to all respondents, at the 75% cut-off for high adopters.

High adopters value university education, perhaps expressing a preference for staff who have been exposed to teaching which is based on cutting-edge research, over staff with perhaps more traditional skills imparted by apprenticeship programmes. It also appears that high adopters are expressing a preference for youthful staff, over older staff with more industry experience who might not be as creative and flexible. The literature confirms the value of graduates to firm-level innovation outcomes (Bowen and Thomas, 2004).

Looking at the other human resource strategies that were listed in the survey, 'Actively encouraging your employees to seek out improvements, through a ''no blame'' organisational culture' was significant in several of the sensitivity analysis tests, but was just below the 95% confidence level for others. Although employee ideas are clearly important to high adopters, multi-skilling and training were not significant in any of the tests.

Introducing new technologies

The finding concerning 'Introducing new technologies' may seem tautological. If these new technologies are adopted from external sources the result simply reflects the way high adopters were defined. However, there is evidence to suggest that at least some of these new technologies are introduced as the result of internal R&D. R&D was a significant determinant of adoption levels at the three percentile cut-off points, however it fell just below the 95% confidence level in sensitivity analysis excluding clients. Nevertheless, the results suggest that R&D is an important factor in differentiating high and low adopters.

Clients represent eight of the 30 high adopters at the 75% cut-off, and they had the highest propensity to value R&D strategies 'highly' or 'very highly', compared to contractors, consultants, manufacturers and other suppliers. This explains the results of the sensitivity analysis. However, it is an unusual finding, as the literature reports that manufacturers are the most likely group in the construction industry to invest in R&D as they have the continuity of work to plan in this way, given their freedom from organising around project-based activity. As Gann (1997, p. 9) notes, in the construction industry context 'materials and components manufacturers … are often in a position to invest in long-term research and new product development'.

The stronger role played by clients in R&D in this survey may be explained by public policy decisions in

Australia during the 1990s which resulted in the technical competence levels of public sector client agencies being largely maintained, while in other parts of the world such clients were being downsized. Much of the client R&D reported here would have arisen from regional materials testing facilities which have been maintained and expanded over the last decade (QDMR personal communication).

Technical capabilities

Enhancing technical capabilities was the final strategy that was significant in defining a respondent as a high or low adopter of advanced technologies and practices. Such capabilities comprise the technologies and technical skills that empower the firm to adapt quickly to opportunities (Walsh and Linton, 2002, p. 64). Together, the three findings—'enhancing technical capabilities', 'introducing new technologies' and 'hiring new graduates'—underscore the value of organisational learning to innovation (Dodgson, 1993). Such learning skills are critical to success in adopting new ideas from outside the firm. Recent empirical research across seven countries suggests that effective technical capability is a function of 'both internal capabilities and openness towards knowledge sharing' (Caloghirou *et al.*, 2004).

The three findings combined also support the main argument of the absorption capacity literature, that the ability of a firm to adopt external advances and apply them successfully is determined by related prior knowledge. The survey suggests that innovation adoption activity is enhanced by prior knowledge gained through employing new graduates, understanding new technologies and enhancing technical capabilities. Cohen and Levinthal (1990), in developing the theory of absorption capacity, further emphasised the importance of a firm maintaining diversity of expertise. This importance is not highlighted in the current survey, with multi-skilling not ranking highly as a determinant of adoption levels.

The ability to successfully implement innovations adopted from external sources is particularly important to contractors and consultants in the construction industry, who have limited scope to undertake R&D and develop their own innovations due to the constraints of project-based production and the pervasively low profitability rates experienced by the majority of these industry participants in Australia, as elsewhere (Reichstein *et al.*, 2005, p. 631).

Business conditions

Every business condition tested was more likely to apply to high adopters than low adopters. However, sensitivity analysis for the classification of high and low innovators, and the inclusion and exclusion of clients showed that individual business condition statements were not robust determinants of adopter class. At the 75% cut-off for high adopters, 'Technologies in the office are changing rapidly' and 'Technologies on the construction/building site are changing rapidly' were significant, regardless of whether clients were included in the sample or not. However, at the 65% cut-off, with weaker adopters in the 'high' group, there were no significant business conditions, regardless of the inclusion or exclusion of clients. Finally, at the 85% cut-off, with clients excluded from the sample, there were no significant conditions.

This may suggest that business strategies are a more important determinant of adoption behaviour, as would seem intuitively plausible, given that a firm has a great deal of latitude in how it responds to its environment and can potentially turn environmental disadvantages around through clever strategy. Firms can use their internal resources to capitalise on opportunities presented by business conditions, and creatively manage the challenges (Nelson, 2005). Indeed, the influential research by Teece *et al.* (1997) concluded nearly a decade ago that 'wealth creation in regimes of rapid technological change depends in large measure on honing internal technological, organisational and managerial processes inside the firm'.

Conclusions

This paper provides guidance to improve the innovation performance of the construction industry. It has identified the strategies that underpin effective adoption of technical and managerial advances by businesses in the Queensland road industry. The research findings should be instructive for construction businesses, public sector construction clients and governments internationally.

Research implications

The survey results suggest that businesses need not feel helpless in the face of daunting business conditions. The strategies they adopt in response to their environment will have a bigger impact on their success in adopting external advances. More specifically, businesses wishing to improve their uptake of innovations can usefully focus on employing new university graduates, perhaps in preference to apprentices and experienced staff. Also, strategies to encourage employee ideas for business improvement by developing a no-blame culture, are likely to promote

adoption rates. These human resource strategies can usefully be augmented by technical strategies involving R&D. Marketing strategies will have a less significant impact on adoption rates, although they may be pursued to achieve other business goals.

The main findings for policy makers are about the quality of university graduates, and the technical competence of public sector construction clients. Australia, for example, is currently facing a paradigm shift in the funding and management of the university sector and many observers are concerned about the possible ramifications on the quality and extent of teaching and research. The implications of this threat extend far beyond the current research, yet even in this narrow arena, falling technology diffusion rates are likely if the quality of university graduates falls significantly.

The research also found that public sector clients in the Queensland road industry have the greatest propensity of any industry group to invest in R&D, even exceeding the incidence within the manufacturer sub-sector. This suggests that the industry has very competent clients, able to expertly judge the value of innovation ideas proposed by the industry. This skill promotes the adoption of industry ideas on projects, but also qualifies the clients to show effective leadership in driving innovation through the supply chain, by promoting their own ideas. This client capability should not be compromised and represents a model that policy makers internationally might find interesting.

Limitations of the study

The current study has not focused on the timing of adoption decisions and interested readers are referred to Tzokas and Saren (1997). Readers interested in the dynamics of adoption decisions in the construction context should see Larsen (2005), Slaughter (2000) and Mitropoulos and Tatum (1999), while those interested in a broader analysis of innovation processes are referred to Manley (2003b). Those interested in exploring the relationship between business conditions and business strategies might review Seaden *et al.* (2003).

Further research

Further research is currently being conducted looking at innovativeness more broadly and developing an innovation index to classify respondents more rigorously as high or low innovators. There are also plans to see if the current results hold for the Australian construction industry. This would extend the geographical and industry coverage of the research. All Australian states would be covered, as would the civil *and* building sectors. Additionally, analysis of business conditions will be extended beyond the competitive conditions covered in the current survey, to include structural features of the firm, such as age, size and market power; financial and project-specific conditions; and government policy. At the same time, the examination of business strategies will be extended to cover a range of knowledge strategies.

Finally, there are plans to specify a time limit on the adoption of prescribed advances, and to improve the integrity of the 'list' approach. The latter will involve exploring the use of advances by a single construction group only, such as contractors, to avoid problems associated with developing a list of advances that is equally suitable for the contractor, consultant, supplier and client sectors.

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